LONG RANGE CAPITAL IMPROVEMENT PLAN

RURAL WATER DISTRICT NO. 9
LEAVENWORTH COUNTY, KANSAS

BARTLETT & WEST ENGINEERS, INC.
1200 SW EXECUTIVE DR.
TOPEKA, KANSAS 66615

OCTOBER, 2022
P.N. 20023.000

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1 GENERAL

Every business needs a plan to effectively guide investment decisions. Rural Water Districts are no different than other businesses in that regard, particularly Districts that serve a high-growth region. To that end, Bartlett & West is pleased to have the opportunity to assist Leavenworth County Rural Water District No. 9 in the development of a long-range growth plan. As part of our services to the District, we have analyzed the deficiencies that currently exist and are likely to exist in the future. The purpose of this analysis was to establish a plan that will serve as a guide for the Board of Directors. Phased improvements are outlined and correlated to growth projections. The immediate and future financial impacts are also illustrated.

RWD No. 9 began operation in 1972 and covers about 60 square miles in west-central Leavenworth County and a small portion in east-central Jefferson County. The District extends north of U.S. 24 Highway between McLouth and Basehor, serving nearly 800 rural customers, with the highest customer density around Tonganoxie.

A fractured sandstone and shale formation serves as a water source for four groundwater supply wells. A small filtering facility removes iron and manganese. The District also purchases water from Suburban Water, with the master meter being located on the same property as the wells. Water from the two sources is blended in the clearwell downstream of the filtering system.

The water distribution system is divided into two hydraulic service areas, each served by an elevated storage tank. The wells and Suburban Water supply transmit to the east water tower and the west pump station transmits to the west water tower. The District maintains nearly 90 miles of 2-inch through 12-inch PVC pipe, with over half of it being 3-inch or smaller.

In evaluating the sufficiency of the existing facilities under future projected demands, a GIS-based hydraulic model was developed. Minimum expected service pressures and facility capacities were analyzed under current peak demands, as well as under projected peak demands in 2030 and 2040. Shortcomings are identified in this report, with improvements recommended and explained. Cost estimates are provided for each improvement and the financial impact is analyzed, both in the short term and long term. As appropriate, multiple options are evaluated, with the most cost-effective alternative being recommended.

Significant improvements will require a significant investment. Funding alternatives are discussed near the end of this report. Annual water rate adjustments are projected, with the assumption that a large initial project will be required and that various smaller projects can be funded through a capital improvement account, without the need for a second loan over the next 20 years.

This planning document should be used by the Board of Directors to address current deficiencies and financially plan for the future. The specific design of each project identified in this report should be re-evaluated prior to construction. The Board should understand that the recommended improvements are directly related to the growth projections established during the analysis, and that actual future growth of the District may not follow the projected growth. A review of the District's growth and of the hydraulics of the system should be conducted at least every five years to determine if revisions to this report are necessary.

2 WATER USE CRITERIA

Water demand criteria are necessary to accurately evaluate a system's capacity and expected hydraulic sufficiency. To this end, Rural Water District No. 9 water usage data from the past 13 years was analyzed. Table 2-1 summarizes this data and reflects a trend of increased water production, consistent with the steady increase of new residential customers. It also illustrates the annual demand fluctuation that corresponds to climatic conditions.

A basic design parameter used in our analysis is average daily use (ADU). This value is derived by dividing the total number of gallons the District sells by the number of active customers served. For hydraulic modeling purposes, to determine a more accurate value for the ADU of a "typical" customer, it is necessary to account separately for the high demand users in the system. Customers who averaged 20,000 gallons per month or more are considered high demand. The District serves 5 customers that met this level of usage during 2021. The combined annual usage for these customers was 2.1 million gallons, an average of 175,000 gallons per month. This equates to 5% of the total usage for all residential and commercial customers. Removing these high demand customers for the basis of determining the hydraulic model criteria, the average daily use for a typical customer over the past ten years is 155 gallons. The highest individual year was 2012, when the overall ADU was 252 gallons, or likely about 210 gpcd when excluding the high demand customers. The hydraulic model developed for this study assigns an average day demand of 210 gpcd for residential customers, with high demand customers being modeled uniquely. The ADU also includes water losses, which is assumed to be distributed evenly amongst all customers in the system. The water loss has historically been about 15%, which is essentially the industry standard average.

In addition to the average daily use, it is necessary to analyze the peak day use. In dry years, and particularly over holiday weekends, peak day demands can challenge the water supply, storage, and distribution systems. The historic high peak month volume produced/purchased was 8.85 million gallons in July, 2012. For that month, the average day volume was 285,000 gallons and the peak day was 345,000 gallons. Daily demand exceeded 300,000 gallons on several other days. The approximate demand per customer (including the five high-usage meters) calculates to 464 gallons for that peak day, representing 1.84 times the 252 gpd daily average per customer for that entire year. The high usage in 2012, due to the dry weather, serves as a basis for projecting future peak-usage conditions. As detailed in Table 2-1, future customer growth can be projected based on historic trends. The future potential peak day and peak annual usage can be projected based on the 2012 precedent. The demand criteria used in this analysis, rounded, is then established as:

Average Day Use	**250 gallons per customer**
Peak Day Use	**460 gallons per customer**

Consideration must also be given to the variation in customer demand over the course of a 24-hour period. Obviously, usage patterns change from day to day, but a typical pattern for the average of a large number of customers, such as the one shown in Figure 2-1, is used to model this variation in demand. The demand for a given hour is calculated by multiplying the average hourly usage by the respective peaking factor. A larger peaking factor represents a greater demand. Consequently, the greatest demand on a system occurs during the peak hour of the peak day. As one might suspect, the greatest demands come in the morning as residents are preparing for work or school, and in the evening as they arrive back home.

The hydraulic analysis of the distribution system simulates the short-term impact imposed by peak instantaneous usage during critical times of the day. The maximum demand by one customer may reach as high as 10 gpm when multiple household appliances and fixtures are being simultaneously utilized. As the number of customers increase on a small branch line, the decreasing probability of simultaneous peak uses results in peak demands approaching an average of about 1.0 gpm per household.

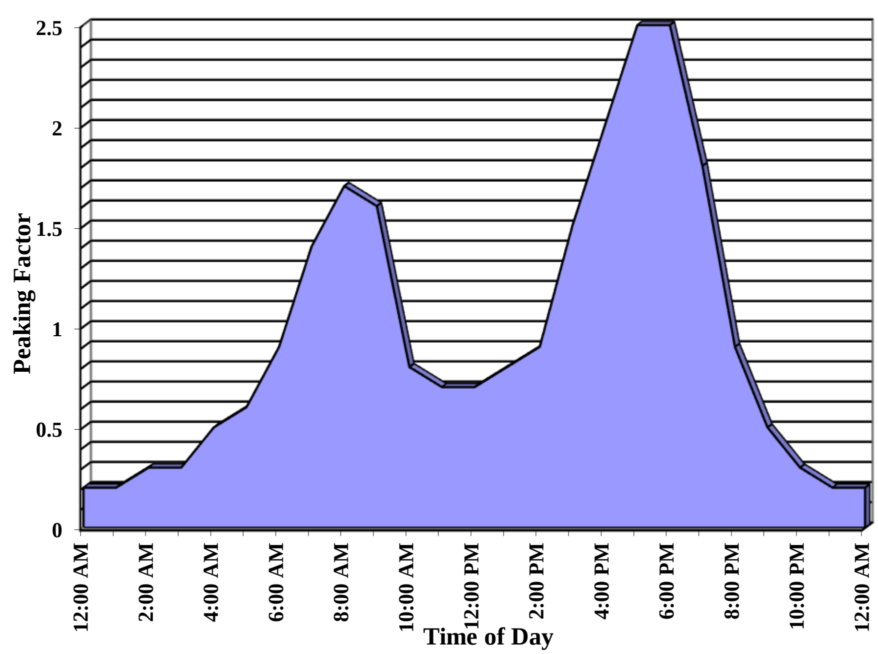

Figure 2-1. Typical daily demand variations

Table 2-1. Water Usage Summary

	Water Volumes in 1000 gal.									
Year	Wells	Purchased	Total Supplied	Sold	Flushing	Lost	Water Loss (%)	Meters	ADU (gal)	Est. Peak Day (gal)
2009	48,059	1,788	49,847	43,282	1,422	5,143	10.3%	745	183	251,284
2010	48,646	1,206	49,852	41,974	277	7,601	15.2%	744	184	251,309
2011	45,814	9,384	55,198	44,695	500	10,003	18.1%	743	204	278,258
2012	48,765	19,580	68,345	53,259	2,057	13,029	19.1%	744	252	344,534
2013	42,141	15,914	58,055	47,499	925	9,631	16.6%	745	213	292,661
2014	38,585	12,395	50,980	43,117	1,077	6,786	13.3%	748	187	256,995
2015	32,452	22,534	54,986	42,479	2,940	9,567	17.4%	753	200	277,190
2016	34,568	21,203	55,771	46,188	3,200	6,383	11.4%	759	201	281,147
2017	30,811	19,769	50,580	43,108	3,900	3,572	7.1%	753	184	254,979
2018	30,496	26,261	56,757	45,586	747	10,424	18.4%	759	205	286,117
2019	35,917	15,833	51,750	41,180	0	10,570	20.4%	782	181	260,877
2020	35,218	17,968	53,186	44,530	0	8,656	16.3%	805	181	268,116
2021	27,400	20,093	47,493	43,017	0	4,476	9.4%	803	162	239,417

Average	38,375	15,687	54,062	44,609	1,311	8,142	14.8%	760	195
Max	48,765	26,261	68,345	53,259	3,900	13,029	20.4%		252

ADU of Max Year:	187,247	gpd
Estimated 2022 Peak Day Potential:	435,000	gpd

average growth rates:	10-yr.	0.8%
	5-yr.	1.1%
	3-yr.	1.9%

Projections

	Water Volumes in 1000 gal.									
Year	Wells	Purchased	Total Supplied	Sold	Flushing	Lost	Water Loss (%)	Meters	ADU (gal)	Est. Peak Day (gal)
2022	48,491	26,110	74,601	62,212	1,311	11,078	14.8%	812	252	376,070
2023	49,040	26,406	75,446	62,932	1,311	11,204	14.8%	821	252	380,333
2024	49,596	26,706	76,302	63,660	1,311	11,331	14.8%	831	252	384,644
2025	50,158	27,008	77,166	64,396	1,311	11,459	14.8%	840	252	389,003
2026	50,727	27,314	78,041	65,141	1,311	11,589	14.8%	850	252	393,412
2027	51,302	27,624	78,926	65,894	1,311	11,720	14.8%	859	252	397,872
2028	51,883	27,937	79,820	66,656	1,311	11,853	14.8%	869	252	402,381
2029	52,471	28,254	80,725	67,426	1,311	11,987	14.8%	879	252	406,942
2030	53,066	28,574	81,640	68,205	1,311	12,123	14.8%	889	252	411,554
2031	53,667	28,898	82,565	68,993	1,311	12,261	14.8%	899	252	416,219
2032	54,276	29,225	83,501	69,790	1,311	12,400	14.8%	909	252	420,937
2033	54,891	29,557	84,447	70,596	1,311	12,540	14.8%	919	252	425,708
2034	55,513	29,892	85,405	71,411	1,311	12,682	14.8%	930	252	430,533
2035	56,142	30,230	86,373	72,235	1,311	12,826	14.8%	940	252	435,412
2036	56,779	30,573	87,352	73,069	1,311	12,972	14.8%	951	252	440,348
2037	57,422	30,920	88,342	73,912	1,311	13,119	14.8%	962	252	445,339
2038	58,073	31,270	89,343	74,765	1,311	13,267	14.8%	973	252	450,386
2039	58,731	31,624	90,356	75,627	1,311	13,418	14.8%	984	252	455,491
2040	59,397	31,983	91,380	76,499	1,311	13,570	14.8%	995	252	460,654
2041	60,070	32,345	92,415	77,381	1,311	13,724	14.8%	1006	252	465,875
2042	60,751	32,712	93,463	78,273	1,311	13,879	14.8%	1017	252	471,155

Over the last 10 years the District has grown at an average of 0.8% annually, or about 6 new customers each year. However, more recently that trend has accelerated. Over the last 5 years the growth has averaged 1.1% annually, and over the last 3 years the growth has averaged 1.9%. Given the proximity to Tonganoxie, Lawrence, and the Kansas City metropolitan area, it is very likely that the District will continue to add a significant number customers in the foreseeable future, particularly if the District is able to accommodate fire flow requirements for high-density development. Fluctuations are expected in the future, just as the District has experienced in the past. Quite likely, the most reliable indicator of future growth is the District's historic growth. Based on that assumption, the projections for the next 20 years are based on continuation of the recent 1% rate. In the hydraulic model, we have weighted the growth to reflect the expectation that the east and south areas of the District will grow at 1.5% annually, compared to 1.0% for the central area and 0.5% for the west and north areas. This is a direct reflection of commuting time to Lawrence and Kansas City and availability to city sewer service.

The projected peak day demand potential in 2022 is about 375,000 gallons, which represents a 9% increase from the last peak day experienced in 2012. The probability of a peak day occurring in any given year depends on temperature and precipitation. The high water demands from 2012 were a reflection of the drought at that time. By 2030, the total annual production/purchase requirement is expected to be 81 MGY, with a peak day demand of 411,000 gallons. Ten years beyond that, in 2040, the projected total annual production is over 91 MG, and the peak day demand is 460,000 gallons. The District is expected to be serving nearly 900 customers in 2030 and almost 1000 customers by 2040.

3 ANALYSIS OF EXISTING SYSTEM

Modest but constant growth over the last several years, in addition to the typical impacts of age, has stressed some facets of the RWD No. 9 system. As a result, there are deficiencies in various areas, as discussed below in detail.

3.1 Water Supply

No other part of a water distribution system matters if there is an inadequate supply. The District is fortunate to have two full-time water supply sources: groundwater wells in a fractured rock formation, and a wholesale supply from Suburban Water. The District's contract with Suburban provides an abundant supply, while the less expensive groundwater supply has been decreasing in capacity over the last several years. The 20-year contract with Suburban Water, executed in May, 2013 and included in Appendix A, provides for a peak day delivery of 288,000 gallons, an annual take-or-pay requirement of 12 MGY, and an annual maximum purchase of 105 MGY. Suburban blends water from Kansas City Board of Public Utilities and groundwater wells. The rate for water purchased is $3.60 per 1,000 gallons, which is the same rate that was established in 2013. The District is fortunate to have a steady rate for water being purchased.

The water quality of the two sources is similar, and of high quality, as illustrated in Table 3-1. The District had no water quality violations in 2019, either in the constituents listed below or the multiple other constituents that were tested. The only noticeable difference in the sources, of any significance, is the Suburban water being almost 40% higher in hardness than the water from the RWD No. 9 wells. High hardness is not a health concern but does have an economic impact on customers, as fixtures and appliances wear out sooner with hard water. For those households that soften, the higher hardness levels require additional salt and/or electrical costs.

Table 3-1. RWD No. 9 supply source water quality

Constituent	Maximum Acceptable Level, ppm	RWD No. 9 Wells, ppm	Suburban Water, ppm
Hardness	NA	240	330
Iron	0.30	0.06	0.02
Manganese	0.05	0.02	0.003
Nitrate	10.0	0.18	0.96
pH	6.5 - 8.5	7.6	7.9

3.1.1 Ground Water

The District's four groundwater wells are drilled into a sandstone and shale formation. From a geological definition, the formation is the Tonganoxie sandstone member of the Stranger formation of the Douglas group of the Virgilian Series. The Source Water Protection Plan, developed by RWD No. 9 in 2016 and included in Appendix B, as well as Kansas Geological Survey Bulletins, included in Appendix C, both provide detailed information about this water supply source. Although the groundwater supply from this formation is not as ample as from the Kansas River alluvium, or other similarly high-yielding alluviums in northeast Kansas, it is sufficient for meeting the demands of RWD No. 9.

Total permitted water rights allow up to 111 MGY, at a flow rate of up to 281 gpm. The four wells are producing at a fraction of that level. Two of the wells (#2 and #5) produce about 13 MGY each, at a rate of 30-32 gpm, and two (#1 and #3) produce about 5 MGY, at a rate of 15-16 gpm. The combined 36 MGY is only half of the potential 2020 annual need of 69 MGY, meaning the remaining half needs to be purchased. This compares to annual production from the wells of almost 50 MGY in 2009-12 and expected annual production of over 100 MGY when they were constructed. The wells have clearly lost capacity. This could either be through declining water levels in the Stranger formation, or more likely due to degradation of the well screen and surrounding gravel pack. Table 3-2 illustrates characteristics of the wells, as reflected in the Division of Water Resources records. Wells #1 and #3 are producing only about 25%-30% of their authorized flow rate, while #2 is at 75% of its authorized flow rate and #5 is operating near its authorized rate.

Table 3-2. Groundwater well characteristics

Well #	Water Right #	Construction Date	Depth to Water	Depth of Well	AF Used	Authorized Quantity, AF	Authorized Rate, GPM
1	43489	1972	86	131	25.07	39.90	50
2	19460	1972	81	138	50.09	110.48	44
3	43488	1972	82	137	19.36	70.58	60
5	19460	1975	81	145	35.04	110.48	32

Due to buildup of iron-consuming bacterial biological matter in the wells' gravel pack and screen, production capacity decreases over time. Wells need to be treated periodically with acid, a high dosage of chlorinated water, and preferably also a biocide chemical in order to recover flow capacity. Over time, steel screens corrode and the capacity recovery through the gravel pack from cleaning is diminished.

Flow capacity can also be limited by the water level in the geological formation, which is a function of precipitation over several months. When they were new, the groundwater level surrounding the wells was 80-85 feet. Tested recently, the static water levels were nearly identical to when they were new, with the exception of well #5 being 12 feet deeper (93' depth versus of 81'). Ironically, though, well #5 is the only one operating at its initial design rate. The drawdown, when the pumps are running, is 8' for wells #1 and #2, 20' for well #5, and 29' for well #3. These drawdown levels are measured inside the casing, so it reflects not only the water level in the formation, but also the restrictions caused by a fouled gravel pack and well screen. The pumps are all set at depths of 130-140 feet, indicating that 25-40 feet of water is maintained over the pumps.

Well #3 appears to currently be the weakest well but was rated for the highest flow rate when new. Since the initial capacity was based on the formation, it appears that the well is greatly fouled, and that a new well may deliver a significant increase in flow. At ages of 45-48 years old, all four of the wells are near the end of their life.

The raw water quality is fair, with hardness and nitrates being at desirable levels but iron and manganese being high. The pressure filter treatment system removes a large portion of the iron and manganese, resulting in a high-quality finished product. Raw water quality for pertinent constituents are shown for each well in Table 3-3. Iron content is highly variable, ranging from two to ten times the maximum secondary contaminant level, depending on the well location. Manganese levels are much more consistent, with the maximum level only being twice the maximum secondary contaminant level. It is noteworthy that the table reflects a post-filter hardness level greater than the flow-weighted blended total. As the samples were not taken at the same time, this discrepancy is likely caused by seasonal variation.

Table 3-3. RWD No. 9 well raw water quality

	Well						
Constituent	**#1**	**#2**	**#3**	**#5**	**Avg.**	**Flow-Weighted Blended Total**	**Post-Filter**
Hardness	231	180	202	185	200	194	240
Iron	0.68	1.53	1.87	3.03	1.78	1.95	0.06
Manganese	0.08	0.10	0.09	0.11	0.10	0.10	0.02
Production Rate, gpm	16	32	16	32	24		96

Figure 3-1 illustrates the typical appearance of the wells, with pitless adaptor units providing access to submersible vertical turbine pumps. Each well site is protected by a secure steel fence, with an electrical disconnect switch net to the well pad.

Figure 3-1. Typical well site

As high-density development has occurred north of Tonganoxie near the wells, see Figure 3-2, the wells have become vulnerable to potential vandalism and also to contamination, particularly lawn herbicides. In 2016, the District worked with the Kansas Rural Water Association to develop a Source Water Protection Plan, which puts in place best practices for minimizing this risk.

Figure 3-2. Well #3

Constructed in 2004-05, as an expansion to an existing clearwell and high service pumping facility, the District's pressure filter system has a capacity of 150 gpm. Chlorine is added in front of the filter, which causes the iron and manganese to oxidize out of solution and into a solid state that can be removed through the filter. After passing through the filter, then into a storage clearwell, water is re-chlorinated then pumped into the distribution system. Fortunately, there are no harmful contaminants to remove, only aesthetic, so the water would be safe to drink even if the treatment plant was not operating at optimal performance. Although styles of filters differ, this is a common treatment method for groundwater. Many filtering systems utilize pressurized steel filter tanks so that the well pumps provide pressure through the tanks and into the distribution system, eliminating the need for a clearwell and second set of pumps.

The filtering and pumping capacity is 50% greater than the current maximum production of almost 100 gpm, with all four wells running, and more than double the 60 gpm firm capacity of the wells, defined as the largest-producing well being out of service. If well production could be increased to 150 gpm, the maximum daily groundwater production/treatment would be 200,000 gallons, over half of the District's estimated 2020 peak day demand.

Figure 3-3. Iron & manganese filter

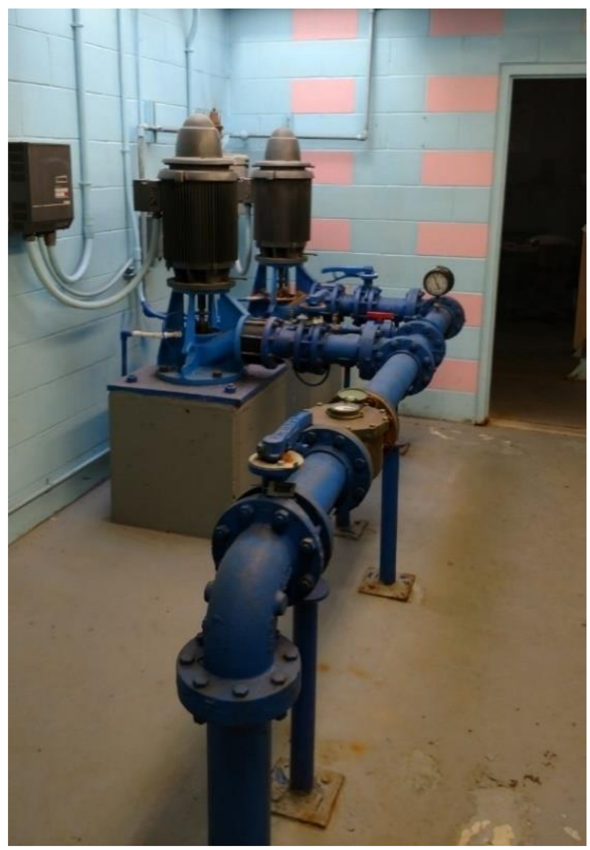

Figure 3-4. Filter high service pumps

Figure 3-5. Filter building and lagoon

Figure 3-6. Filter building lab

Figure 3-7. Filter building chlorine room

The treatment plant sends water to the distribution system with a free chlorine residual, meaning no ammonia is added. Since Suburban water is a combined chlorine supply (with ammonia) and should not simply be mixed with free chlorine water, the District must over-feed chlorine to the water leaving the clearwell in order to achieve free chlorine disinfection. This is referred to as break-point free chlorination and is necessary so that all ammonia in the water is bound with chlorine and the excess chlorine can then provide a consistent free chlorine residual. Figure 3-8 provides a graphical illustration.

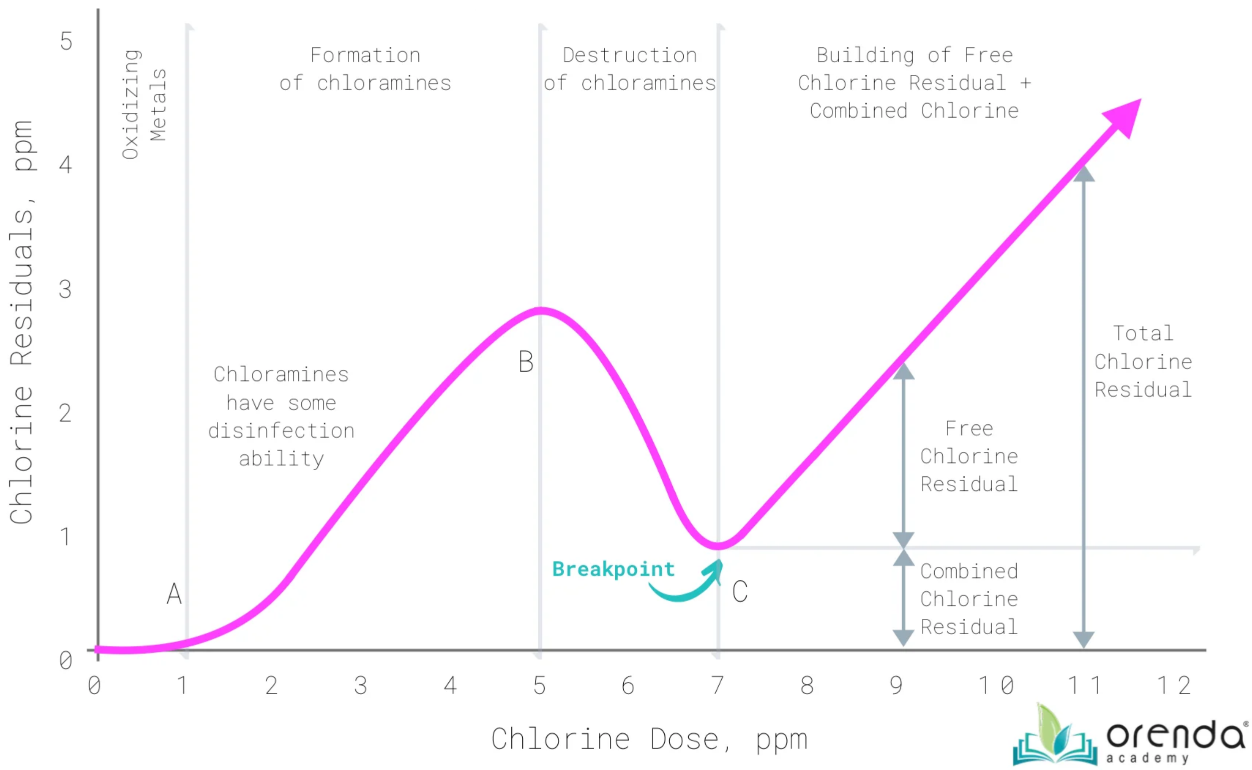

Figure 3-8. Breakpoint chlorination illustration

3.1.2 Redundancy

Emergencies are part of a water system operation and should be planned for. Power outages, transmission line breaks, low groundwater levels, and source contamination are all valid considerations. As such, redundancy is recommended, either in the form of backup power generation, alternate water supplies, or a combination.

The supply from Suburban is ample to meet nearly all of the District's demands but, based on contract limitations, falls 15% - 20% short on a peak day. Under an emergency situation, the contract terms can probably be circumvented. On the contrary, the wells can only meet 25% of a peak day demand and therefore are not a reliable backup to the Suburban supply. The former wholesale water district pump station, two miles southwest of the wells, provides a 240 gpm pumping capacity from Suburban. Currently this is only operated in very high demand times. Emergency connections with other entities, such as Tonganoxie or McLouth should be considered.

The only significant deficiency noted is the lack of emergency power for the west pump station. The west water tower provides emergency storage for more than a day, so only an extended power outage, such as one caused by an ice storm, would jeopardize supply to customers served by that pump station. The District may want to consider purchasing a generator mounted on a trailer that could be used at the wells, treatment building, or west pump station.

Figure 3-9. Suburban Water standby pump station

3.2 Pumping/Transmission

Pumping and transmission capacities are heavily related to each other, as flow rates are generally limited by the maximum pressure rating of existing pipeline, which is a function of the friction loss in the pipe. Therefore, replacing small pumps with larger pumps typically will not suffice as a means to increase flow unless existing pipe is also replaced or paralleled with larger pipe.

The District's water supply is blended in the treatment plant's 67,000-gallon clearwell then pumped to the northwest through nearly 4 miles of 6-inch and 8-inch line to the east water tower. Two high service pumps produce 150 gpm each, with about 135 psi discharge pressure. Under average demands of about 160,000 gallons, only one pump is needed. Running 24 hours a day, the pump can produce 216,000 gallons, which is 35% greater than the average day demand. However, under projected peak day demands of 350,000 gallons, either both pumps would be required, producing a combined flow of about 300 gpm, or flow would need to come through the 240 gpm Suburban wholesale pump station.

The west pump station pumps are rated for 150 gpm each, pulling water from an 8" line and delivering it to the west water tower through 3 miles of 6" and 1½ miles of 5" water line. Under current peak day conditions, 140,000 gpd is anticipated by customers served from this zone. One pump would need to operate 16 hours to meet that demand. Thus, unlike the high service pumps, there is always a redundant pump, even on peak days.

One particular concern with the west pump station is the need to replace impellers every two years. Cavitation has been known to cause premature failure in pump impellers, but that would typically only occur when pressures are near 0 psi. The hydraulic model of the District's distribution system indicates that suction-side pressures should consistently be above 40 psi. If there were breaks in the suction-side transmission line, or frequent high-volume flushing on that line, pressures could drop below 20 psi, in which a low-suction-pressure cutout switch could be added to stop the pump. District staff reports that breaks and flushing are not happening on that pipeline so cavitation is unlikely. There is also a possibility of the wells pumping sand and rock fragments into the distribution line, which could cause mechanical failure of the impellers. A strainer in front of the high service pump meter would reduce or eliminate that occurrence.

Figure 3-10. West pump station pumps

Figure 3-11. West pump station

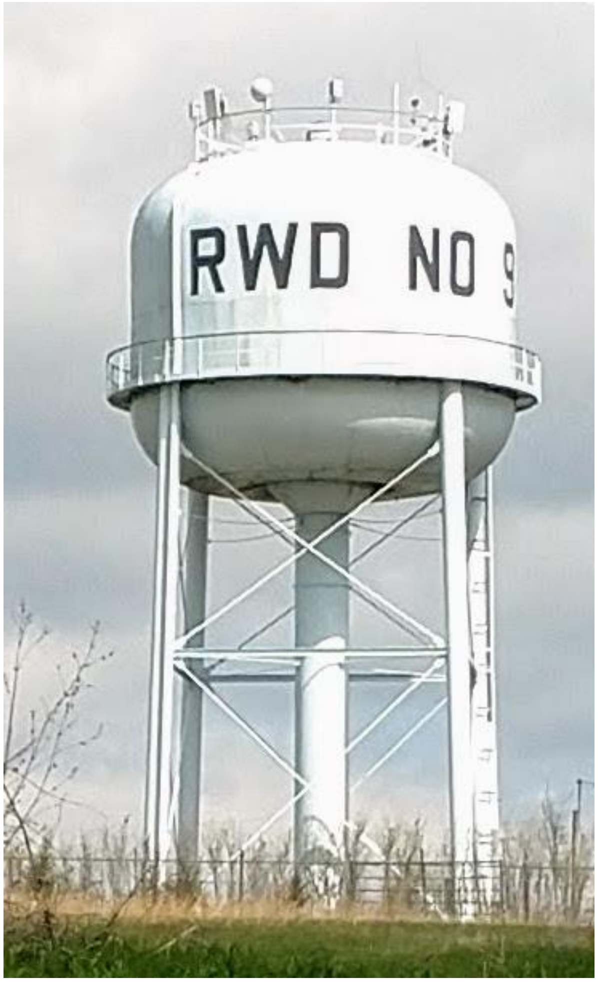

Figure 3-12. #1 (east) water tower

3.3 Storage

A water storage facility should be sized to allow adequate operational drawdown, meet peak-period demands beyond the pumping capacity (equalization storage), and provide emergency storage for fire flows, pipe breaks, pump failures or power outages. Typically, a third of the storage is allocated to each of these uses. The total volume usually corresponds closely to an average day demand for the area it serves.

RWD No. 9 has recently constructed two elevated water storage tanks to replace their original standpipes. The #1 water tower (east) has a capacity of 200,000 gallons and the #2 water tower (west) has a capacity of 150,000 gallons. The combined volume significantly exceeds the District's anticipated drought-year average day demand of nearly 200,000 gallons. The District should have ample storage for many years to come. If there is a deficiency, it is likely due to stagnant water. Internal mixing can be added if the problem arises, or periodic intentional overflow of the tanks can purge the older, low-quality water that has stratified near the top of the bowl.

Table 3-4 summarizes the capacity sufficiency of these two water towers and the other major facilities under existing peak day demands. Note that the table reflects the scenario of one pump being out of service for each item. This is referred to as "firm capacity" and is widely used as the limitation for establishing reliable capacity. Redundant pumps are a requirement of nearly all regulatory and funding agencies.

Table 3-4. Capacity assessment under current peak day demands

Pumping/Process	Flow Rate, gpm	Maximum Daily Production, gal.	2020 Peak Day Demand, gal.	% of 2020 Peak Day
Wells	60	86,400	347,000	25%
Treatment	150	216,000	347,000	62%
High Service, 1 pump	150	216,000	347,000	62%
High Service, 2 pumps	300	432,000	347,000	124%
Suburban pump station	240	345,600	347,000	100%
Suburban Water contract	200	288,000	347,000	83%
West Pump Station	150	216,000	132,000	164%

** Note -- all values reflect firm capacity*

Water Towers	Volume, gal.	Equalization Storage, gal.	2020 Peak Equal. Storage Required, gal.	% of 2020 Requirement
West	150,000	50,000	9,000	556%
East	200,000	67,000	45,000	149%

3.4 Distribution System

The District's distribution system is in good condition, both in terms of physical integrity and also relative to capacity. The pressure delivered to a customer is created by the combination of their meter elevation in relation to the water elevation in a storage tank, minus the friction loss that occurs as water moves through the pipe between the tank and their meter. In general terms, acceptable friction loss corresponds to flows at or below those shown in Table 3-5.

Table 3-5. Pipeline friction loss targets

Pipe Size	Preferable Friction Loss at or Below Flow of	Corresponding No. of Cust.
2-inch	15 gpm	5
3-inch	35 gpm	25
4-inch	60 gpm	55

A few segments of the distribution system have demands significantly higher than these levels. However, most of them are 2-inch lines that are relatively short branch lines off of larger transmission lines. Some segments have modeled peak flows of 1.5 to 2 times the preferable level shown in the table. However, in these instances, the minimum pressures remain above 30 psi.

The hydraulic model, simulating peak instantaneous demand conditions, shows adequate pressures throughout the system, with only one exception. The highest elevation in the District is at the far west end, adjacent to the east City limits of McLouth. At this location, with an elevation of 1175', the modeled low pressure is 17 psi. The maximum pressure at the same location is only 29 psi, so pipeline friction loss is high but not dramatic. The ground elevation at that site, compared to the overflow elevation of the west water tower, is the primary cause of the low pressure.

In a few other locations, the minimum pressure is expected to be between 20 psi and 30 psi, which is above the State-mandated minimum of 20 psi, but less than most households prefer. Only 10 to 15 customers are likely to be affected by these relatively low pressures. See Figure 3-13 for color-coded minimum pressures. In many cases, the low pressures may be short-lived, as customers adjust their use to accommodate the lack of pressure. This "self-governing" mechanism tends to hide the severity of the problem, as pressures are maintained at the expense of flow.

There are a couple segments of 2-inch glue-joint PVC that are a maintenance concern. Glued joints do not allow deflection and, thus, result in the pipe developing critical fatigue stresses. Replacing these segments with gasketed slip-joint PVC should be a priority for the District.

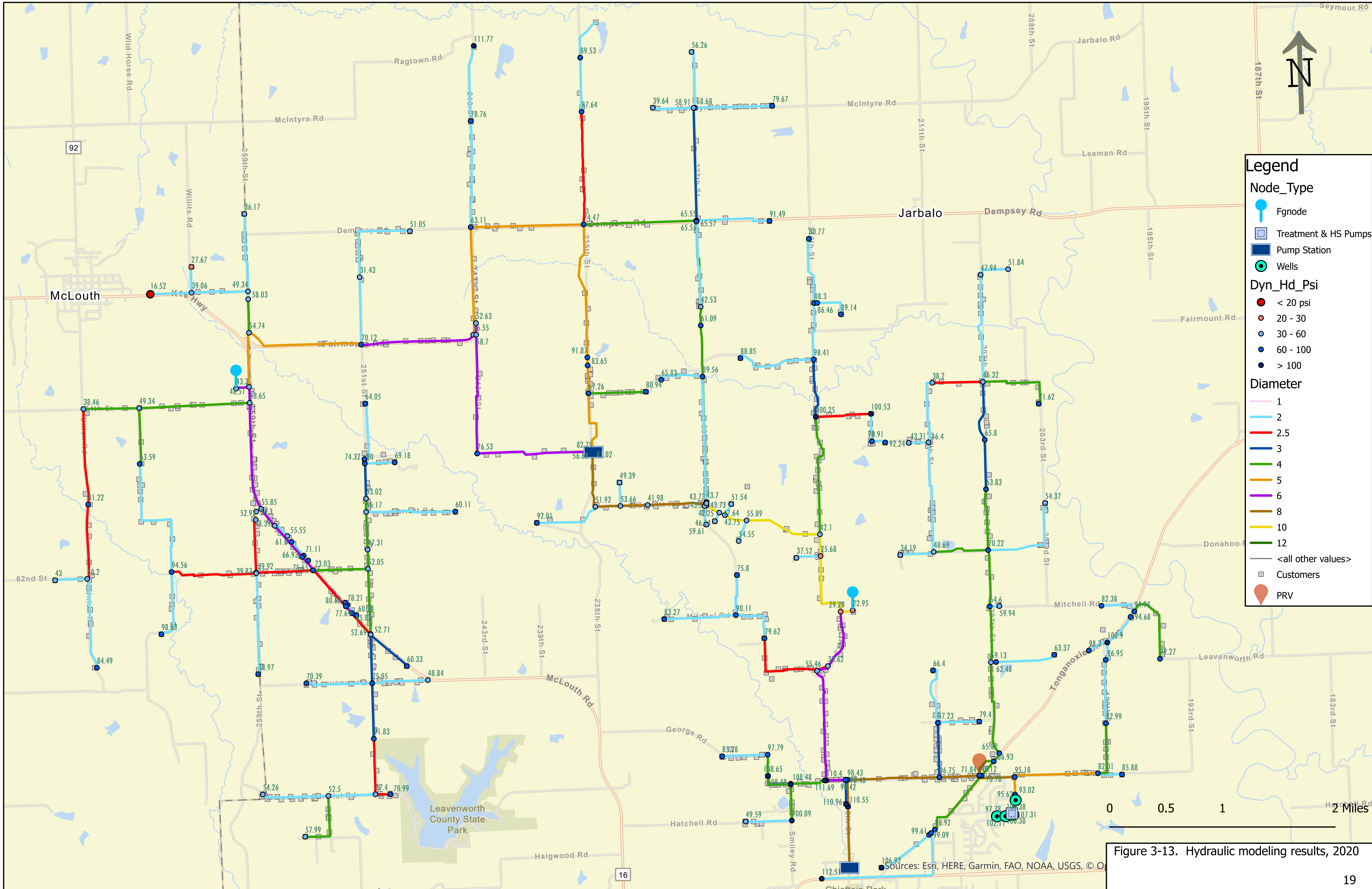

Figure 3-13. Hydraulic modeling results, 2020

4 ANALYSIS OF SYSTEM UNDER FUTURE DEMANDS

The growth projections presented in Section 2 provide a basis for evaluating the capacities of District facilities at a 10-year and 20-year interval.

4.1 Water Supply

Over the last six years, since the contract with Suburban Water was signed, the District has averaged about two-thirds of water being produced from the groundwater wells and one-third being supplied by Suburban Water. Due to the deteriorating production from the wells, the District has relied more heavily on Suburban, with about 40% now being purchased and 60% being produced. Replacing one or more of the low-producing groundwater wells would enable a greater production-versus-purchase ratio for future years.

Given similar water qualities between the two options, the future water supply blend should largely be a financial consideration. With the declining condition of the old existing wells, the District needs to evaluate the long-term economics of investing in new wells versus buying nearly all water from Suburban or another entity. A life-cycle analysis provides a valuable comparison. Tables 4-1 through 4-5 provide detailed 20-year life cycle financial comparisons for unique scenarios, and Table 4-6 summarizes those results. The specific scenarios are as follows:

- Scenario #1: Do not construct new wells and gradually purchase more water from Suburban
- Scenario #2: Replace wells #1 and #3 with two new wells and strive for at least 75% supplied from wells
- Scenario #3: Install three new wells and maximize the groundwater well supply
- Scenario #4: Purchase additional property and install a total of five new wells, abandoning the Suburban contract when it expires in 2033
- Scenario #4a: Purchase additional property and install a total of five new wells, renewing the Suburban contract when it expires in 2033

As is the nature with long-term analyses, several assumptions are required, relative to future inflationary increases, Suburban Water rate increase, facility life expectancy, and operational expenses. The following assumptions were made:

1.	Life expectancy of new wells, years:	40
2.	Annual cost increase from Suburban Water:	3.0%
3.	Annual inflationary rate:	3.0%
4.	Groundwater well cost of production per 1,000 gallons:	$1.00
5.	Average annual well maintenance cost, included in #4:	$17,000

Table 4-1. Scenario #1: Do not replace existing wells and gradually increase amount purchased from Suburban Water

Estimated Total Project Cost: $0

			Groundwater Supply						Suburban Water						
Year	Annual Demand, MGY	Peak Day Demand, MGD	Annual Production, MGY	Cost of Production per 1,000	Annual Production Cost	Amortized capital cost	Total Annual Cost	Present Value	Annual Purchase, MGY	Cost of Purchase per 1,000	Annual Purchase Cost	Operations Cost	Total Annual Cost	Present Value	Combined Present Value
2024	59.16	0.38	35.00	$1.00	$35,000	$0	$35,000	$35,000	24.16	$4.05	$97,867	$8,000	$105,867	$105,867	$140,867
2025	59.84	0.39	34.30	$1.03	$35,329	$0	$35,329	$34,467	25.54	$4.17	$106,521	$8,240	$114,761	$111,962	$146,429
2026	60.51	0.39	33.61	$1.06	$35,661	$0	$35,661	$33,943	26.90	$4.30	$115,578	$8,487	$124,065	$118,087	$152,029
2027	61.20	0.40	32.94	$1.09	$35,996	$0	$35,996	$33,426	28.26	$4.43	$125,056	$8,742	$133,797	$124,244	$157,670
2028	61.89	0.40	32.28	$1.13	$36,335	$0	$36,335	$32,917	29.61	$4.56	$134,972	$9,004	$143,976	$130,436	$163,353
2029	62.59	0.41	31.64	$1.16	$36,676	$0	$36,676	$32,416	30.96	$4.70	$145,347	$9,274	$154,621	$136,662	$169,079
2030	63.30	0.41	31.00	$1.19	$37,021	$0	$37,021	$31,923	32.30	$4.84	$156,198	$9,552	$165,750	$142,926	$174,849
2031	64.02	0.42	30.38	$1.23	$37,369	$0	$37,369	$31,437	33.64	$4.98	$167,546	$9,839	$177,385	$149,228	$180,665
2032	64.75	0.42	29.78	$1.27	$37,720	$0	$37,720	$30,959	34.97	$5.13	$179,413	$10,134	$189,547	$155,570	$186,529
2033	65.48	0.43	29.18	$1.30	$38,075	$0	$38,075	$30,488	36.30	$5.28	$191,821	$10,438	$202,259	$161,954	$192,442
2034	66.22	0.43	28.60	$1.34	$38,433	$0	$38,433	$30,024	37.63	$5.44	$204,791	$10,751	$215,543	$168,382	$198,405
2035	66.97	0.44	28.03	$1.38	$38,794	$0	$38,794	$29,567	38.95	$5.61	$218,350	$11,074	$229,423	$174,854	$204,420
2036	67.73	0.44	27.47	$1.43	$39,159	$0	$39,159	$29,117	40.27	$5.77	$232,520	$11,406	$243,926	$181,373	$210,489
2037	68.50	0.45	26.92	$1.47	$39,527	$0	$39,527	$28,673	41.58	$5.95	$247,329	$11,748	$259,077	$187,940	$216,613
2038	69.28	0.45	26.38	$1.51	$39,898	$0	$39,898	$28,237	42.90	$6.13	$262,802	$12,101	$274,903	$194,556	$222,793
2039	70.06	0.46	25.85	$1.56	$40,273	$0	$40,273	$27,807	44.21	$6.31	$278,970	$12,464	$291,433	$201,225	$229,032
2040	70.86	0.46	25.33	$1.60	$40,652	$0	$40,652	$27,384	45.52	$6.50	$295,860	$12,838	$308,697	$207,946	$235,330
2041	71.66	0.47	24.83	$1.65	$41,034	$0	$41,034	$26,967	46.83	$6.69	$313,503	$13,223	$326,726	$214,723	$241,690
2042	72.47	0.47	24.33	$1.70	$41,420	$0	$41,420	$26,557	48.14	$6.89	$331,932	$13,619	$345,551	$221,556	$248,113
2043	73.29	0.48	23.84	$1.75	$41,809	$0	$41,809	$26,153	49.45	$7.10	$351,179	$14,028	$365,207	$228,447	$254,600
							Totals	$607,463						$3,317,936	$3,925,399

Table 4-2. Scenario #2: Replace two wells and minimize purchase from Suburban Water

Estimated Total Project Cost: $800,000

			Groundwater Supply						Suburban Water						
Year	Annual Demand, MGY	Peak Day Demand, MGD	Annual Production, MGY	Cost of Production per 1,000	Annual Production Cost	Amortized capital cost	Total Annual Cost	Present Value	Annual Purchase, MGY	Cost of Purchase per 1,000	Annual Purchase Cost	Operations Cost	Total Annual Cost	Present Value	Combined Present Value
2024	59.16	0.38	45.00	$1.00	$45,000	$34,610	$79,610	$79,610	14.16	$4.05	$57,367	$8,000	$65,367	$65,367	$144,977
2025	59.84	0.39	45.00	$1.03	$46,350	$34,610	$80,960	$78,985	14.84	$4.17	$61,886	$8,240	$70,126	$68,415	$147,400
2026	60.51	0.39	45.00	$1.06	$47,741	$34,610	$82,350	$78,382	15.51	$4.30	$66,656	$8,487	$75,143	$71,522	$149,905
2027	61.20	0.40	45.00	$1.09	$49,173	$34,610	$83,783	$77,800	16.20	$4.43	$71,691	$8,742	$80,433	$74,690	$152,490
2028	61.89	0.40	45.00	$1.13	$50,648	$34,610	$85,258	$77,239	16.89	$4.56	$77,004	$9,004	$86,008	$77,919	$155,158
2029	62.59	0.41	45.00	$1.16	$52,167	$34,610	$86,777	$76,698	17.59	$4.70	$82,608	$9,274	$91,882	$81,210	$157,909
2030	63.30	0.41	45.00	$1.19	$53,732	$34,610	$88,342	$76,177	18.30	$4.84	$88,517	$9,552	$98,069	$84,565	$160,742
2031	64.02	0.42	45.00	$1.23	$55,344	$34,610	$89,954	$75,675	19.02	$4.98	$94,746	$9,839	$104,585	$87,984	$163,659
2032	64.75	0.42	45.00	$1.27	$57,005	$34,610	$91,615	$75,192	19.75	$5.13	$101,311	$10,134	$111,445	$91,469	$166,661
2033	65.48	0.43	45.00	$1.30	$58,715	$34,610	$93,325	$74,728	20.48	$5.28	$108,229	$10,438	$118,667	$95,020	$169,748
2034	66.22	0.43	45.00	$1.34	$60,476	$34,610	$95,086	$74,281	21.22	$5.44	$115,515	$10,751	$126,266	$98,639	$172,920
2035	66.97	0.44	45.00	$1.38	$62,291	$34,610	$96,900	$73,852	21.97	$5.61	$123,189	$11,074	$134,262	$102,327	$176,180
2036	67.73	0.44	45.00	$1.43	$64,159	$34,610	$98,769	$73,440	22.73	$5.77	$131,268	$11,406	$142,674	$106,086	$179,526
2037	68.50	0.45	45.00	$1.47	$66,084	$34,610	$100,694	$73,045	23.50	$5.95	$139,772	$11,748	$151,520	$109,916	$182,961
2038	69.28	0.45	45.00	$1.51	$68,067	$34,610	$102,676	$72,667	24.28	$6.13	$148,721	$12,101	$160,822	$113,818	$186,485
2039	70.06	0.46	45.00	$1.56	$70,109	$34,610	$104,718	$72,304	25.06	$6.31	$158,137	$12,464	$170,601	$117,794	$190,098
2040	70.86	0.46	45.00	$1.60	$72,212	$34,610	$106,822	$71,958	25.86	$6.50	$168,042	$12,838	$180,880	$121,845	$193,803
2041	71.66	0.47	45.00	$1.65	$74,378	$34,610	$108,988	$71,626	26.66	$6.69	$178,459	$13,223	$191,682	$125,973	$197,599
2042	72.47	0.47	45.00	$1.70	$76,609	$34,610	$111,219	$71,310	27.47	$6.89	$189,413	$13,619	$203,033	$130,178	$201,488
2043	73.29	0.48	45.00	$1.75	$78,908	$34,610	$113,518	$71,008	28.29	$7.10	$200,929	$14,028	$214,957	$134,462	$205,470
							Totals	$1,424,973						$1,824,736	$3,249,709

Table 4-3. Scenario #3: Construct three new wells and maximize the groundwater supply

Estimated Total Project Cost: $1,300,000

				Groundwater Supply							Suburban Water							
Year	Annual Demand, MGY	Peak Day Demand, MGD		Annual Production, MGY	Cost of Production per 1,000	Annual Production Cost	Amortized capital cost	Total Annual Cost	Present Value		Annual Purchase, MGY	Cost of Purchase per 1,000	Annual Purchase Cost	Operations Cost	Total Annual Cost	Present Value		Combined Present Value
2024	59.16	0.38		47.16	$1.00	$47,165	$56,241	$103,406	$103,406		12.00	$4.05	$48,600	$8,000	$56,600	$56,600		$160,006
2025	59.84	0.39		47.84	$1.03	$49,270	$56,241	$105,511	$102,938		12.00	$4.17	$50,058	$8,240	$58,298	$56,876		$159,814
2026	60.51	0.39		48.51	$1.06	$51,468	$56,241	$107,709	$102,519		12.00	$4.30	$51,560	$8,487	$60,047	$57,154		$159,673
2027	61.20	0.40		49.20	$1.09	$53,762	$56,241	$110,003	$102,148		12.00	$4.43	$53,107	$8,742	$61,848	$57,432		$159,581
2028	61.89	0.40		49.89	$1.13	$56,155	$56,241	$112,396	$101,825		12.00	$4.56	$54,700	$9,004	$63,704	$57,712		$159,538
2029	62.59	0.41		50.59	$1.16	$58,653	$56,241	$114,894	$101,550		12.00	$4.70	$56,341	$9,274	$65,615	$57,994		$159,544
2030	63.30	0.41		51.30	$1.19	$61,260	$56,241	$117,501	$101,321		12.00	$4.84	$58,031	$9,552	$67,583	$58,277		$159,597
2031	64.02	0.42		52.02	$1.23	$63,980	$56,241	$120,221	$101,138		12.00	$4.98	$59,772	$9,839	$69,611	$58,561		$159,699
2032	64.75	0.42		52.75	$1.27	$66,819	$56,241	$123,060	$101,001		12.00	$5.13	$61,565	$10,134	$71,699	$58,847		$159,848
2033	65.48	0.43		53.48	$1.30	$69,781	$56,241	$126,022	$100,909		12.00	$5.28	$63,412	$10,438	$73,850	$59,134		$160,043
2034	66.22	0.43		54.22	$1.34	$72,871	$56,241	$129,113	$100,863		12.00	$5.44	$65,314	$10,751	$76,066	$59,422		$160,285
2035	66.97	0.44		54.97	$1.38	$76,097	$56,241	$132,338	$100,861		12.00	$5.61	$67,274	$11,074	$78,348	$59,712		$160,573
2036	67.73	0.44		55.73	$1.43	$79,462	$56,241	$135,703	$100,903		12.00	$5.77	$69,292	$11,406	$80,698	$60,004		$160,906
2037	68.50	0.45		56.50	$1.47	$82,973	$56,241	$139,214	$100,989		12.00	$5.95	$71,371	$11,748	$83,119	$60,296		$161,285
2038	69.28	0.45		57.28	$1.51	$86,637	$56,241	$142,878	$101,118		12.00	$6.13	$73,512	$12,101	$85,613	$60,590		$161,709
2039	70.06	0.46		58.06	$1.56	$90,459	$56,241	$146,700	$101,291		12.00	$6.31	$75,717	$12,464	$88,181	$60,886		$162,177
2040	70.86	0.46		58.86	$1.60	$94,447	$56,241	$150,688	$101,507		12.00	$6.50	$77,989	$12,838	$90,826	$61,183		$162,690
2041	71.66	0.47		59.66	$1.65	$98,608	$56,241	$154,849	$101,766		12.00	$6.69	$80,328	$13,223	$93,551	$61,481		$163,247
2042	72.47	0.47		60.47	$1.70	$102,949	$56,241	$159,190	$102,067		12.00	$6.89	$82,738	$13,619	$96,358	$61,781		$163,849
2043	73.29	0.48		61.29	$1.75	$107,478	$56,241	$163,719	$102,411		12.00	$7.10	$85,220	$14,028	$99,248	$62,083		$164,493
								Totals	$1,930,120							$1,123,944		$3,054,063

Table 4-4. Scenario #4: Install five wells, expand treatment facility, and minimize purchase from Suburban

Estimated Total Project Cost: $2,000,000

			Groundwater Supply						Suburban Water						
Year	Annual Demand, MGY	Peak Day Demand, MGD	Annual Production, MGY	Cost of Production per 1,000	Annual Production Cost	Amortized capital cost	Total Annual Cost	Present Value	Annual Purchase, MGY	Cost of Purchase per 1,000	Annual Purchase Cost	Operations Cost	Total Annual Cost	Present Value	Combined Present Value
2024	59.16	0.38	47.16	$1.00	$47,165	$86,525	$133,689	$133,689	12.00	$4.05	$48,600	$8,000	$56,600	$56,600	$190,289
2025	59.84	0.39	47.84	$1.03	$49,270	$86,525	$135,795	$132,483	12.00	$4.17	$50,058	$8,240	$58,298	$56,876	$189,359
2026	60.51	0.39	48.51	$1.06	$51,468	$86,525	$137,993	$131,343	12.00	$4.30	$51,560	$8,487	$60,047	$57,154	$188,497
2027	61.20	0.40	49.20	$1.09	$53,762	$86,525	$140,286	$130,270	12.00	$4.43	$53,107	$8,742	$61,848	$57,432	$187,702
2028	61.89	0.40	49.89	$1.13	$56,155	$86,525	$142,680	$129,261	12.00	$4.56	$54,700	$9,004	$63,704	$57,712	$186,973
2029	62.59	0.41	50.59	$1.16	$58,653	$86,525	$145,178	$128,316	12.00	$4.70	$56,341	$9,274	$65,615	$57,994	$186,310
2030	63.30	0.41	51.30	$1.19	$61,260	$86,525	$147,784	$127,434	12.00	$4.84	$58,031	$9,552	$67,583	$58,277	$185,711
2031	64.02	0.42	52.02	$1.23	$63,980	$86,525	$150,505	$126,614	12.00	$4.98	$59,772	$9,839	$69,611	$58,561	$185,176
2032	64.75	0.42	52.75	$1.27	$66,819	$86,525	$153,343	$125,856	12.00	$5.13	$61,565	$10,134	$71,699	$58,847	$184,703
2033	65.48	0.43	53.48	$1.30	$69,781	$86,525	$156,305	$125,158	12.00	$5.28	$63,412	$10,438	$73,850	$59,134	$184,292
2034	66.22	0.43	54.22	$1.34	$72,871	$86,525	$159,396	$124,520	12.00	$5.44	$65,314	$10,751	$76,066	$59,422	$183,942
2035	66.97	0.44	54.97	$1.38	$76,097	$86,525	$162,621	$123,941	12.00	$5.61	$67,274	$11,074	$78,348	$59,712	$183,653
2036	67.73	0.44	67.73	$1.43	$96,571	$86,525	$183,096	$136,142	0.00	$5.77	$0	$0	$0	$0	$136,142
2037	68.50	0.45	68.50	$1.47	$100,596	$86,525	$187,120	$135,741	0.00	$5.95	$0	$0	$0	$0	$135,741
2038	69.28	0.45	69.28	$1.51	$104,788	$86,525	$191,313	$135,397	0.00	$6.13	$0	$0	$0	$0	$135,397
2039	70.06	0.46	70.06	$1.56	$109,155	$86,525	$195,679	$135,110	0.00	$6.31	$0	$0	$0	$0	$135,110
2040	70.86	0.46	70.86	$1.60	$113,704	$86,525	$200,228	$134,879	0.00	$6.50	$0	$0	$0	$0	$134,879
2041	71.66	0.47	71.66	$1.65	$118,442	$86,525	$204,967	$134,703	0.00	$6.69	$0	$0	$0	$0	$134,703
2042	72.47	0.47	72.47	$1.70	$123,378	$86,525	$209,903	$134,583	0.00	$6.89	$0	$0	$0	$0	$134,583
2043	73.29	0.48	73.29	$1.75	$128,520	$86,525	$215,045	$134,516	0.00	$7.10	$0	$0	$0	$0	$134,516
							Totals	$2,485,441						$697,722	$3,183,163

Table 4-5. Scenario #4a: Same as Scenario #4 but renew contract with Suburban in 2033

Estimated Total Project Cost: $2,000,000

			Groundwater Supply						Suburban Water						
Year	Annual Demand, MGY	Peak Day Demand, MGD	Annual Production, MGY	Cost of Production per 1,000	Annual Production Cost	Amortized capital cost	Total Annual Cost	Present Value	Annual Purchase, MGY	Cost of Purchase per 1,000	Annual Purchase Cost	Operations Cost	Total Annual Cost	Present Value	Combined Present Value
2024	59.16	0.38	47.16	$1.00	$47,165	$86,525	$133,689	$133,689	12.00	$4.05	$48,600	$8,000	$56,600	$56,600	$190,289
2025	59.84	0.39	47.84	$1.03	$49,270	$86,525	$135,795	$132,483	12.00	$4.17	$50,058	$8,240	$58,298	$56,876	$189,359
2026	60.51	0.39	48.51	$1.06	$51,468	$86,525	$137,993	$131,343	12.00	$4.30	$51,560	$8,487	$60,047	$57,154	$188,497
2027	61.20	0.40	49.20	$1.09	$53,762	$86,525	$140,286	$130,270	12.00	$4.43	$53,107	$8,742	$61,848	$57,432	$187,702
2028	61.89	0.40	49.89	$1.13	$56,155	$86,525	$142,680	$129,261	12.00	$4.56	$54,700	$9,004	$63,704	$57,712	$186,973
2029	62.59	0.41	50.59	$1.16	$58,653	$86,525	$145,178	$128,316	12.00	$4.70	$56,341	$9,274	$65,615	$57,994	$186,310
2030	63.30	0.41	51.30	$1.19	$61,260	$86,525	$147,784	$127,434	12.00	$4.84	$58,031	$9,552	$67,583	$58,277	$185,711
2031	64.02	0.42	52.02	$1.23	$63,980	$86,525	$150,505	$126,614	12.00	$4.98	$59,772	$9,839	$69,611	$58,561	$185,176
2032	64.75	0.42	52.75	$1.27	$66,819	$86,525	$153,343	$125,856	12.00	$5.13	$61,565	$10,134	$71,699	$58,847	$184,703
2033	65.48	0.43	53.48	$1.30	$69,781	$86,525	$156,305	$125,158	12.00	$5.28	$63,412	$10,438	$73,850	$59,134	$184,292
2034	66.22	0.43	54.22	$1.34	$72,871	$86,525	$159,396	$124,520	12.00	$5.44	$65,314	$10,751	$76,066	$59,422	$183,942
2035	66.97	0.44	54.97	$1.38	$76,097	$86,525	$162,621	$123,941	12.00	$5.61	$67,274	$11,074	$78,348	$59,712	$183,653
2036	67.73	0.44	55.73	$1.43	$79,462	$86,525	$165,987	$123,420	12.00	$5.77	$69,292	$11,406	$80,698	$60,004	$183,424
2037	68.50	0.45	56.50	$1.47	$82,973	$86,525	$169,498	$122,957	12.00	$5.95	$71,371	$11,748	$83,119	$60,296	$183,253
2038	69.28	0.45	57.28	$1.51	$86,637	$86,525	$173,161	$122,551	12.00	$6.13	$73,512	$12,101	$85,613	$60,590	$183,141
2039	70.06	0.46	58.06	$1.56	$90,459	$86,525	$176,984	$122,201	12.00	$6.31	$75,717	$12,464	$88,181	$60,886	$183,087
2040	70.86	0.46	58.86	$1.60	$94,447	$86,525	$180,972	$121,907	12.00	$6.50	$77,989	$12,838	$90,826	$61,183	$183,090
2041	71.66	0.47	59.66	$1.65	$98,608	$86,525	$185,133	$121,668	12.00	$6.69	$80,328	$13,223	$93,551	$61,481	$183,150
2042	72.47	0.47	60.47	$1.70	$102,949	$86,525	$189,474	$121,484	12.00	$6.89	$82,738	$13,619	$96,358	$61,781	$183,265
2043	73.29	0.48	61.29	$1.75	$107,478	$86,525	$194,003	$121,354	12.00	$7.10	$85,220	$14,028	$99,248	$62,083	$183,437
							Totals	$2,395,076						$1,123,944	$3,519,019

Table 4-6. Summary of water supply option 20-year present values

Scenario	% Wells	% Suburban	20-Year Total PV Cost
1	44%	56%	$ 3,925,399
2	69%	31%	$ 3,249,709
3	82%	18%	$ 3,054,063
4	88%	12%	$ 3,183,163
4a	82%	18%	$ 3,519,019

Table 4-6 shows the trend of decreased long-term water supply costs as the groundwater supply is increased and the Suburban Water supply is decreased, or at least to a point. The amortized annual cost/debt payment of two to five new wells, along with the well production cost, is less than the cost of purchase from Suburban Water. Having four good wells that produce at least 30-40 gpm each is the most cost-effective. Adding a fifth well may not provide significant cash-flow value, but it does provide a valuable backup so that four wells can be run consistently, and it is still less than purchasing over half of the water from Suburban. Under Scenario #3, wells #1 and #3 would be abandoned. Depending on the new well sites, wells #2 and #5 could be left in service as part of a rotation.

A thorough life-cycle analysis should identify the biggest potential variances and consider the financial sensitivity of those. In this case, Suburban Water had a 7-year history of not increasing the water rate until just recently when it was increased from $3.60 to $3.93 per 1,000 gallon rate. Whether this is oversight, indicative of steady operational costs by Suburban, or reflective of a benevolent seller is left to speculation. In our 20-year analysis, we assumed an average annual rate increase of 3.0%, the same as the assumed inflationary rate. A variation of 1.0% annually can have a significant impact. Table 4-7 illustrates what the 20-year total present value cost would be at various average rate increases below the 3.0%.

Table 4-7. Sensitivity analysis of assumed future Suburban rate increases

Scenario	20-Year Total Present Value Cost			
	0%	1%	2%	3%
1	$3,093,087	$3,337,222	$3,613,205	$3,925,399
2	$2,831,279	$2,954,925	$3,093,752	$3,249,709
3	$2,835,155	$2,900,283	$2,972,941	$3,054,063
4	$3,095,049	$3,122,534	$3,151,864	$3,183,163
4a	$3,300,111	$3,365,239	$3,437,897	$3,519,019

As one would expect, with assumed lower average annual rate increases from Suburban, the 20-year total cost decreases and the financial benefit of new wells is also decreased. However, in all of the cases, the trend still holds that production and filtering of groundwater is less expensive than purchasing water, up to a capital investment threshold. If Suburban never raises rates, only Scenarios #2 and #3 are cost effective, with Scenario #4 essentially being break-even. At 3% annual rate increases, installing 2 to 5 new wells is between 17% and 22% less expensive.

This planning document is prepared with a 20-year vision. However, long-term water supply decisions need to be considered over an even longer period. Given that the life expectancy of the wells is 40+ years, it is prudent to consider the present values over a 40-year period. Simplifying the analysis to include only Scenarios #1 - #3, with an assumed 3.0% annual rate increase from Suburban, and assuming that the existing wells could actually last another 40 years (which is extremely unlikely), the calculated 40-year total present value of the two options is:

Scenario #1 40-year total present value = $10.0 million

Scenario #2 40-year total present value = $8.1 million

Scenario #3 40-year total present value = $6.8 million

At a difference of 20% to 30%, it is evident that the District should prioritize maintaining and increasing groundwater production for their future water supply.

Presumably there will be locations for new well sites within the property already owned by the District, as illustrated in Figure 4-1. However, the Kansas Department of Health and Environment requires a 100-foot protective radius around each well, so unless that requirement can be waived it may be necessary to negotiate with neighboring landowners for a protective easement. The District is advised, and may be required, to purchase additional property, as the wells should be separated by a quarter mile. This is a Division of Water Resources requirement, unless the wells are permitted as "batteries". Exceptions can be made, if supported by geological analysis and testing.

The sandstone and shale rock comprising the Tonganoxie member of the Stranger Formation is widespread. There are numerous places that would likely provide adequate yield from a well. The yield may vary significantly by location, though, so the best course of action is to employ a geologist, identify landowners that are receptive to selling a site, and negotiate the right to conduct test drilling. Options to purchase property could be negotiated prior to test drilling, where the selling price for, say, an acre of land (either purchased or leased) would be pre-determined. The properties to the south or east would be attractive sites, if available, while sites further away from the existing wells would likely provide similar groundwater yield, but would entail significant cost in new raw water line, electrical, and controls. Given the cost advantage of producing versus purchasing, the District could justify a significant investment for a well site, preferably within a half-mile of the existing wells. Keeping the wells at a quarter-mile spacing should increase the overall yield from the formation, as the wells' cone of depression will not be interfering with each other.

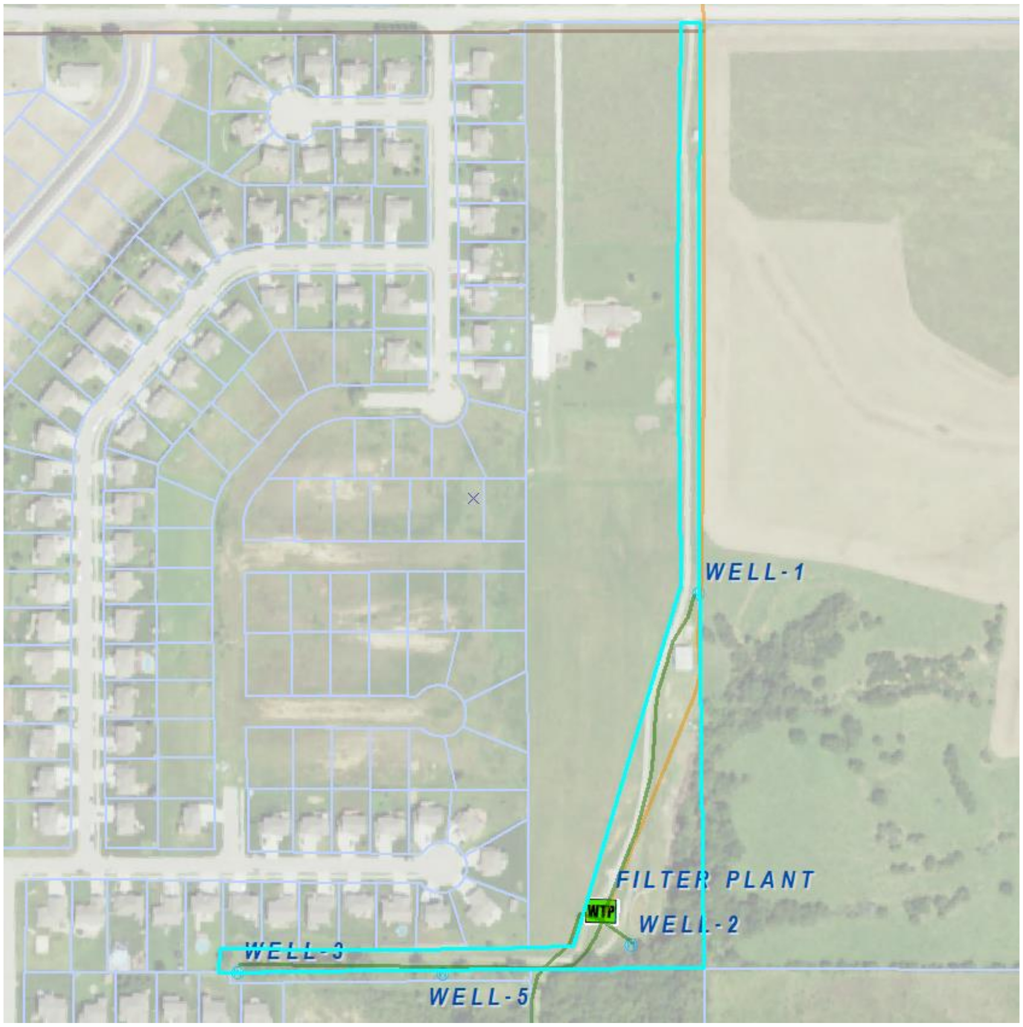

Figure 4-1. RWD No. 9 property owned at well sites

If the water supply is eventually expanded to a capacity beyond 150 gpm from wells that are running, it will be necessary to expand the treatment capacity of the iron and manganese filtering system. This could be accomplished by either constructing a second unit, or by replacing the existing unit with a larger one. In either case, it will likely be necessary to expand the building that houses the filter. Based on our growth projections, this expansion would not be required until at least 2040, unless the Suburban Water contract is not renewed in 2033.

4.2 Pumping/Transmission

High-density development, most likely to occur within a mile of the Hwy 24 and Tonganoxie Rd. corridors in the southeast corner of the District, will require significant fire flow. Figure 4-2 illustrates the numerous relatively large undeveloped tracts that are prime for high-density development, provided that Tonganoxie, or possibly Basehor, is willing to provide sewer service. These areas could be annexed into city limits, but still be served water from RWD No. 9. The District may need to strengthen their legal position for that to be viable.

As waterline improvements are made within the RWD No. 9 transmission and distribution system, it is prudent to design for a reasonable fire flow capacity. This will likely be the dictating factor of design for many waterlines. The District's existing transmission line along 219th, south of the east water tower, is only 6" and is insufficient for current demands, much less the fire flow demands that would be required from high-density development. It has also been experiencing frequent breaks, likely due to lifetime fatigue stresses. As a minimum, this 2-mile segment of waterline should be replaced with a 10" line. Strong consideration should be given to a 12" line or perhaps even a 14" line. A cost/benefit analysis of these diameter options will be discussed in Section 5.

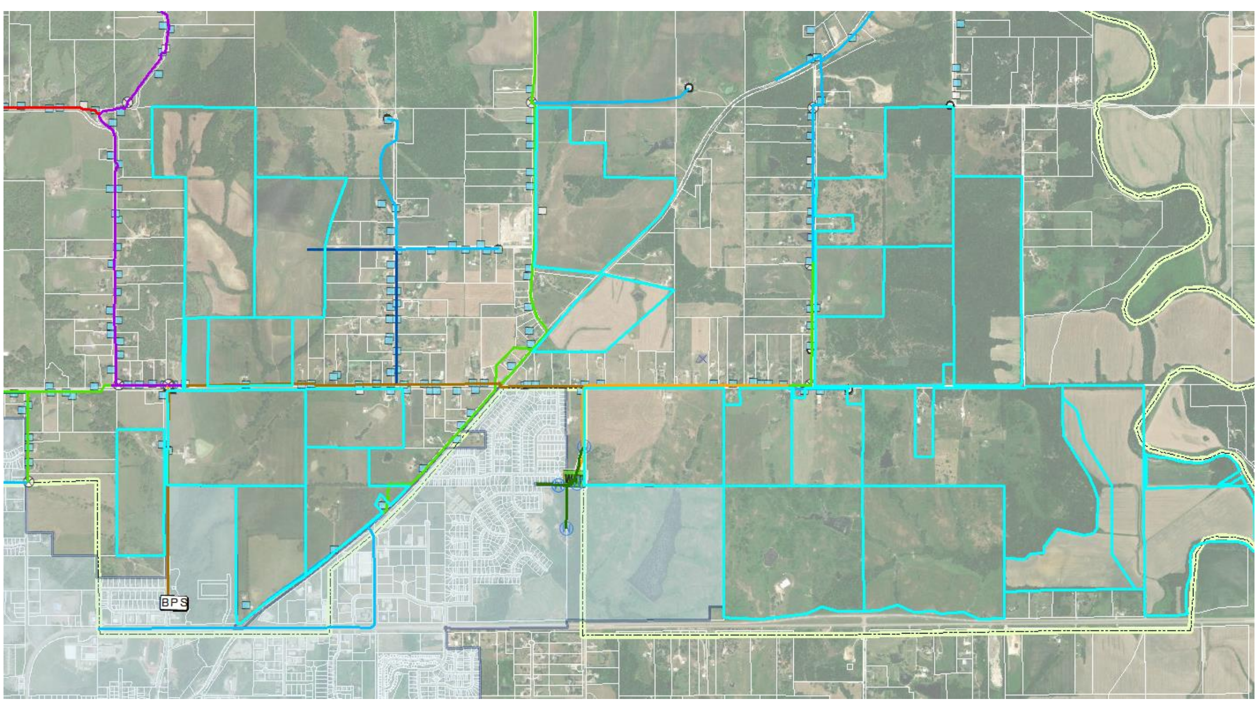

Figure 4-2. Potential high-density development areas

If a subdivision is annexed into the City of Tonganoxie, the Tonganoxie Fire Department and Planning Department would have jurisdiction to establish the fire flow requirements. Most cities follow the standards set by the Insurance Service Organization (ISO). Those standards call for a minimum fire flow of 500 gpm. When the spacing between houses are less than 30 feet, those requirements can increase to 750 gpm, or as much as 1,000 gpm. The fire flow requirements for new construction can be substantially greater for commercial, industrial, or governmental facilities. It is not uncommon for those to require as much as 2,000 gpm, although 1,000 gpm is a more typical requirement.

Table 4-8 provides a summary of the transmission water line size that would be required to meet various flow rates along the Hwy 24 and Tonganoxie Rd. corridors, being supplied from the east water tower. Replacing part of the transmission line, namely the 6" south of the water tower, with a larger line than required from this table, may allow the other portion of the transmission line, the 8" along Parallel Road, to meet fire flow demands significantly above the 500 gpm noted. In other words, if friction loss in the first half of the transmission line is relatively minimal, it can be much greater in the second half of the transmission line.

Table 4-8. Transmission line required for fire flow demand

Fire Flow, gpm	Pipe Size
500	8"
750	10"
1,000	10"
1,500	12"
2,000	14"

4.3 Storage

The two existing water towers are sufficient for long-term demands but the District may need to consider another water tower along the Hwy 24 corridor if extraordinarily high fire flow, such as 2,000 gpm for a large commercial or industrial operation, becomes a requirement in the future. Otherwise, the District is in great shape in terms of storage, probably through 2050.

As shown in Table 4-9, aside from the water supply deficiency and high service pumps, other facilities in the District are adequately sized for the next 20 years.

Table 4-9. Capacity assessment under projected peak day demands

Pumping/Process	Flow Rate, gpm	Maximum Daily Production, gal.	2030 Peak Day Demand, gal.	% of 2030 Peak Day	2040 Peak Day Demand, gal.	% of 2040 Peak Day
Wells	60	86,400	384,000	23%	424,000	20%
Treatment	150	216,000	384,000	56%	424,000	51%
High Service, 1 pump	150	216,000	384,000	56%	424,000	51%
High Service, 2 pumps	300	432,000	384,000	113%	424,000	102%
Suburban pump station	240	345,600	384,000	90%	424,000	82%
Suburban Water contract	200	288,000	384,000	75%	424,000	68%
West Pump Station	150	216,000	134,000	161%	140,000	154%

** Note -- all values reflect firm capacity*

Water Towers	Volume, gal.	Equalization Storage, gal.	2030 Peak Equal. Storage Required, gal.	% of 2030 Requirement	2040 Peak Equal. Storage Required, gal.	% of 2040 Requirement
West	150,000	50,000	10,000	500%	11,000	455%
East	200,000	67,000	52,000	129%	59,000	114%

4.4 Distribution System

Continued growth will lead to higher peak flow rates and lower service pressures. Applying assumed annual growth rates, we analyzed the hydraulic model of the distribution system under 2030 and 2040 projected demands. The projected future growths are 0.5% annually in the north/northwest, 1.0% annually in the central and west, and 1.5% annually in the south and east. Figures 4-3 and 4-4 illustrate the modeled low service pressures if no pipeline improvements were made in the next 20 years. Critically-low pressures develop in some areas, particularly where expected growth is the greatest. Higher growth rates would worsen the situation, although the highest growth is expected where elevations are relatively low, leading to higher pressures based on the comparative water tower overflow elevation. The higher elevations in the north and northwest, where pressures would be lower, are likely to experience lower growth.

Relatively minor waterline improvements will likely be required in the eastern part of the District as growth occurs. Other improvements will likely be based on either failing pipe, such as glue-joint PVC, or areas of concentrated growth. For instance, a large parcel of land sub-dividing in an area served by a 2-inch line would likely necessitate a waterline upgrade.

There are several 2-inch lines that are still in service but have been paralleled with larger lines due to growth. These should be abandoned if there is concern with the condition of that pipe, although there will be costs associated with switching over customer services. In particular, the 2-inch lines on 218th & 227th can be abandoned.

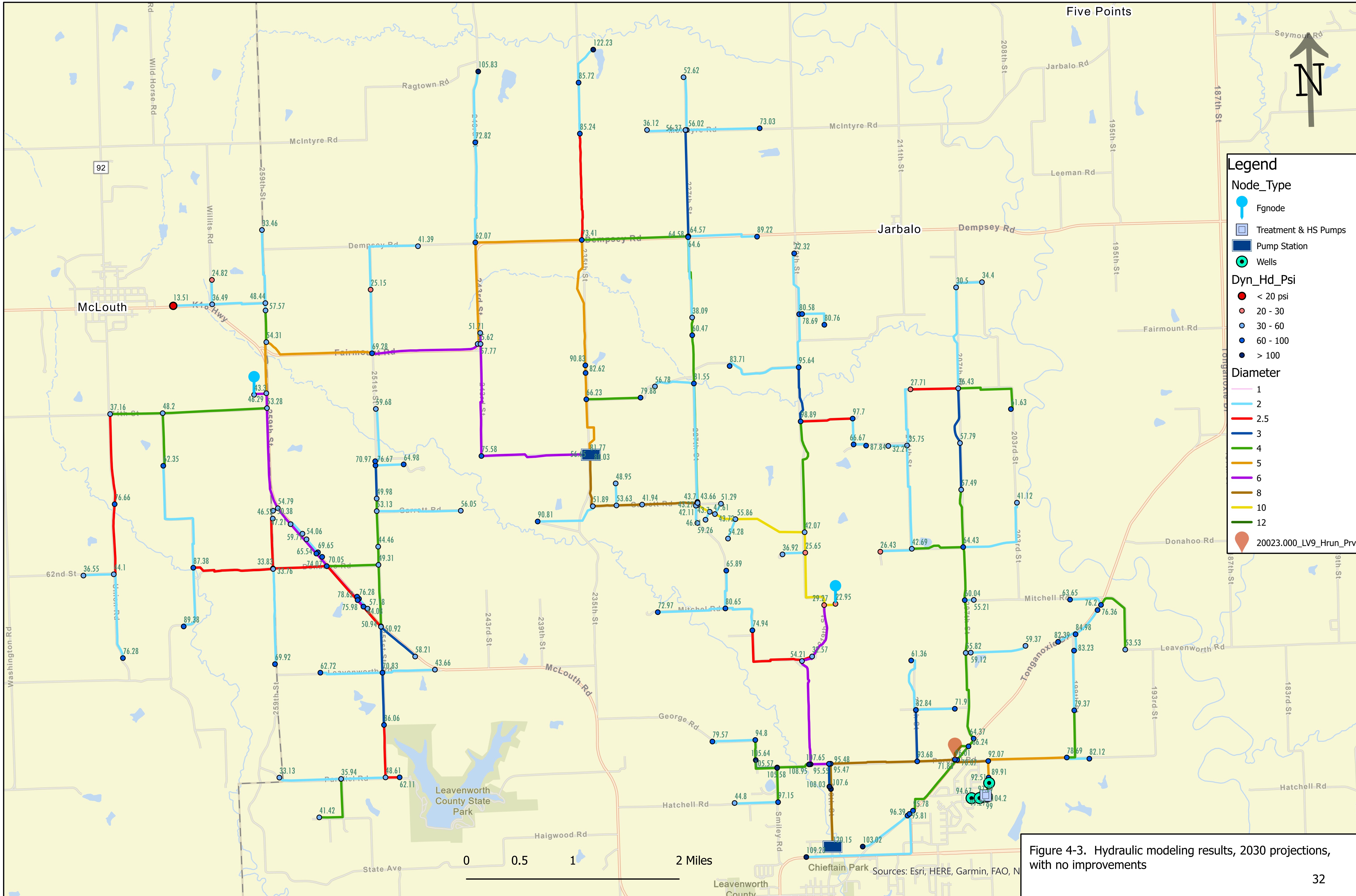

Figure 4-3. Hydraulic modeling results, 2030 projections, with no improvements

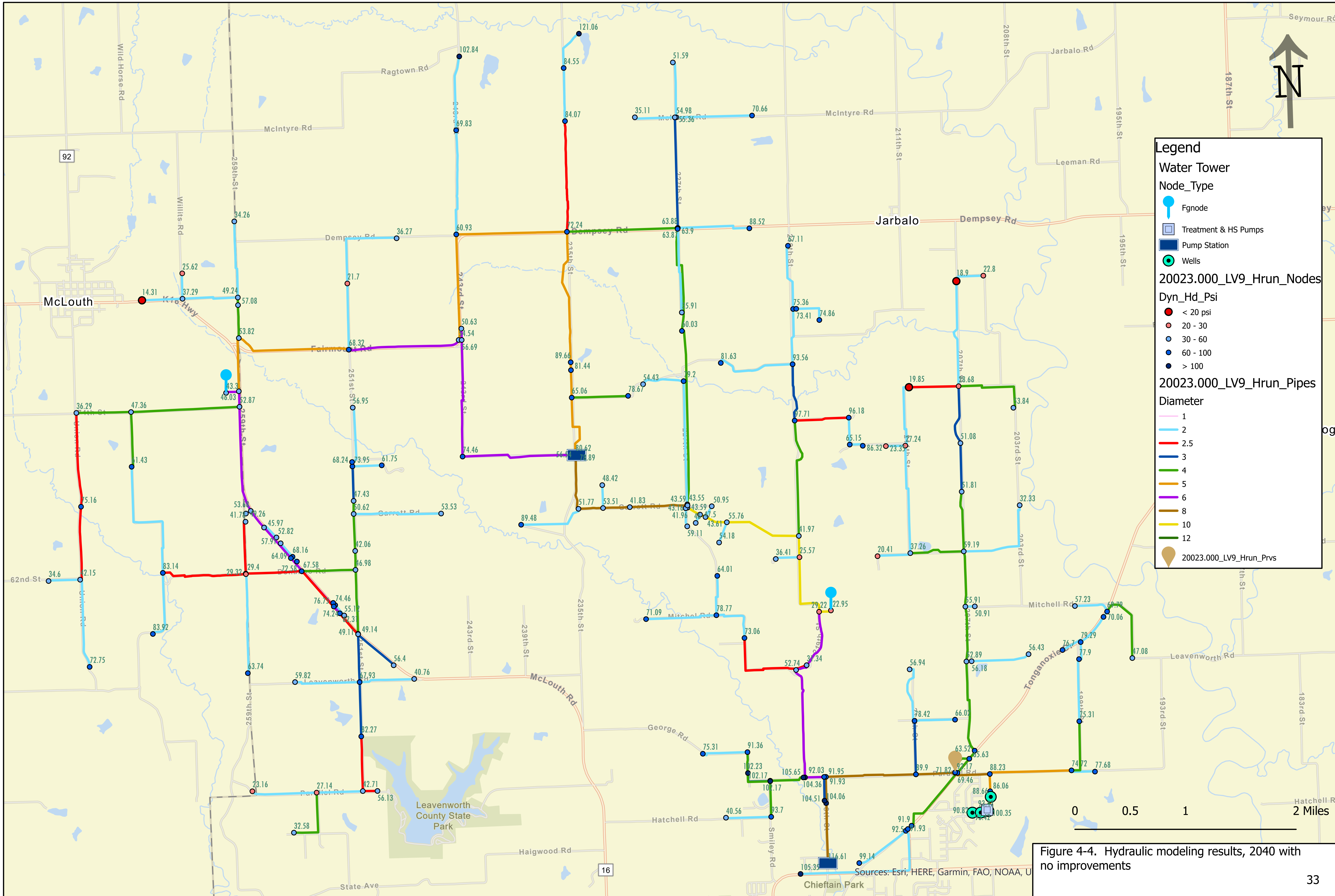

Figure 4-4. Hydraulic modeling results, 2040 with no improvements

5 PROPOSED IMPROVEMENTS

Several improvements are recommended over the next several years to address the deficiencies noted. Securing an improved groundwater supply is paramount. Other improvements are less critical and can be delayed. Future growth will dictate the timeline for various waterline upgrades, with fire flow requirements potentially dictating the size. Projects could be bundled and funded through loans, could be constructed periodically with funding through the annual budget, or a combination of the two.

Specific improvements are identified below and shown graphically in Figure 5-1. Cost estimates are provided in Section 6 and the financial impact on water rates is addressed in Section 7.

5.1 High Priority Improvements

1. **Construct at least two wells.** The District has invested significant time and expense in 2020 identifying suitable locations for new groundwater wells, both south and east of the existing wells. Two new sites have been identified to the south, which are expected to provide 35-40 gpm each. Wells #1 and #3 should be abandoned, while wells #2 and #5 can be left in service, each producing 25-30 gpm. With three pumps active, and one in standby, the design flow rate will be at 90-100 gpm, and would allow for about 45 MGY in production, with the remaining to be purchased annually from Suburban Water. This corresponds to one of the most cost-effective long-term options, Scenario #2, as outlined in Section 4.

   Over the 40-year life expectancy of the new wells, this scenario is likely $1.5 to $2.0 million (15%-20%) less than a gradually-increasing reliance on Suburban Water. Thus, it is worth the $800,000 investment.

2. **Replace the existing 6-inch transmission line south of the #1 (east) water tower.** Peak flows and the corresponding friction losses are excessive in this critical 9,000 ft. segment of waterline, being nearly three times as high as the typical design standard. Minimum service pressures are 10-15 psi lower throughout the southeast portion of the District because of the high friction losses. This line also is incapable of supporting fire flow demands that accompany high-density growth, which continues to develop along the Highway 24 corridor.

As a minimum, a 10-inch line would be required to meet expected fire flow requirements, but a 12-inch line may be a wiser long-term investment, as it provides capacity for 1,000 gpm, or greater. Flows of up to 750 gpm could be supplied with a new 10-inch and the existing 8-inch waterlines. Flows of up to 1,000 gpm can be accommodated without replacing the existing 8-inch line, but only if a new 12-inch line is constructed in place of the existing 6-inch. Flows over 1,000 gpm would require that the existing 8-inch line also be replaced. For flows at or above 1,500 gpm, 14-inch or 16-inch line would be required. Alternatively, the combination of a new 12-inch and the existing 8-inch could serve demands up to 1,000 gpm and a new water tower be constructed if fire flows in excess of 1,000 gpm are required.

The cost estimates in Section 6 illustrate that the projected cost of the 10-inch is $616,900, versus $846,700 for 12-inch, and $1,131,700 for 14-inch. If fire flows were ignored, under the scenario of the District having no desire to serve future subdivisions, an 8-inch line would be an adequate replacement. The approximate cost difference between 12-inch and 8-inch is $400,000. A simplified cost-benefit analysis of this investment could be based on the value of each customer added. In addition to the $6,000 benefit unit fee revenue, the present value of 40 years of a $30 per month water rate margin (income minus variable costs) is $10,000. Thus, if each new customer is worth $16,000 in present value revenue, and the cost to upgrade from 8-inch to 12-inch is $400,000, then only 25 new customers are required to recover the investment in the larger waterline. It is very likely that more than 25 customers will be added through high-density development if the District has the capacity to meet fire flows and the legal position to defend their right to serve.

3. **Use the Suburban "wholesale" pump station in an automated mode.** With the well capacity increased to about 150 gpm, water from Suburban will not be required on a daily basis. When it is required, though, in order to keep the water towers full, it is preferable to take water from Suburban through the old wholesale pump station, rather than blending at the well house clearwell. By doing so, the 150 gpm pumping capacity at the clearwell would be devoted to maximizing production from the wells, while an additional 240 gpm capacity could be provided through the wholesale pump station. In extreme cases, such as after a main transmission line break, the second clearwell high service pump could provide blended water from Suburban through the well house clearwell. To automate the wholesale pump station, the telemetry controls should trigger the start of a pump when the water level in the #1 tower drops to a certain level. The variable frequency drives could be utilized to limit the

flow rate, if desired. Chlorine would need to be added, in an automated mode, to achieve the desired residual level. Staff reports that most of this automation is in place already and simply needs to be implemented.

4. **Paint the #1 (east) water tower.** The District's primary water tower has not been painted since its construction in 2004. Typical water tower coating systems are rated for 20 years. A thorough inspection should be conducted soon, with a particular focus on the interior roof of the bowl, where corrosion is usually the most severe. It is anticipated that, as a minimum, the interior of the bowl will need to be sandblasted to bare metal and re-coated. The primer adhesion of the exterior should be evaluated. It may be adequate to waterblast the exterior and apply an overcoat.
5. **Replace 2" with 4" on 199th, north of Parallel Rd**. In the high-growth southeast corner of the District, the existing 2-inch waterline will become insufficient. As a minimum, this pipeline should be replaced with 4-inch. Potential high-density development would dictate a larger line, capable of meeting fire flow demands.
6. **Add polyphosphate to water at treatment plant.** The large gravity filter removes most of the precipitated iron and manganese from the groundwater. However, District staff has observed deposits of iron and manganese in the distribution system waterlines. Using a polyphosphate sequestering agent would keep most residual iron and manganese in solution, while also doing the same with hardness. Calcium deposits on household fixtures and appliances would be reduced. It also helps stabilize the water in a manner that reduces lead and copper corrosion. The polyphosphate can be feed with a small pump, sitting on a 55-gallon drum next to the high service pumps. The initial investment is minimal, and the feed can be discontinued if the benefit is ultimately determined to not be worth the chemical cost. Since water from the wells will be blended in the system with water from Suburban, through the pump station, it may be necessary to also feed polyphosphate at the pump station.
7. **Acquire a standby generator at the west pump station.** The District lacks a backup generator, which is particularly critical for the west pump station. In an extended power-outage, the west part of the District would be reliant upon the storage in the water tower. This would suffice for a day or two, given the ample storage capacity, but there is still an element of risk. The District could either install a permanent generator at the pump station, or purchase a trailer-mounted generator, which would provide for secure storage in the District's shop and could also be used to power a well if needed.

5.2 Five to Ten-Year Improvements

1. **Establish a standby connection with City of McLouth.** The District has waterline close to McLouth in two locations, a 2-inch along K-16 highway on the east edge of the City and a 4-inch that extends east-west along 74th St. from Union Rd. to Tower #2. The latter waterline is across the road from McLouth's supply line from Jefferson Co. RWD No. 13. With the construction of a road crossing, a meter pit, valves, and a couple pipeline connections, the District could benefit from a valuable emergency connection. The District's Tower #2 overflow elevation of 1240' compares to McLouth's south water tower overflow elevation of about 1300', meaning that gravity flow would fill the District's tower. Discussions should be initiated with the City to gauge their interest.
2. **Replace 2" glue joint PVC pipe with 4" PVC waterline.** Glued joints are notoriously problematic, as they create fatigue stresses by not allowing for joint deflection. The District only has two segments of such pipe remaining in the distribution system. Eventually these need to be replaced. The two areas are on Parallel Rd., between 255th and 259th, in the southwest corner of the District; and along Kissinger Rd., west of 227th St., a mile northeast of the west pump station. Allowing for future growth, 4-inch pipe is recommended.
3. **Construct a 4-inch loop between 207th & 219th, north of Tower #1**. As growth continues in the northeast part of the District, low pressures will develop as pipeline capacity becomes critical. The District could recover capacity by replacing 2 to 3 miles of existing 4-inch waterline along 207th, north of Parallel Rd., with 6-inch or 8-inch line. Alternately, and preferably, the District is advised to construct 2¼ miles of 4-inch, replacing segments of 2-inch and 2½-inch along Green, Hollingsworth, 211th, and Kissinger Roads, completing a loop between the central and east parts of the distribution system. A pressure reducing valve would be required east of 219th, to match the existing PRV at 207th and Parallel Rd.

5.3 Ten to Fifteen-Year Improvements

1. **Construct three wells, abandoning #2 and/or #5**. The immediate large project, identified in 5.1.1, involving the construction of two new wells, included leaving wells #2 and #5 in service. By 2035, these wells will be over 60 years old and likely no longer producing an appreciable volume. New wells would allow these old wells to be abandoned. With three new wells, presumably east of the existing wells, there would be four wells operating, with one in standby, likely producing a combined 130-150 gpm.

2. **Paint the #2 (west) water tower**. Constructed in 2014, the west water tower will not need re-coating for several years. However, given the significant cost of this, it needs to be included in the 20-year improvement plan. By 2034, it will likely need a full interior sand blast, with re-coating, and an exterior high-pressure water blast, with over-coating.
3. **Replace the 5" on Parallel Rd., in the southeast corner of the District, with 8" in order to accommodate fire flow for development**. The timeline for this project is dependent on both future high-density development and the condition of the pipe itself. It is possible that a developer will fund the replacement cost if necessitated by fire flow for a large subdivision.

5.4 Fifteen to Twenty-Year Improvements

1. **Replace 2", 2½" and 3" with 4" on 251st, K-16 to Parallel, then west on Parallel to 254th**. This is one of the few distribution pipeline segments that is close to its hydraulic capacity. Although less critical than the 2-inch waterline east of McLouth, it is anticipated that by 2035-2040, growth will have taxed this pipe segment to the point of inadequate service. Unless high-density development becomes relevant in this area northwest of Tonganoxie, a 4-inch line should provide ample capacity.
2. **Replace 2" with 4" on 251st, north of Fairmont Rd**. The addition of several more customers on this waterline could dictate the need to replace a half-mile, or so, of the existing 2-inch waterline with 4-inch. Relatively high elevations lead to expected minimum pressures in the 20-30 psi range with only minimal new growth.
3. **Construct two wells**. Assuming that the economic benefit of producing versus purchasing water is still valid, two new wells would presumably provide for a combined groundwater supply of at least 200 gpm firm capacity. Given proper spacing between wells, guided by groundwater exploration involving a geologist, and regular well maintenance, the District should be able to maintain 35 to 40 gpm for each well. These would be the sixth and seventh wells constructed over a 20-year period.
4. **Expand treatment plant from 150 gpm to 300 gpm.** With a seventh well constructed, and allowing for all wells to be used simultaneously in peak-demand situations, 250-300 gpm could likely be produced. With a timeline of 2040 or after, the estimated peak day is 430,000 gal. At 300 gpm, the peak day production capacity would match that. If the contract with Suburban is renewed beyond 2033, this excess capacity becomes redundant, or potentially available for supply to other RWDs or cities. This expansion could either come in the form

of a second filtering unit, similar to the existing unit, or in replacing the existing with one twice the size. Under either option, the existing building will need to be expanded, or a new building constructed. Prior to the construction of this costly improvement, an updated analysis of the long-term supply options should be re-visited. Maximizing the groundwater supply is the most cost-effective option at this time partially because of the "sunk cost" of the existing treatment facility. As part of this project, it may be necessary to construct a second sludge lagoon.

5.5 Performance of Improved System

The improvements outlined above are primarily related to the economics of water supply alternatives, enhancing fire flow delivery capability, adding redundancy, addressing major maintenance items, and improving segments of the distribution system. The benefits can be quantified in Tables 5-1 and 5-2 below. Other benefits are financial in nature and incorporated into the analysis provided in Section 7.

Table 5-1. Minimum pressure modeled improvements

	Modeled Minimum Pressure, psi				
Location	2020	2030, unimproved	2040, unimproved	2030, improved	2040, improved
Hatchell Rd. west of Smiley Rd. (north of Tonganoxie)	50	45	41	57	55
north of 227th & McIntyre (northern extreme of District)	56	53	52	53	52
211th & Kissinger (east edge of District)	38	28	20	28	54
Mitchell Rd. & Tonganoxie Rd. (SE corner of District)	82	64	57	76	111
255th & Parallel (SW corner of District)	52	36	27	36	70

Table 5-2. Capacity assessment under projected peak day demands, with improvements

Pumping/Process	Flow Rate, gpm	Maximum Daily Production, gal.	2030 Peak Day Demand, gal.	% of 2030 Peak Day	2040 Peak Day Demand, gal.	% of 2040 Peak Day
Wells	150	216,000	384,000	56%	424,000	51%
Treatment	150	216,000	384,000	56%	424,000	51%
High Service, 1 pump	150	216,000	384,000	56%	424,000	51%
High Service, 2 pumps	300	432,000	384,000	113%	424,000	102%
Suburban pump station	240	345,600	384,000	90%	424,000	82%
Suburban Water contract	200	288,000	384,000	75%	424,000	68%
West Pump Station	150	216,000	134,000	161%	140,000	154%

** Note -- all values reflect firm capacity*

Water Towers	Volume, gal.	Equalization Storage, gal.	2030 Peak Equal. Storage Required, gal.	% of 2030 Requirement	2040 Peak Equal. Storage Required, gal.	% of 2040 Requirement
West	150,000	50,000	10,000	500%	11,000	455%
East	200,000	67,000	52,000	129%	59,000	114%

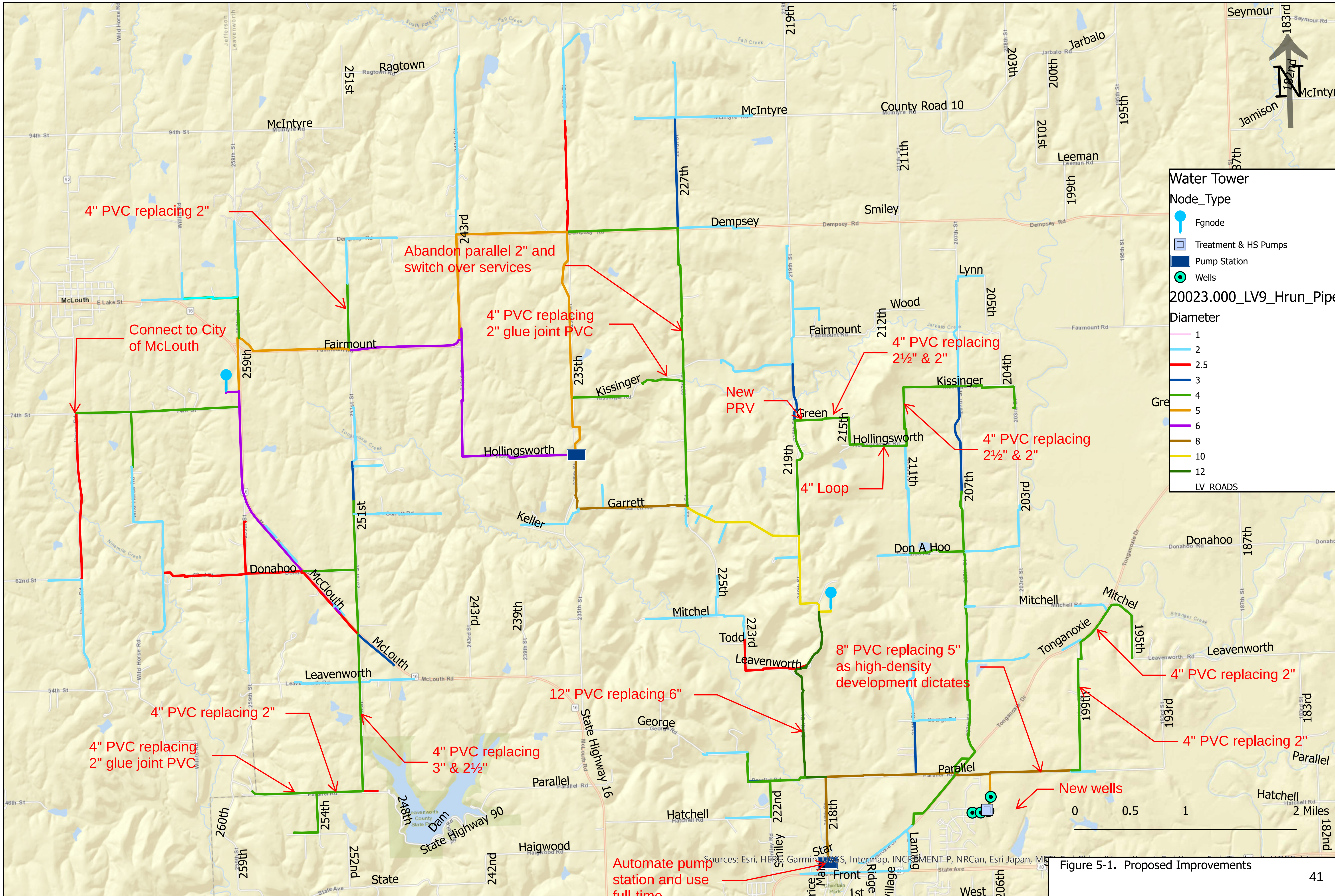

Figure 5-1. Proposed Improvements

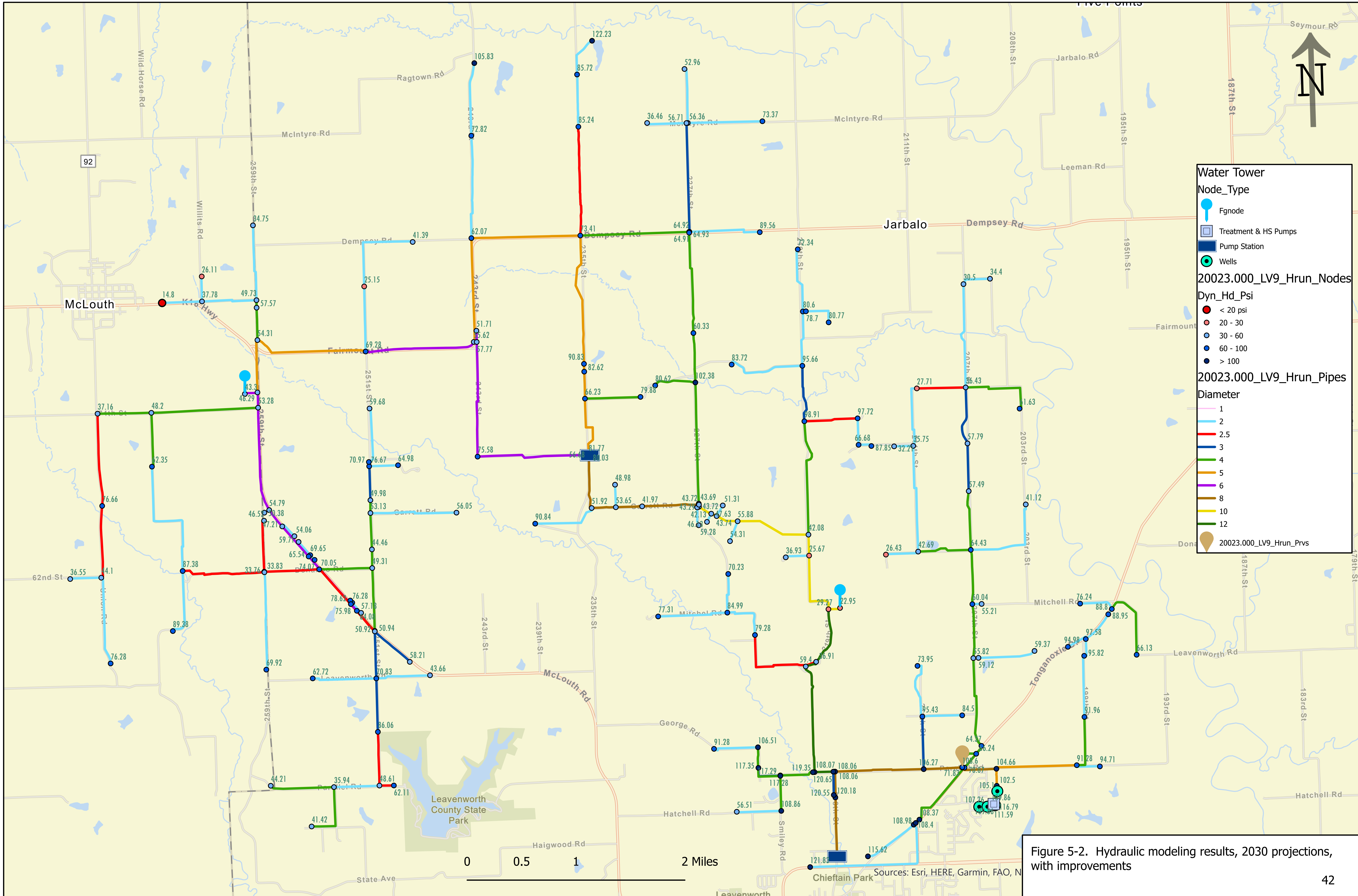

Figure 5-2. Hydraulic modeling results, 2030 projections, with improvements

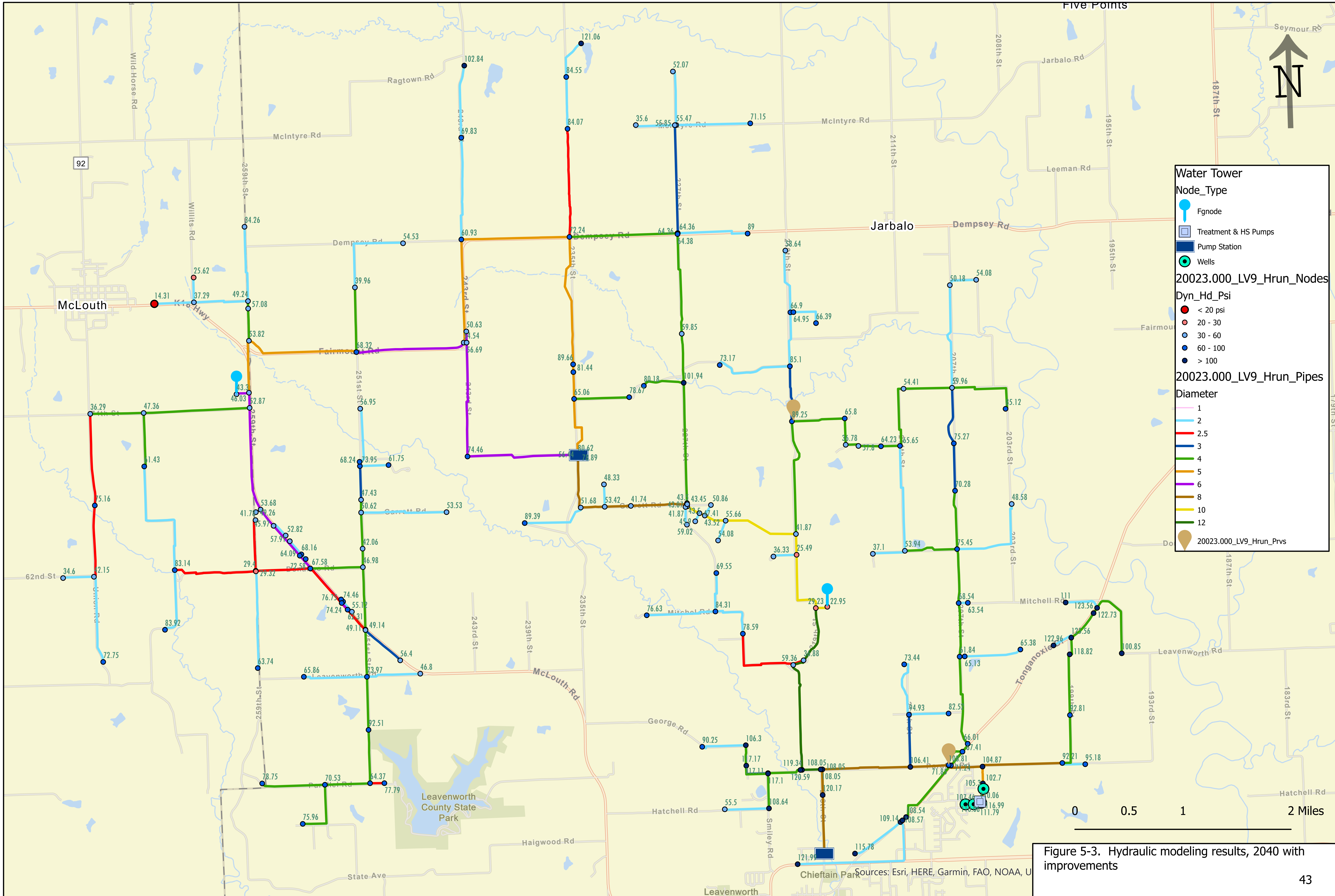

Figure 5-3. Hydraulic modeling results, 2040 with improvements

Figure 5-4. Proposed new well sites

6 COST ESTIMATES

The cost estimates in this report are intended to provide a general representation as to the magnitude of each proposed project. No specific field investigations were made. These estimates are based upon prices from similar recent projects and represent the engineer's best judgment. Actual construction prices will vary from the estimates. Multiple options are presented for replacing the existing wells with 2 to 5 new wells, and also for installing the new transmission line south of the #1 water tower with either 10-inch, 12-inch or 14-inch pipe.

A combined estimate, with greater cost detail, is provided for the proposed $2.1 million immediate large project, which includes two wells, a 12-inch transmission line, and re-coating the #1 water tower.

Construct two wells on property south of WTP					
Item	**Description**	**Unit**	**Quantity**	**Unit Price**	**Extension**
1	4" Cl. 200 PVC Pipe	L.F.	1,750	15.00	26,250
2	4" Valve & Box	EA.	4	1,000	4,000
3	Connect to Existing Pipeline	EA.	1	2,000	2,000
4	Cleanout	EA.	3	2,000	6,000
5	Well with Pump & Pitless unit	EA.	2	110,000	220,000
6	Meter & Controls Steel Vault	EA.	1	90,000	90,000
7	Pigging Concrete Vault	EA.	2	25,000	50,000
8	Electrical Service	L U M P	S U M		50,000
9	Driveway & Site Work	L U M P	S U M		70,000
10	Contingencies	L U M P	S U M		52,000
	Total Construction Cost				**$ 570,250**
	Geologist, Engineering, Inspection, Land Purchase, Legal, Financing, Etc.				$ 230,000
	Total Project Cost				**$ 800,250**

Construct two wells on property east of WTP and one well south of WTP					
Item	**Description**	**Unit**	**Quantity**	**Unit Price**	**Extension**
1	6" PVC Pipe	L.F.	5,400	$ 20.00	$ 108,000
2	4" PVC Pipe	L.F.	3,300	12.00	39,600
3	6" Valve & Box	EA.	2	1,200	2,400
4	4" Valve & Box	EA.	4	1,000	4,000
5	Connect to Existing Pipeline	EA.	1	1,500	1,500
6	Cleanout	EA.	4	1,000	4,000
7	Well with Pump & Pitless unit	EA.	3	110,000	330,000
8	Meter & Controls Steel Vault	EA.	1	90,000	90,000
9	Pigging Concrete Vault	EA.	2	30,000	60,000
10	Electrical Service	L U M P	S U M		120,000
11	Driveway & Site Work	L U M P	S U M		100,000
12	Contingencies	L U M P	S U M		86,000
	Total Construction Cost				**$ 945,500**
	Geologist, Engineering, Inspection, Land Purchase, Legal, Financing, Etc.				$ 360,000
	Total Project Cost				**$ 1,305,500**

Construct four wells on property east of WTP and one well south of WTP					
Item	**Description**	**Unit**	**Quantity**	**Unit Price**	**Extension**
1	6" PVC Pipe	L.F.	5,400	$ 20.00	$ 108,000
2	4" PVC Pipe	L.F.	4,500	13.00	58,500
3	6" Valve & Box	EA.	2	1,200	2,400
4	4" Valve & Box	EA.	6	1,000	6,000
5	Connect to Existing Pipeline	EA.	1	1,500	1,500
6	Cleanout	EA.	6	1,000	6,000
7	Well with Pump & Pitless unit	EA.	5	110,000	550,000
8	Meter & Controls Vault	EA.	2	90,000	180,000
9	Pigging Concrete Vault	EA.	3	30,000	90,000
10	Electrical Service	L U M P	S U M		170,000
11	Driveway & Site Work	L U M P	S U M		125,000
12	Contingencies	L U M P	S U M		130,000
	Total Construction Cost				**$ 1,427,400**
	Geologist, Engineering, Inspection, Land Purchase, Legal, Financing, Etc.				$ 550,000
	Total Project Cost				**$ 1,977,400**

Transmission Line South of East Water Tower, 10" Alternative					
Item	**Description**	**Unit**	**Quantity**	**Unit Price**	**Extension**
1	10" PVC Pipe	L.F.	8,800	$ 40.00	$ 352,000
2	10" Road Crossing	EA.	5	10,000	50,000
3	10" Valve & Box	EA.	6	2,200	13,200
4	Connect to Existing Pipeline	EA.	5	2,000	10,000
5	Air Release Valve	EA.	2	1,500	3,000
6	Re-connect Existing Service	EA.	31	700	21,700
7	Hydrant	EA.	2	5,000	10,000
8	Contingencies	LUMP SUM			50,000
	Total Construction Cost				**$ 509,900**
	Engineering, Inspection, Easements, Legal, Financing, Etc.				$ 107,000
	Total Project Cost				**$ 616,900**

Transmission Line South of East Water Tower, 12" Alternative					
Item	**Description**	**Unit**	**Quantity**	**Unit Price**	**Extension**
1	12" PVC Pipe	L.F.	8,800	$ 60.00	$ 528,000
2	12" Road Crossing	EA.	5	12,000	60,000
3	12" Valve & Box	EA.	6	3,000	18,000
4	Connect to Existing Pipeline	EA.	5	2,200	11,000
5	Air Release Valve	EA.	2	1,500	3,000
6	Re-connect Existing Service	EA.	31	700	21,700
7	Hydrant	EA.	2	5,000	10,000
8	Contingencies	LUMP SUM			60,000
	Total Construction Cost				**$ 711,700**
	Engineering, Inspection, Easements, Legal, Financing, Etc.				$ 135,000
	Total Project Cost				**$ 846,700**

Transmission Line South of East Water Tower, 14" Alternative					
Item	**Description**	**Unit**	**Quantity**	**Unit Price**	**Extension**
1	14" PVC Pipe	L.F.	8,800	$ 85.00	$ 748,000
2	14" Road Crossing	EA.	5	14,500	72,500
3	14" Valve & Box	EA.	6	3,500	21,000
4	Connect to Existing Pipeline	EA.	5	2,500	12,500
5	Air Release Valve	EA.	2	1,500	3,000
6	Re-connect Existing Service	EA.	31	700	21,700
7	Hydrant	EA.	2	5,000	10,000
8	Contingencies	LUMP SUM			70,000
	Total Construction Cost				**$ 958,700**
	Engineering, Inspection, Easements, Legal, Financing, Etc.				$ 173,000
	Total Project Cost				**$ 1,131,700**

Replace 2" glue joint PVC with 4" PVC, Parallel (255th - 259th) & Kissinger, west of 227th					
Item	**Description**	**Unit**	**Quantity**	**Unit Price**	**Extension**
1	4" PVC Pipe	L.F.	5,500	$ 14.00	$ 77,000
2	4" Road Crossing	EA.	1	5,000	5,000
3	4" Valve & Box	EA.	2	1,100	2,200
4	Stream Crossing Bores, RJ PVC Pipe	L.F.	300	50	15,000
5	Connect to Existing Pipeline	EA.	2	1,800	3,600
6	Air Release Valve	EA.	2	1,500	3,000
7	Re-connect Existing Service	EA.	17	650	11,050
8	Cleanout	EA.	2	1,000	2,000
9	Contingencies	LUMP SUM			18,000
	Total Construction Cost				**$ 136,850**
	Engineering, Inspection, Easements, Legal, Financing, Etc.				$ 28,700
	Total Project Cost				**$ 165,550**

Establish Emergency Connection to City of McLouth					
Item	**Description**	**Unit**	**Quantity**	**Unit Price**	**Extension**
1	4" PVC Pipe	L.F.	200	$ 20.00	$ 4,000
2	4" Road Crossing	EA.	1	6,000	6,000
3	4" Valve & Box	EA.	2	1,100	2,200
4	Connect to Existing Pipeline	EA.	2	1,800	3,600
5	Cleanout	EA.	1	1,100	1,100
6	2" Meter Pit	EA.	1	14,000	14,000
7	Contingencies	LUMP SUM			3,000
	Total Construction Cost				**$ 33,900**
	Engineering, Legal, Etc.				$ 6,100
	Total Project Cost				**$ 40,000**

Construct 4" PVC loop between 207th & 219th, north of Tower 1					
Item	**Description**	**Unit**	**Quantity**	**Unit Price**	**Extension**
1	4" PVC Pipe	L.F.	12,000	$ 14.00	$ 168,000
2	4" Road Crossing	EA.	6	5,000	30,000
3	4" Valve & Box	EA.	3	1,100	3,300
4	Stream Crossing Bores, RJ PVC Pipe	L.F.	300	50	15,000
5	Connect to Existing Pipeline	EA.	2	1,800	3,600
6	Air Release Valve	EA.	2	1,500	3,000
7	Re-connect Existing Service	EA.	20	650	13,000
8	Cleanout	EA.	1	1,000	1,000
9	Pressure Reducing Valve	EA.	1	8,000	8,000
10	Contingencies	LUMP SUM			37,000
	Total Construction Cost				**$ 281,900**
	Engineering, Inspection, Easements, Legal, Financing, Etc.				$ 62,000
	Total Project Cost				**$ 343,900**

Replace 2" with 4" PVC on 251st, north of Fairmount Rd.					
Item	**Description**	**Unit**	**Quantity**	**Unit Price**	**Extension**
1	4" PVC Pipe	L.F.	3,000	$ 14.00	$ 42,000
2	4" Valve & Box	EA.	2	1,100	2,200
3	Stream Crossing Bores, RJ PVC Pipe	L.F.	200	50	10,000
4	Connect to Existing Pipeline	EA.	2	1,800	3,600
5	Air Release Valve	EA.	1	1,500	1,500
6	Re-connect Existing Service	EA.	1	650	650
7	Cleanout	EA.	1	1,000	1,000
8	Contingencies	L U M P S U M			9,000
	Total Construction Cost				**$ 69,950**
	Engineering, Inspection, Easements, Legal, Financing, Etc.				$ 15,400
	Total Project Cost				**$ 85,350**

Replace 3", 2½" & 2" with 4" PVC on 251st & Parallel					
Item	**Description**	**Unit**	**Quantity**	**Unit Price**	**Extension**
1	4" PVC Pipe	L.F.	9,700	$ 14.00	$ 135,800
2	4" Road Crossing	EA.	2	5,000	10,000
3	4" Valve & Box	EA.	5	1,100	5,500
4	Stream Crossing Bores, RJ PVC Pipe	L.F.	400	50	20,000
5	Connect to Existing Pipeline	EA.	5	1,800	9,000
6	Air Release Valve	EA.	3	1,500	4,500
7	Re-connect Existing Service	EA.	12	650	7,800
8	Cleanout	EA.	1	1,000	1,000
9	Contingencies	L U M P S U M			29,000
	Total Construction Cost				**$ 222,600**
	Engineering, Inspection, Easements, Legal, Financing, Etc.				$ 49,000
	Total Project Cost				**$ 271,600**

Replace 2" with 4" PVC on 199th, north of Parallel					
Item	**Description**	**Unit**	**Quantity**	**Unit Price**	**Extension**
1	4" PVC Pipe	L.F.	3,800	$ 14.00	$ 53,200
2	4" Road Crossing	EA.	2	5,000	10,000
3	4" Valve & Box	EA.	4	1,100	4,400
4	Stream Crossing Bores, RJ PVC Pipe	L.F.	200	50	10,000
5	Connect to Existing Pipeline	EA.	4	1,800	7,200
6	Air Release Valve	EA.	1	1,500	1,500
7	Re-connect Existing Service	EA.	9	650	5,850
8	Cleanout	EA.	1	1,000	1,000
9	Contingencies	L U M P S U M			14,000
	Total Construction Cost				**$ 107,150**
	Engineering, Inspection, Easements, Legal, Financing, Etc.				$ 23,600
	Total Project Cost				**$ 130,750**

Replace 5" PVC on Parallel, west of 199th, with 8" PVC					
Item	**Description**	**Unit**	**Quantity**	**Unit Price**	**Extension**
1	8" PVC Pipe	L.F.	4,300	$ 30.00	$ 129,000
2	2" PVC Pipe	L.F.	100	8.00	800
3	8" Road Crossing	EA.	1	8,000	8,000
4	2" Road Crossing	EA.	1	3,500	3,500
5	8" Valve & Box	EA.	2	1,900	3,800
6	2" Valve & Box	EA.	1	800	800
7	Connect to Existing Pipeline	EA.	3	1,900	5,700
8	Re-connect Existing Service	EA.	9	700	6,300
9	Hydrant	EA.	2	4,000	8,000
10	Contingencies	LUMP SUM			25,000
	Total Construction Cost				**$ 190,900**
	Engineering, Inspection, Easements, Legal, Financing, Etc.				$ 38,200
	Total Project Cost				**$ 229,100**

Proposed Immediate Improvements Combined

Item	**Description**	**Unit**	**Quantity**	**Unit Price**	**Extension**
1	12" Cl. 200 PVC Pipe	L.F.	8,760	$ 60.00	$ 525,600
2	4" Cl. 200 PVC Pipe	L.F.	9,330	12.00	111,960
3	12" Valve & Box	EA.	5	3,000	15,000
4	10" Valve & Box	EA.	1	2,200	2,200
5	4" Valve & Box	EA.	10	1,000	10,000
6	12" Type 2 Road Crossing	EA.	2	12,000	24,000
7	4" Type 2 Road Crossing	EA.	3	6,000	18,000
8	1" Type 2 Road Crossing	EA.	1	2,000	2,000
9	12" Type 2 Stream Crossing	EA.	1	30,000	30,000
10	4" Type 2 Stream Crossing	EA.	1	10,000	10,000
11	4" Type 1 Stream Crossing	EA.	1	5,000	5,000
12	4" Type 0 Stream Crossing	EA.	1	1,000	1,000
13	Connect to Existing Pipeline	EA.	7	2,000	14,000
14	6" Wet Tap Connection	EA.	1	3,000	3,000
15	Re-connect Existing Service	EA.	40	700	28,000
16	Relocate & Re-connect Existing Service	EA.	1	1,300	1,300
17	Cleanout	EA.	6	2,000	12,000
18	Air Release Valve	EA.	4	1,500	6,000
19	Hydrant	EA.	1	5,000	5,000
20	Cap & Block	EA.	2	800	1,600
21	Install Pipeline in Road R/W	L.F.	2,500	2.00	5,000
22	Well with Pump & Pitless unit	EA.	2	110,000	220,000
23	Meter & Controls Steel Vault	EA.	1	90,000	90,000
24	Pigging Concrete Vault	EA.	1	30,000	30,000
25	Electrical Service	LUMP SUM			50,000
26	Driveway & Site Work	LUMP SUM			70,000
27	Re-coat #1 Water Tower	LUMP SUM			170,000
28	Contingencies	LUMP SUM			150,000
	Total Construction Cost				**$ 1,610,660**
	Engineering				$ 150,000
	Geological & Test Drilling				$ 70,000
	Environmental Review, Archeological				$ 20,000
	Inspection				$ 60,000
	Legal & Abstracting				$ 20,000
	Land Purchase				$ 170,000
	Total Project Cost				**$ 2,100,660**

7 FINANCIAL IMPACT

With over $5 million in improvements recommended over the next 20 years, and $2.1 million needed very soon, the District requires a financing plan. These projects can be funded through a series of annually-funded small projects, a relatively large long-term loan, or a combination of the two.

Several loan options are available, with loan terms ranging 20 to 40 years. Historically-low loan interest rates range from about 2.0% to 3.5%, subsidized through government programs: the 20-year or 30-year Kansas Department of Health and Environment State Revolving Loan (KDHE SRF) and the 40-year United States Department of Agriculture Rural Development (USDA RD) loan. Due to relatively high income levels, the District is likely not eligible for grant funds. When comparing the two options, USDA and KDHE, there are four primary differentiators: KDHE's interest rate is about a third less than USDA's (currently 2.0%/2.3% versus 3.5%); the USDA loan is for 40 years, versus KDHE's term of either 20 or 30 years; the KDHE loan requires a 1.25 debt coverage ratio that will have a significant impact on customer rates; and finally perhaps the biggest differentiator is that the USDA loan carries with it the Federal 1926b boundary legal protection that is important for rural water districts near sprawling urban environments.

For the sake of providing a preliminary financial analysis in this report, it is assumed that the initial large proposed project will be funded through the 30-year KDHE loan, and that subsequent projects will be funded from a capital improvement account. Table 7-1 summarizes recommended projects, their cost, annual deposits to the capital improvement fund, and the impact on water rates. For some pipeline improvements, the project is divided into two years so that it can be adequately funded. In some years there is simply an allowance for unidentified miscellaneous minor improvements, which might include replacing old segments of pipeline.

An initial monthly rate increase of 25% would be required for the immediate recommended improvements relative to two new groundwater wells, a new 12-inch transmission line south of the #1 tower, re-coating the #1 tower, and a mile of 4-inch waterline. Thereafter, an average annual rate increase of nearly 3%, dedicated to capital improvements, would fund the remainder of the projects. The actual annual increase to rates might need to be closer to 5% to keep up with inflationary increases related to labor, materials, utilities, and water purchase cost. This level of annual rate increases is only slightly higher than the District's recent history. Over the past 10 years, the District has averaged annual rate increases of 4.2%.

The current average monthly water bill is $68, based on a $25.65 minimum and $7.05 per 1,000 gallons, with an average usage of 6,000 gallons. This would need to increase by $18 per month initially to service the new debt and generate the KDHE-required 1.25 debt coverage ratio. Subsequently, an average annual increase of about $2.00 per month will be needed to fund other improvements through 2042. An additional annual adjustment of about $1.50 per month would be required for inflationary impacts on operations. This inflationary adjustment would be diluted by growth of new customers, both in terms of the benefit unit fee collected and the additional monthly revenue. By 2035 it is projected that the average monthly bill would gradually need to increase from the current average of $68 per month to about $122, representing an average of 4.3% annually.

Table 7-2 details the projected revenue and expenses, with the basis of the projections being the audited values from 2018 to 2021. Customer growth and inflation are factored into the estimates for 2023, 2025, 2030, and 2035. The assumed rate schedule and benefit unit fees are shown to the left of the respective annual revenue categories. These rates reflect the projections outlined in Table 7-1.

New debt payments and allocations to both the short-lived asset and capital improvement accounts are shown near the bottom. It is assumed that new debt payments to KDHE would begin in 2025. Improvements funded by developers or individual customers are excluded from future budget estimates, as this is a break-even scenario for the District.

The bottom of Table 7-2 summarizes the 2018-2021 fixed and variable costs for groundwater production and treatment. Fixed production costs averaged $0.77 per 1,000 gallons and include portions of labor and repairs. Variable costs, consisting of chemicals and most of the electrical, averaged $0.17 per 1,000 gallons sold. The combined average cost of $0.94 per 1,000 gallons compares very favorably to the $3.93 per 1,000 gallons rate charged by Suburban Water. The difference in the cost is a reflection of amortized unit capital costs. Suburban has included their facility depreciation into their rate calculations, just as RWD No. 9 would need to budget for debt and maintenance costs associated with the wells and treatment. As can be calculated from the life-cycle analysis, with well water being about 20% less than Suburban water over 40 years, the approximate equivalent cost of debt and maintenance associated with a groundwater supply is $2.20 per 1,000 gallons.

Table 7-1. Improvement and Budgeting Schedule

Year	Improvement Project	Construction Cost, Present Day Values	Construction Cost, Future Values	Annual Debt Payment	Savings in Water Purchased	Deposit to Capital Improvement Fund	Year-End Capital Improvement Fund Balance	Monthly Rate Increase Required	Cumulative Monthly Rate Increase above Present	Annual Rate Increase as %
2023-2024	2 groundwater wells, 12" south of #1 tower, re-coat #1 tower, 4" replacing 2" on 199th	$2,100,660	$2,100,660	$108,856	$30,500	$0	$0	$8.27	$8.27	12.2%
2025	Add polyphosphate	$15,000	$16,900	$108,856	$33,614	$20,000	$3,100	$1.39	$9.65	1.8%
2026	Standby generator	$25,000	$29,000	$108,856	$36,842	$40,000	$14,100	$1.59	$11.24	2.0%
2027	Misc. minor improvements	$30,000	$35,800	$108,856	$40,188	$60,000	$38,300	$1.54	$12.79	1.9%
2028	Establish standby connection with McLouth on 74th St.	$40,000	$49,200	$108,856	$43,655	$80,000	$69,100	$1.50	$14.29	1.9%
2029	Misc. minor improvements	$50,000	$63,300	$108,856	$47,248	$100,000	$105,800	$1.46	$15.74	1.8%
2030	Replace 2" glue joint PVC with 4"	$82,775	$108,000	$108,856	$50,970	$120,000	$117,800	$1.41	$17.16	1.7%
2031	Replace 2" glue joint PVC with 4"	$82,775	$111,200	$108,856	$54,825	$149,000	$155,600	$2.23	$19.39	2.6%
2032	4" Loop between 219th & 207th, north of Tower #1	$171,950	$238,000	$108,856	$58,817	$178,000	$95,600	$2.17	$21.56	2.5%
2033	4" Loop between 219th & 207th, north of Tower #1	$171,950	$245,200	$108,856	$62,952	$207,000	$57,400	$2.11	$23.68	2.4%
2034	Re-coat the #2 (west) water tower	$100,000	$146,900	$108,856	$67,233	$236,000	$146,500	$2.06	$25.73	2.2%
2035	Misc. minor improvements	$50,000	$75,600	$108,856	$71,664	$265,000	$335,900	$2.00	$27.73	2.1%
2036	Construct a new well and transmission line	$250,000	$389,500	$108,856	$76,252	$294,000	$240,400	$1.94	$29.68	2.0%
2037	Construct a new well and transmission line	$250,000	$401,200	$108,856	$81,000	$323,000	$162,200	$1.89	$31.56	1.9%
2038	Replace 5" with 8" PVC pipe on Parallel Rd.	$114,550	$189,300	$108,856	$85,913	$360,000	$332,900	$2.55	$34.11	2.6%
2039	Replace 5" with 8" PVC pipe on Parallel Rd.	$114,550	$195,000	$108,856	$90,997	$397,000	$534,900	$2.48	$36.59	2.4%
2040	Replace 2" with 4" on 251st, north of Fairmont	$85,350	$149,700	$108,856	$96,258	$434,000	$819,200	$2.41	$38.99	2.3%
2041	Replace 2", 2½" & 3" with 4" on 251st & Parallel	$135,800	$245,300	$108,856	$101,700	$471,000	$1,044,900	$2.34	$41.34	2.2%
2042	Replace 2", 2½" & 3" with 4" on 251st & Parallel	$135,800	$252,600	$108,856	$107,329	$508,000	$1,300,300	$2.28	$43.61	2.1%
2043	Construct new well & expand filtering system to 300 gpm	$1,000,000	$1,916,100	$108,856	$113,151	$615,800	$0	$8.21	$51.82	7.4%
	Totals	**$5,006,160**	**$6,958,460**				**Averages**	**$2.59**		**2.9%**
									adding 2% for operational inflation	**4.9%**
							10-year historic avg. rate increase		4.2%	

Table 7-2. Cash-Basis Annual Budget Analysis, assuming 30-Year KDHE loan

Projections are based on average precipitation & temperature

Statistics

	2018	2019	2020	2021	Projected 2023	Projected 2025	Projected 2030	Projected 2035
No. of Customers	759	782	805	803	821	840	889	940
Annual Sold, MG	45.6	41.2	44.5	43.0	45.5	46.5	49.2	52.0

Revenue

Item		2018		2019		2020		2021	*Factor*	Projected 2023	*Factor*	Projected 2025	*Factor*	Projected 2030	*Factor*	Projected 2035
Monthly Minimums	*$ 20.20*	$ 183,982	*$ 20.20*	$ 189,557	*$ 22.65*	$ 218,799	*$ 24.15*	$ 232,709	*$ 27.00*	$ 266,103	*$ 35.00*	$ 352,812	*$ 39.00*	$ 415,924	*$ 50.00*	$ 564,148
Residential Water Sales	*$ 5.75*	$ 262,120	*$ 5.98*	$ 246,256	*$ 6.22*	$ 276,977	*$ 6.62*	$ 284,773	*$ 7.25*	$ 329,610	*$ 8.50*	$ 395,249	*$ 10.00*	$ 491,955	*$ 12.00*	$ 624,569
Benefit Unit Sales	*$ 6,000*	$ 54,000	*$ 6,000*	$ 48,000	*$ 6,000*	$ 135,400	*$ 6,000*	$ 102,000	*$ 6,500*	$ 61,000	*$ 7,000*	$ 68,000	*$ 8,000*	$ 82,000	*$ 9,000*	$ 81,000
Rent Income		$ 7,334		$ 7,491		$ 6,367		$ 7,118		$ 7,700		$ 8,200		$ 9,500		$ 11,000
Interest		$ 3,467		$ 5,315		$ 2,994		$ 2,429		$ 3,900		$ 4,100		$ 4,800		$ 5,500
Aide-in-Construction		$ 15,935		$ 17,519						$ 18,300		$ 19,400		$ 22,500		$ 26,100
Misc Income		$ 7,347				$ 6,659		$ 2,281		$ 5,900		$ 6,300		$ 7,300		$ 8,500
Total Revenues		$ 534,184		$ 514,138		$ 647,196		$ 631,310		$ 692,513		$ 854,061		$ 1,033,979		$ 1,320,817

2022 rates are $25.65 min & $7.05/1000 gal.

Projections are based on assumed 3% annual inflation

Expenses

Item	2018	2019	2020	2021	Projected 2023	Projected 2025	Projected 2030	Projected 2035
Water purchases	$ 90,836	$ 53,204	$ 63,868	$ 76,185	$ 80,300	$ 71,691	$ 101,311	$ 139,772
Salaries, payroll taxes, benefits	$ 129,468	$ 142,271	$ 152,812	$ 172,881	$ 183,400	$ 194,600	$ 225,600	$ 261,500
Chemicals (chlorine)	$ 3,700	$ 3,800	$ 3,900	$ 4,000	$ 4,200	$ 4,500	$ 5,200	$ 6,000
Utilities and telephone	$ 25,896	$ 21,703	$ 27,604	$ 27,309	$ 28,000	$ 29,700	$ 34,400	$ 39,900
Office expenses	$ 5,834	$ 16,052	$ 17,783	$ 17,003	$ 15,500	$ 16,400	$ 19,000	$ 22,100
Repairs & maintenance	$ 109,227	$ 156,780	$ 135,987	$ 62,294	$ 126,800	$ 134,600	$ 156,000	$ 180,800
Locates	$ 704	$ 583	$ 806	$ 828	$ 800	$ 800	$ 1,000	$ 1,100
Contract labor	$ 7,150	$ 7,398	$ 50,131	$ 20,363	$ 23,200	$ 24,600	$ 28,600	$ 33,100
Professional fees	$ 7,006	$ 6,620	$ 9,877	$ 14,307	$ 10,300	$ 11,000	$ 12,700	$ 14,700
Machine hire	$ 45,307	$ 46,635	$ 45,724	$ 21,376	$ 43,400	$ 46,100	$ 53,400	$ 61,900
Insurance	$ 8,663	$ 15,853	$ 20,835	$ 20,962	$ 22,200	$ 23,600	$ 27,400	$ 31,800
Water protection fee, tax	$ 4,007	$ 2,678	$ 5,907	$ 3,806	$ 4,000	$ 4,200	$ 4,900	$ 5,700
Mileage, rent, etc.	$ 16,355	$ 27,527	$ 13,614	$ 1,079	$ 2,000	$ 2,100	$ 2,400	$ 2,800
Annual budget for well treatment	$ 15,000	$ 15,000	$ 15,000	$ 15,000	$ 16,400	$ 17,400	$ 20,200	$ 23,400
Capital Improvements	$ -	$ 69,446	$ 345,130	$ 279,089	$ -	$ 21,000	$ 126,000	$ 271,000
Short-lived asset replacement fund					$ 64,300	$ 68,200	$ 79,100	$ 91,700
Debt (ex. expires in 2022)	$ 29,820	$ 29,820	$ 29,820	$ 29,820	$ 18,180	$ 128,600	$ 128,600	$ 128,600
Total Expenses	$ 498,973	$ 615,370	$ 938,798	$ 766,302	$ 642,980	$ 799,091	$ 1,025,811	$ 1,315,872
NET OPERATING MARGIN	**$ 35,211**	**$ (101,232)**	**$ (291,602)**	**$ (134,992)**	**$ 49,533**	**$ 54,970**	**$ 8,168**	**$ 4,946**
Debt coverage ratio:						1.26	1.82	3.04

Average cost of water production per 1,000 gallons					
	2018	**2019**	**2020**	**2021**	Avg
Fixed	$0.76	$0.67	$0.70	$0.94	$0.77
Variable	$0.17	$0.16	$0.16	$0.20	$0.17
Total	$0.93	$0.82	$0.86	$1.14	$0.94

As noted in the 2023 expense budget, it is recommended that $64,300 be set aside each year for various short-lived asset replacements. Table 7-3 provides detail of the calculations for these significant asset replacement costs. Funds should be deposited into a separate account so that large infrequent expenses are not funded from the operating account. This should be a separate account from the capital improvement fund that was addressed in Table 7-1.

Table 7-3. Short-lived asset depreciation

Item	Expected Life, years	Replacement Cost	Quantity	Total Cost	Budget per year
Service Meters	20	$ 225	800	$ 180,000	$ 9,000
Water tower re-coating	20	$ 100,000	2	$ 200,000	$ 10,000
Water tower inspections	3	$ 5,000	2	$ 10,000	$ 3,333
Air Release Valves	20	$ 2,000	20	$ 40,000	$ 2,000
Pump Replacement	20	$ 20,000	9	$ 180,000	$ 9,000
VFD Replacement	15	$ 10,000	9	$ 90,000	$ 6,000
Well maintenance	3	$ 12,000	5	$ 60,000	$ 20,000
Telemetry Controls	15	$ 75,000	1	$ 75,000	$ 5,000
Total					**$ 64,333**

In addition to monthly minimum fees and the rate per 1,000 gallons, revenues can also be generated through increased benefit unit fees. A good way to view those fees is as a proportionate value of the system, such as with a stock certificate. Based on depreciated replacement value, not the original construction value as most audits reflect, an estimate of all RWD No. 9 facilities is about $5.5 million, as illustrated in Table 7-4. The capacity of each specific facility differs, but 900 meters is likely a reasonable average value. The resulting value per meter, then, is $6,100, which is equal to the current benefit unit fee. As additional improvements are constructed, the pro-rata value per meter would increase. Based on a new $2.1 million project the improved system value will be about $7.5 million. Customer capacity will also increase to at least 1,000. Accordingly, the calculated benefit unit fee could gradually be increased to $7,500. With other improvements over the next 10 years, the valuation would continue to increase. Table 7-2 reflects an assumed increase in the benefit unit fee to $8,000 by 2030 and $9,000 by 2035.

Table 7-4. System Valuation

PVC Waterline & Appurtenances				
Diameter	Miles	Replacement Cost	Average Age	Depreciated Value*
2	33.0	$ 3,277,000	47	$ 710,000
2.5	7.8	$ 854,000	47	$ 185,000
3	5.4	$ 643,000	47	$ 139,000
4	15.7	$ 2,188,000	40	$ 729,000
5	6.9	$ 1,375,000	47	$ 298,000
6	7.6	$ 1,516,000	40	$ 505,000
8	4.0	$ 1,193,000	25	$ 696,000
10	2.0	$ 805,000	47	$ 174,000
12	0.5	$ 236,000	47	$ 51,000
Total	**82.9**			**$ 3,487,000**
		** based on life expectancy of*	*60*	*years*

Water Towers			
Capacity	Replacement Cost	Average Age	Depreciated Value*
150,000 gallons	$ 600,000	6	$ 555,000
200,000 gallons	$ 700,000	16	$ 513,000
Total			**$ 1,068,000**
	** based on life expectancy of*	*80*	*years*

Wells			
Description	Replacement Cost	Average Age	Depreciated Value*
Four 30 gpm wells, 135' deep, electrical, pitless units, pipe	$ 2,000,000	46	$ 133,000
	** based on life expectancy of*	*50*	*years*

Clearwell, Treatment, H.S. Pumps			
Description	Replacement Cost	Average Age	Depreciated Value*
Building, equipment, electrical	$ 800,000	15	$ 467,000
	** based on life expectancy of*	*50*	*years*

Pump Stations & Telemetry			
Description	Replacement Cost	Average Age	Depreciated Value*
West Pump Station	$ 250,000	16	$ 142,000
Suburban "Wholesale" P.S.	$ 350,000	16	$ 198,000
Total			**$ 340,000**
	** based on life expectancy of*	*50*	*years*

GRAND TOTAL VAULE	**$ 5,495,000**
Approximate meter capacity	900
Value per meter	$6,106

8 ENVIRONMENTAL IMPACT

Funding agencies will require an environmental assessment. Fortunately, much of the pipeline will be installed through established yards or otherwise already-disturbed areas. Therefore, hopefully the impact to nature and historical resources will be minimal. There may be endangered species that require special consideration.

Existing waterline easements can likely be utilized, and a number of the new wells could be installed on the property already owned by the District. An additional well site or two should be pursued.

The contractor will need to comply with the National Pollutant Discharge Elimination System. Erosion will be controlled by directional boring as necessary, particularly through streams. Roads will be bored and encased. Rock may be a challenge for parts of this project, both during installation and cleanup. Virtually the entire project will be re-seeded upon completion.

If State or Federal funding is pursued, a formal intergovernmental review process will be required, followed by the preparation of an Environmental Assessment Report.

9 CONCLUSION AND RECOMMENDATIONS

With nearly 50 years of operation and consistent growth, Leavenworth Co. RWD No. 9 is reaching the capacity or life expectancy of a few major components of the water supply and transmission system. Investments are needed to accommodate future growth. The most immediate needs are relative to an increased groundwater supply and the transmission line south of the east water tower. A mile of 4" waterline and re-coating the east water tower are also included as high priority items. It is recommended that these items be constructed as one large project and funded through a 30-year KDHE SRF loan. Other improvements will be needed over the next 20 years but can likely be funded through a properly maintained capital improvement fund.

Without these improvements, the District will need to increasingly rely on the slightly more expensive water from Suburban. The District would also be vulnerable to inadequate fire flow capacity and perhaps unable to serve high-density developments within the District. Such shortcomings have recently led to multiple parcels being annexed from RWD No. 9 and into Tonganoxie city limits. The loss of revenue from these high-density developments negatively impacts all members of the District. The District's recent annual growth rate has averaged about 1.0%, but it could have been much higher if the development around Tonganoxie was being served by RWD No. 9. Given the net present worth of one residential customer being about $16,000, the District can afford to make substantial investments in order to accommodate growth.

Redundancy is also a priority, as the District needs a standby generator for the west pump station. Upgrades to various distribution waterlines, water tower re-coating, and an expansion of the groundwater supply and treatment facilities are lower priority needs.

In present values, the recommended improvements total the following amounts, shown over 5-year increments:

2024-2028	$ 2.2 million
2029-2033	$ 560,000
2034-2038	$ 760,000
2039-2043	$ 1.5 million

A monthly rate increase of $18.00, phased in over the next two years, would provide the needed revenue for the immediate large project, in addition to meeting common inflationary increases in the budget. New loan debt payments will not be required until construction is complete, most likely no sooner than the middle of 2024. After the initial rate increase, annual increases of about $2.00 per month, if devoted strictly to capital improvements, would fund an additional $3 million in future projects. About $1.50 per month increases are also needed annually for operational inflationary adjustments. The combination of these would be an annual $3.50 per month increase in the average monthly rates. Factoring in the 2023-2024 rate increase of $18.00 per month, the average annual increase over 20 years is 4.9%, which is close to the District's average over the last 10 years.

The District Board of Directors has expressed the desire to proceed with a funding application to the KDHE State Revolving Loan Fund for the initial $2.1 million project. A tentative project schedule is as follows:

Pre-Construction Milestone	**Date**
Submittal to Funding Agency	October, 2022
Funding Approval	Jan., 2023
Design	Jan. – March., 2023
State Agency Approval	May, 2023
Bid Process	June – July, 2023
Contract Award	Aug., 2023
Construction Milestone	
Begin Construction	Oct., 2023
Completion	Summer, 2024

Once desirable permanent well locations are found, and property acquired, the District should make application to the Kansas Division of Water Resources for new appropriations for potential new sites. This can be submitted and approved prior to beginning design.

Appendix A
Wholesale supply contracts

LAW OFFICES OF

ANDERSON & BYRD

A Limited Liability Partnership

JOHN L. RICHESON
JAMES G. FLAHERTY
R. SCOTT RYBURN
KEITH A. BROCK

216 S. HICKORY, P. O. BOX 17
OTTAWA, KANSAS 66067
(785) 242-1234, *Telephone*
(785) 242-1279, *Facsimile*
www.andersonbyrd.com

ROBERT A. ANDERSON
(1920-1994)
RICHARD C. BYRD
(1920-2008)

May 28, 2013

Sent by Facsimile
Original Mailed 5/28/13

CONTAINS CONFIDENTIAL INFORMATION

Ms. Patrice Petersen-Klein
Executive Director
Kansas Corporation Commission
1500 S. W. Arrowhead Road
Topeka, Kansas 66604-4027

Received
on
MAY 2 8 2013
by
State Corporation Commission
of Kansas

Re: Suburban Water, Inc.
Rural Water District #9

Dear Ms. Petersen-Klein:

Please file the enclosed Application for Approval of Wholesale Water Supply Contract on behalf of Suburban Water, Inc., d/b/a Suburban Water Company. I would appreciate receiving a file stamped copy of this cover letter as well as a file stamped copy of the Application for my files. A return envelope is included.

Thank you for your assistance. If you have any questions, please call.

Sincerely,

James G. Flaherty

James G. Flaherty
jflaherty@andersonbyrd.com

JGF/rr
Enclosure

Received
on

MAY 28 2013

by
State Corporation Commission
of Kansas

BEFORE THE STATE CORPORATION COMMISSION
OF THE STATE OF KANSAS

In the Matter of the Application of Suburban Water, Inc., d/b/a Suburban Water Company, for Approval of a Wholesale Water Supply Contract with Rural Water District #9, Leavenworth County, Kansas	)))))	Docket No. 13-SUBW-_____-CON

APPLICATION FOR APPROVAL OF WHOLESALE WATER SUPPLY CONTRACT

Suburban Water, Inc., d/b/a Suburban Water Company, ("Suburban") requests the Kansas Corporation Commission ("Commission") issue an order approving the attached wholesale water supply contract dated May 21, 2013, between Suburban and Rural Water District #9, Leavenworth County, Kansas ("RWD #9") ("Wholesale Water Supply Contract"), and for other related relief that may be required to fulfill the intents and purposes of the Wholesale Water Supply Agreement. In support of its request, Suburban states as follows:

1. Suburban is a water public utility certificated by the Commission to transact the business of a water public utility in a designated service area in Leavenworth County, Kansas. A certified copy of the Certificate of Incorporation and Bylaws of Suburban are already on file with the Commission and incorporated herein for all purposes.

2. Pleadings, notices, orders and other correspondence and communications concerning this Application should be addressed to the undersigned counsel as well as to:

Travis J. Miles
Suburban Water Company
1216 N. 155th Street, P. O. Box 588
Basehor, Kansas 66007
travis@suburbanwaterinc.com

3. The Wholesale Water Supply Contract which is designated as ***CONFIDENTIAL*** pursuant to K.S.A. 66-1220a and K.A.R. 82-1-221a, is attached as Appendix A to this Application and is incorporated herein by reference. The wholesale water supply market is a competitive market. Disclosure of the rates and terms contained in the Wholesale Water Supply Contract by Suburban to the public will place Suburban at a competitive disadvantage in the competitive wholesale water supply market.

4. Subject to the terms of the Wholesale Water Supply Contract, Suburban agrees to sell and deliver water to RWD #9. The delivery point of supply to RWD #9 from Suburban shall be at the intersection of 206th Street and State Avenue (US Hwy. 24/40) in the southwest part of Leavenworth County, Kansas.

5. The transaction will promote the public interest in that Suburban is ready, willing and able to provide the wholesale water supplies described in the Wholesale Water Supply Contract and approval will provide RWD #9 an additional source of water supply for its customers. Suburban has access to water supplies to fulfill the requirements of the Wholesale Water Supply Contract. Approval of the contract will not interfere with Suburban's ability to provide water supplies and water utility service to its existing retail customers, and in fact, will be beneficial to Suburban's existing retail customers in that the contract will generate additional revenue for Suburban to use to cover its cost of providing utility service to all customers.

WHEREFORE, pursuant to K.S.A. 66-1,231, 66-1,233, 66-104 and 66-136, Suburban requests the Commission issue an order authorizing, consenting to, and approving the Wholesale Water Supply Contract and granting such other relief deemed by the Commission just and proper to accomplish the purpose of this Application and to consummate the transaction described herein.

James G. Flaherty, #11177
ANDERSON & BYRD, LLP
216 S. Hickory, P. O. Box 17
Ottawa, Kansas 66067
(785) 242-1234, telephone
(785) 242-1279, facsimile
jflaherty@andersonbyrd.com
Attorneys for Suburban Water, Inc.

VERIFICATION

STATE OF KANSAS)
)ss:
COUNTY OF FRANKLIN)

James G. Flaherty, of lawful age, being first duly sworn on oath, states:

That he is the attorney for Suburban Water, Inc., named in the foregoing Application for Approval of Wholesale Water Supply Contract, and is duly authorized to make this affidavit; that he has read the foregoing Application, and knows the contents thereof; and that the facts set forth therein are true and correct to the best of his knowledge, information and belief.

James G. Flaherty

SUBSCRIBED AND SWORN to before me this 28th day of May, 2013.

NOTARY PUBLIC - State of Kansas
RONDA ROSSMAN
My Appt. Exp. 6/25/2014

Notary Public

Appointment/Commission Expires:

CONTRACT FOR WATER SUPPLY

THIS CONTRACT, made in duplicate, and entered into this 21st day of May, 2013, by and between Rural Water District #9, Leavenworth County, Kansas, hereinafter referred to as "District #9," and Suburban Water, Inc., hereinafter referred to as "Suburban," and

WITNESSETH:

WHEREAS, Suburban is engaged in the business of providing water for domestic, industrial, commercial and wholesale purposes; and

WHEREAS, at the present time Suburban produces a portion of its own water supply from ground water wells, and purchases the remainder from the Board of Public Utilities, an administrative agency of the Unified Government of Wyandotte County and Kansas City, Kansas ("BPU"), pursuant to a contract dated the 6th day of April, 2000. In the future Suburban may purchase water from other suppliers; and

WHEREAS, District #9 is engaged in the business of providing water to its customers, all of said customers located in areas outside the certificated service area of Suburban.

NOW, THEREFORE, in consideration of the covenants, terms and conditions of this Contract, as herein contained, Suburban agrees to sell and District #9 agrees to purchase wholesale water in accordance with the terms and conditions more fully set forth hereafter.

ARTICLE I

1.1 **GENERAL PROVISIONS AND REPRESENTATIONS AND WARRANTIES.** This Contract and all the provisions, endorsements, and modifications thereof shall inure to the benefit of and be binding upon the parties hereto and their respective successors and assigns.

1.2 This Contract shall be governed by the laws of the State of Kansas and the parties agree that this Contract is entered into in the County of Leavenworth, Kansas.

1.3 Each party represents and warrants to the other party that it is duly organized, validly existing and in good standing under the laws of the jurisdiction of its formation; it has, or will have as of the Effective Date, all regulatory authorizations necessary for it to legally perform its obligations under this Contract; the execution, delivery and performance of this Contract are within its powers, have been duly authorized by all necessary action and do not violate any of the terms and conditions in its governing documents, and contracts to which it is a party or any law, rule, regulation, order or the like applicable to it; this Contract and each other document executed and delivered in accordance with this Contract constitutes its legally valid and binding obligation enforceable against it in accordance with its terms; there is not pending or to its knowledge, threatened against it any legal proceedings that could materially and adversely affect its ability to perform its obligations under this Contract; it is acting for its own account, had made its own independent decision to enter into this Contract and as to whether this Contract is appropriate or proper for it based upon its own judgment, is not relying upon the advice or recommendations of the other party in so doing, and is capable of assessing the merits of and understanding, and understands and accepts, the terms, conditions and risks of this Contract; and it has entered into this Contract in connection with the conduct of its business and it has the capacity or ability to make or take delivery of the water supplies referred to in this Contract to which it is a party.

ARTICLE II

2.1 **BILLING AND RATES.** Based on the meter readings at the Connection Point as that term is defined herein, Suburban shall furnish to District #9, not later than the fifth working day of each month, an itemized statement of the quantity of water furnished to District #9 during the preceding month. Beginning on the date of first delivery of the water supply from Suburban to District #9, District #9 shall pay to Suburban for water delivered in accordance with the rate and charges as set forth herein on or before the last day of each month for water furnished to District #9 during the preceding month. Any billed amount unpaid by the last day of the month in which the bill is received by District #9 shall bear a penalty at the rate of one percent (1%) per month on the unpaid balance until paid in full. The parties agree that the initial payment rate for the sale of water from Suburban to District #9 shall be a commodity charge of three dollars and sixty cents ($3.60) per one thousand (1,000) gallons purchased in that month, which includes the current Contribution to General Fund Fee, previously referred to as a PILOT fee that BPU charges to Suburban. The commodity charges shall be increased during the term of this Contract in the amount equal to any increase in the rate at which Suburban purchases water from its wholesale suppliers. Suburban shall notify District #9 of any rate increases when Suburban is in receipt of the notice of an increase in rates from its wholesale suppliers. The increase in rates to District #9 shall be effective on the same date that the rate increase becomes effective on Suburban from its wholesale suppliers and the increase shall be in the amount equal to the increase charged by Suburban's wholesale suppliers.

2.2 In addition to the monthly commodity charges, District #9 agrees to pay for and reimburse Suburban for any taxes or other governmental charges imposed on Suburban relating to the sale of water under this Contract and such charges will be added to District #9's monthly bill. If District #9 claims any exemption from any sales or use taxes or other governmental charges imposed on Suburban relating to the sale of water under this Contract, then it must provide proof of such exemption to the satisfaction of Suburban before being relieved of its obligation to reimburse Suburban for said taxes or other governmental charges.

2.3 All claims as to error in the preparation and computation of monthly bills, must, in each instance, be submitted by the claiming party to the other party in writing within two years from the date when such bill was rendered, otherwise each such claim shall for all purposes be considered and held to be waived.

ARTICLE III

3.1 **TERM.** The primary term ("Term") of this Contract shall be from the first day of the month immediately following the date of approval of this Contract by the KCC set forth in a final non-appealable order that is satisfactory to Suburban ("Effective Date") through the date occurring twenty (20) years after the Effective Date, and this Contract shall automatically renew thereafter for additional one year terms unless notice to terminate is provided by either party hereto at least six (6) months in advance Both parties agree to make a good faith effort to complete, as soon as possible, their respective portions of the construction required to affect the interconnection of their systems.

ARTICLE IV

EVENTS OF DEFAULT; REMEDIES; BANKRUPTCY; PERFORMANCE ASSURANCE.

4.1 **EVENTS OF DEFAULT.** An "Event of Default" shall mean, with respect to a party (a "Defaulting Party"), the occurrence of any of the following:

(a) the failure to make, when due, any payment required pursuant to this Contract if such failure is not cured within thirty (30) business days after written notice;

(b) any representation or warranty made by such party herein is false or misleading in any material respect when made or when deemed made or repeated;

(c) the failure to perform any material covenant or obligation set forth in this Contract if such failure is not cured within thirty (30) days after written notice;

(d) such party is bankrupt;

(e) such party is affected by the occurrence of a material change in the creditworthiness, financial condition or ongoing business of that party and such change is or is reasonably likely to materially and adversely affect the party's ability to perform hereunder, provided however, that such material change shall not be considered an Event of

Default if, pursuant to the pertinent provisions of this Section of the Contract, such affected party establishes and maintains for so long as the material change is continuing, Performance Assurance, as that term is defined herein, to the benefit of the other party which is in the form or amount acceptable to the other party; or

(f) such party fails to establish, maintain or increase the Performance Assurance when required pursuant to this Section of the Contract.

4.2 **REMEDIES.** Upon the occurrence of an Event of Default (including the expiration of applicable cure periods), the non-defaulting party (the "Non-Defaulting Party") may terminate this Contract upon thirty (30) days prior notice.

4.3 **BANKRUPTCY.** Upon the filing of a petition by or against the Defaulting Party under the Bankruptcy Code, the Defaulting Party, as debtor and as debtor-in-possession, agrees to adequately protect the Non-Defaulting Party as follows:

(a) to cure or provide adequate assurance to cure each and every obligation of the Defaulting Party under this Contract until such time as this Contract is either rejected or assumed by order of the Bankruptcy Court;

(b) to pay all monetary obligations required under this Contract, including, without limitation, the payment of all sums required to be paid by the Defaulting Party under the terms and conditions of this Contract as reasonable compensation for the water supplied under this Contract;

(c) to provide the Non-Defaulting Party a minimum 30 days' prior written notice, unless a shorter period is permitted by the Bankruptcy Code of any proceedings relating to any assumption of this Contract or any intent to vacate or abandon this Contract, which vacating or abandonment shall be deemed a rejection of this Contract; and

(d) to perform to the benefit of the Non-Defaulting Party as otherwise required under the Bankruptcy Code.

4.4 **PERFORMANCE ASSURANCE.** Upon the occurrence of a material change that may adversely affect performance of a party, the affected party will promptly provide the unaffected party with written notice of an event which to the knowledge of the subject party with notice or passage of time or both, would constitute an Event of Default, identifying with reasonable specificity in such notice the nature and extent of the material change. Within 30 days after receiving such notice, the unaffected party may give written notice requesting Performance Assurance in an amount equal to a pre-payment for three months of water based upon the average amount of water used per month in the preceding 12 month period. Upon receipt of such notice requesting such Performance Assurance, the party affected by the material change shall have 30 business days to cure the potential Event of Default by providing such Performance Assurance requested by the unaffected party. In the event the affected party fails to provide such Performance Assurance acceptable to the unaffected party within 30 business days of receipt of notice, then an Event of Default under this Section shall be deemed to have occurred, and the Non-Defaulting Party will be entitled to the remedies set forth in this Contract.

ARTICLE V

5.1 **RE-SALE.** It is further agreed that any and all water supplied to District #9 pursuant to the terms hereof shall be sold solely to customers within the service boundaries of District #9. The water shall not be resold by District #9 to any other water district, unit of government, or any third person whatsoever, for resale purposes without the knowledge and prior written approval of Suburban, with said approval being entirely within the discretion of Suburban.

ARTICLE VI

6.1 **INTERRUPTION OF SERVICE.** In the event of interruption of the supply of water by Suburban, its wholesale suppliers, or District #9's ability to deliver water to its customers, due to

Force Majeure, no liability shall accrue by or against either party to this Contract during the term of such interruption. "Force Majeure" means an event not anticipated as of the Effective Date, which is not within the reasonable control of the party claiming suspension (the "Claiming Party"), and which by the exercise of due diligence, the Claiming Party is unable to overcome or obtain or cause to be obtained a commercially reasonable substitute therefore. Force Majeure may include, but is not restricted to: fire, flood, storm, extreme weather, or other acts of God; civil disturbance; labor dispute; labor or material shortage; failure or breakdown of equipment or facilities whether or not from any cause listed above resulting in a partial or full shut down of Suburban's or District #9's system; sabotage; action or restraint by court order or public or governmental authority (so long as the Claiming Party has not applied for or assisted in the application for and has opposed where and to the extent reasonable such government action); and loss of water supply from Suburban's wholesale suppliers not caused by any action on the part of Suburban. Force Majeure shall not be based on (i) the loss of District #9's customers or markets; (ii) District #9s inability to economically use the water supply; (iii) Suburban's ability to sell the water at a price greater than the price established by this Contract, or (iv) District #9s inability to pay for the water supply. Interruption of the water supply that Suburban receives from its wholesale suppliers shall be deemed to be Force Majeure.

6.2 In order to make repairs to or changes in Suburban's facilities for supplying and delivering the water supply under this Contract, Suburban reserves the right, without incurring any liability therefore, to suspend the supply and delivery of water supply to District #9 for periods up 72 hours to effect such repairs or changes, and in such manner as not to inconvenience District #9 unnecessarily.

ARTICLE VII

7.1 **WATER QUALITY.** It is understood and agreed that Suburban will provide a high quality drinking water with a chloramines residual from Suburban's sources of supply in accordance with KDHE standards and that meets the applicable requirements of all local, state, and federal regulations. Any further treatment and re-chlorination that may be required for compatibility with other waters within District #9's distribution system shall be the responsibility of District #9. District #9 is responsible to meet all local, state and federal regulations beyond the point of supply from Suburban.

ARTICLE VIII

8.1 **QUANTITY OF WATER; DISTRICT #9'S ABILITY TO MAKE-UP MINIMUM TAKE UNDERAGES.** The initial quantities of water to be supplied by Suburban to District #9 pursuant to this Contract shall not exceed 300 gallons per minute for a peak flow rate for four hours per day duration, 200 gallons per minute for a maximum day rate for twelve hours per day duration, with a continuous flow rate of 150 gallons per minute, and with a Take-or-Pay minimum annual purchase volume of 12,000,000 gallons. The peak flow rate of 300 gallons per minute for 4 hours and the maximum day flow rate of 200 gallons per minute for 12 hours, may be taken in the same 24 hour time period.

8.2 If District #9 has not been able to take the minimum annual purchase volume of 12,000,000 gallons, during the calendar year, then within 20 days following the end of that calendar year Suburban shall deliver District #9 an invoice for the amount of the underage (the difference between 12,000,000 gallons and the actual gallons taken during the calendar year) that District #9 was not able to take during the calendar year multiplied by the rate per 1,000 gallons in effect for that calendar year ("Take-or- Pay Requirement"). District #9 shall be required to pay the invoice for the Take-or-Pay Requirement within thirty (30) days after receiving the invoice. In a partial calendar year in which this Contract is in effect, or in a calendar year in which the rate per 1,000 gallons has changed during the year, then the invoice shall be prorated to take into account the partial year or the different rates in effect during that calendar year. The Take-or-Pay Requirement shall be abated on a pro-rated basis for any period of curtailment or termination of water service during the period of an unforeseen interruption as set forth in Article VI. It is expressly understood and agreed that fire protection service is not provided under this Contract. Suburban shall deliver water to District #9 at the point of supply set forth in Article IX at a minimum residual pressure of 50 psi at a 150 gallons per minute flow rate.

ARTICLE IX

9.1 **DELIVERY POINT OF SUPPLY.** The Delivery Point of supply to District #9 from Suburban shall be at the intersection of 206th Street and State Avenue (U.S. Hwy. 24/40) in the southwest part of Leavenworth County, Kansas. Suburban shall construct, maintain, own and operate its: water mains; water meter; and control valves upstream of the meter to be located at the connection point on the south side of State Avenue. District #9 shall at its cost connect to Suburban's water main on the downstream side of Suburban's meter inside the meter vault, and construct, maintain, own and operate its water mains, backflow preventer, and control valves from the connection point to its existing water distribution system.

9.2 Subject to the indemnification provisions in this Contract, Suburban shall be deemed to be in exclusive control (and responsible for any damages or injury caused thereby) of the water supply provided hereunder prior to the Delivery Point for water supply provided to District #9. District #9 shall be deemed to be in exclusive control (and responsible for any damages or injury caused thereby including the payment for the cost of any of the water supply lost) of such water supply at and from the Delivery Point. Suburban warrants that it will deliver to District #9 the contract quantity free and clear of all liens, claims and encumbrances arising prior to the Delivery

Point. Title to and risk of loss related to the contract quantity shall transfer from Suburban to District #9 at the Delivery Point.

9.3 The Delivery Point for the water supply to be supplied to District #9 shall be at the meter to be installed by Suburban at the Delivery Point. District #9 shall pay Suburban on the Effective Date thirty five thousand dollars ($35,000) for the cost of the meter. Suburban shall own the meter and shall be responsible for the maintenance of that meter. District #9 reserves the right to have the water meter tested at any time at District #9's expense.

ARTICLE X

10.1 **CONNECTION.** All connections to District #9 and Suburban's distribution systems shall be constructed according to the standards, rules and regulations of the Kansas Department of Health and Environment. It is further agreed that should District #9 receive water from other sources that constitute an undesirable cross-connection that does not comply with the standards, rules and regulations of the Kansas Department of Health and Environment, Suburban shall have the right to suspend water service to District #9, upon written notice specifying the unsuitable condition or connection. Water service shall be resumed upon the parties' mutual agreement that the unsuitable condition or connection has been remedied. Suburban acknowledges and consents to District #9's existing sources of supply from water wells owned and operated by District #9 and Public Wholesale Water Supply District #6 (Bonner Springs). Annually, District #9 shall provide a written list to Suburban of other systems and sources from which it receives water.

ARTICLE XI

11.1 **METERING AND OTHER DELIVER POINT EQUIPMENT.** The installation of the meter shall be the responsibility of and shall be owned by Suburban. As set forth above, District #9 shall pay Suburban $35,000 for the cost of the meter. Suburban shall operate, and maintain the necessary metering equipment and required devices of standard type for properly measuring the quantity of water delivered to District #9. A meter registering not more than two percent (2%) above or below the test result shall be deemed to be accurate. The previous readings of any meter disclosed by the test to be inaccurate shall be corrected for the three (3) months preceding the test in accordance with the percentage of inaccuracy found.

11.2 If any meter fails to register for any period, the amount of water furnished during such period shall be determined by taking the quantity of water that was metered by District #9's meter that they will use to meter the quantity of water purchased by District #9 from Suburban, in addition to Suburban's three-inch (3") meter.

11.3 If District #9's meter should be found to be inaccurate or nonfunctional, then the amount of water furnished during such period shall be determined by taking the amount of water billed by District #9 during such period, less water taken from District #9's other sources of water. The remaining amount of unaccounted for water shall be deemed to have been purchased from Suburban, unless the parties agree to a different amount.

11.4 District #9 shall be responsible for paying for and constructing the back flow valve, control valves and vault at the Delivery Point and operating said equipment at its own cost. Suburban shall approve of District #9's construction plans relating to the Delivery Point equipment it plans to install prior to District #9's construction and installation of said Delivery Point equipment.

ARTICLE XII

12.1 **NOTICES.** All notices pertaining to this Contract shall be addressed to Suburban in writing at its general offices at 1216 N. 155th Street, Basehor, Kansas 66007. Telephone or verbal communications shall not be considered proper notice. The business address of District #9 is P.O. Box 295, Tonganoxie, Kansas 66086, and all communications shall be made in writing to District #9 at said address and shall constitute proper notice. Either party to this Contract may re-designate the notice address by providing, in writing, to the other party, the newly designated place of notice with 30 days advanced notice.

<u>ARTICLE XIII</u>

13.1 **INDEMNITY - DISTRICT #9.** It is expressly understood and agreed that Suburban shall not be liable to District #9 or third parties for damages of any kind whatsoever caused by District #9, or its agents or servants, in the performance of its duties in the operation and maintenance of District #9's system and that District #9 shall save Suburban harmless from any loss or damages, or expenses incurred in connection therewith. Further, District #9 agrees to indemnify Suburban from third party litigation caused by District #9, or its agents or servants, and any and all damages arising there from.

<u>ARTICLE XIV</u>

14.1 **INDEMNITY - SUBURBAN.** It is expressly understood and agreed that District #9 shall not be liable to Suburban or third parties for any damages of any kind whatsoever caused by Suburban, or its agents or servants, in the performance of its duties in the operation and maintenance of Suburban's system and that Suburban shall save District #9 harmless from any loss or damages, or expense incurred in connection therewith. Further, Suburban agrees to indemnify District #9 from third party litigation caused by Suburban, or its agents or servants, and any and all damages arising there from.

<u>ARTICLE XV</u>

15.1 **NOTICE OF IMPROVEMENTS.** District #9 agrees, as a courtesy, to advise Suburban in writing of all proposed extensions to its distribution system which involve the installation of water mains of a diameter of six inches and larger. The intent of this courtesy advice is to allow potential improvements to Suburban's distribution system in correlation with District #9's distribution system in such a fashion that could be mutually beneficial to both parties.

Article XVI

16.1 **Kansas Corporation Commission ("KCC") Approval.** This Contract and all of the terms and conditions herein are contingent upon approval of the Contract by the KCC. This Contract shall not become effective until Suburban receives a final non-appealable order to the satisfaction of Suburban from the KCC approving the Contract. Each party shall act in good faith and shall use commercially reasonable efforts necessary to obtain the KCC's approval of this Contract. If the KCC does not approve this Contract, as written, it shall be deemed null and void unless otherwise agreed upon by both parties. Delivery of water supply under this Contract is subject to the General Terms and Conditions of Suburban's tariffs at present on file with the KCC and any subsequent modifications or substitutions thereof lawfully made.

Article XVII

17.1 **Limitations of Warranties.** There is no warranty of fitness for a particular purpose for the water to be sold under the terms of this Contract.

Article XVIII

18.1 **Water Conservation.** Suburban reserves the right to restrict the flow of water to District #9 at a rate that can adequately meet District #9's average daily demand. Provided, that such restriction shall only be invoked at such time and so long as BPU restricts flow of water to Suburban.

Article XIX

19.1 **Miscellaneous Provisions.** Neither party shall assign this Contract or its rights hereunder without the prior written consent of the other party, with such consent to not be unreasonably withheld. Any assignee shall agree in writing to be bound by the terms and conditions hereof. In the event of any such assignment, if the non-assigning party reasonably determines that the assignee does not meet the non-assigning party's credit worthiness criteria for similarly sized entities as the assignee, the non-assigning party may require the assignee to provide suitable guaranty or other credit or performance support in order to meet the credit and performance requirements of the non-assigning party.

19.2 Any and all suits for any breach of this Contract or for rescission or specific performance of this Contract shall be filed and maintained in the Leavenworth County, Kansas District Court. The interpretation and performance of this Contract shall be in accordance with the laws of the State of Kansas, without reference to principles of conflicts of laws. Each party waives its respective rights to any jury trial with respect to any litigation arising under or in connection with this Contract.

19.3 No waiver by either party of any default of the other under this Contract shall operate as a waiver of future default, whether of like or different character or nature.

19.4 Any provision declared or rendered unlawful by any applicable court of law or regulatory agency or deemed unlawful because of a statutory change (individually or collectively, such events referred to as "Regulatory Event") will not otherwise affect the remaining lawful obligations that arise under this Contract; and provided , further, that if a Regulatory Event occurs, the parties shall use commercially reasonable efforts to reform this Contract in order to give effect to the original intention of the parties.

19.5 This Contract shall be considered for all purposes as prepared through the joint efforts of the parties and shall not be construed against one party or the other as a result of the preparation, substitution, submission or other event of negotiation, drafting or execution hereof. The parties agree that this Contract shall not be interpreted or construed to favor either party more than the other.

19.6 This Contract constitutes the final, complete and entire agreement between the parties relating to the subject matter contemplated by this Contract and supersedes any previous agreements, representations, or discussions, whether oral or written, between the parties relating to the subject matter contemplated by this Contract.

IN WITNESS WHEREOF, the parties hereto have caused this Contract to be executed in duplicate on the day and year first above written.

RURAL WATER DISTRICT #9
LEAVENWORTH COUNTY, KANSAS

By: Richard H Muzzy

Printed Name: Richard H. Muzzy

Title: Chairman, Rural Water District #9

SUBURBAN WATER, INC.

By: Raphael D. Breuer

Printed Name: Raphael D. Breuer

Title: President

CONFIDENTIAL

Appendix B
Source Water Protection Plan

RURAL WATER DISTRICT No. 9, LEAVENWORTH COUNTY

SOURCE WATER PROTECTION PLAN

Outcrop of sandstone on west bank of Stranger Creek, Leavenworth County, Kansas.

Approved by the Governing Body and Signed by the Chair

August 16, 2016

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1. SOURCE WATER PROTECTION AREA DESCRIPTION

Rural Water District No. 9, Leavenworth County Point of Diversion Locations and Information:

Identification Name or Number	Well No. 1
Legal Description	NE¼ SE¼ NE¼ 3-11-21E
County	Leavenworth
Distance from SE Corner	3,400' N × 10' W
DWR File Number	43,489
Authorized Quantity (m.g.y.) and Rate (g.p.m.)	13.000 m.g.y. & 50 g.p.m.
Normal Quantity and Rate (Range)	6.140 m.g.y. & 25 g.p.m.
Status	In Use

Identification Name or Number	Well No. 2
Legal Description	SE¼ SE¼ NE¼ 3-11-21E
County	Leavenworth
Distance from SE Corner	2,740' N × 150' W
DWR File Number(s)	19,460
Authorized Quantity (m.g.y.) and Rate (g.p.m.)	36.000 m.g.y. & 44 g.p.m. (Quantity shared with Well No. 5)
Normal Quantity and Rate (Range)	10.270 m.g.y. & 20 g.p.m.
Status	In Use

Identification Name or Number	Well No. 3
Legal Description	SW¼ SE¼ NE¼ 3-11-21E
County	Leavenworth
Distance from SE Corner	2,680' N × 900' W
DWR File Number	43,488
Authorized Quantity (m.g.y.) and Rate (g.p.m.)	23.000 m.g.y. & 60 g.p.m.
Normal Quantity and Rate (Range)	7.210 m.g.y. & 33 g.p.m.
Status	In Use

Identification Name or Number	Well No. 4
Legal Description	SE¼ NE¼ SE¼ 3-11-21E
County	Leavenworth
Distance from SE Corner	1,840' N × 330' W
DWR File Number(s)	43,487
Authorized Quantity (m.g.y.) and Rate (g.p.m.)	39.000 m.g.y. & 95 g.p.m.
Normal Quantity and Rate (Range)	15.600 m.g.y. & 54 g.p.m.

Status	In Use

1. **Source Water Assessment and Source Water Protection Area (cont.)**

Identification Name or Number	Well No. 5
Legal Description	SE¼ SE¼ NE¼ 3-11-21E
County	Leavenworth
Distance from SE Corner	2,680' N × 460' W
DWR File Number(s)	19,460
Authorized Quantity (m.g.y.) and Rate (g.p.m.)	36.000 m.g.y. & 32 g.p.m. (Quantity shared with Well No. 2)
Normal Quantity and Rate (Range)	8.420 m.g.y. & 15 g.p.m.
Status	In Use

Basis of Source Water Protection Areas:

Many factors were considered before a determination was made of the areas that should be designated as the source water protection area for Rural Water District No. 9, Leavenworth County (Leavenworth RWD 9). The full 2-mile "circle" of the Source Water Assessment that was completed in 2003 was the starting point of the discussion. An evaluation of the surface water flow directions, the presumed bedrock topography and the known and presumed properties of the aquifer were evaluated.

Based on the location of the wellfield and the nearby water well drilling logs, it can easily be determined that the aquifer supplying water to Leavenworth RWD 9 is the Tonganoxie Sandstone. Kansas Geological Survey Bulletin No. 86, Part 5, published in 1950, gives a description of this valley-fill member of the Stranger Formation. The valley has a maximum width of about 20 miles and a depth of 90 to 100 feet in Leavenworth County. It is believed that the stream that cut the valley flowed in a southwestly direction, as the bottom of the channel deepens from northeast to southwest. There is evidence of this valley in Missouri, in Platte and Clay Counties, where it is only about 50 feet deep. It's presence further upstream has been eroded from the geologic record. The Missouri River cut its valley through the Stranger formation, and the base of the current valley lies lower in elevation than the Tonganoxie Sandstone, so there is no hydrologic connection between the bisected channel, nor with the Missouri River Alluvium. In Kansas, the Tonganoxie Sandstone is comprised of four distinct kinds of materials (from bottom to top): basal conglomerate, sandstone, shale and coal. The valley is cut into and through the Weston Shale, the South Bend Limestone, the Rock Lake Shale and into the top of the Stanton Limestone. It is capped by the Vinland Shale and the Haskell Limestone (above the Vinland). (In some locations, the Ireland Sandstone, which is a younger valley-fill deposit, may cut through the Haskell and Vinland into the Tonganoxie.) A large outcrop of sandstone is present on the west side of Stranger Creek at the Leavenworth Road Bridge, approximately 2.25 miles from the wellfield.

1. Source Water Assessment and Source Water Protection Area (cont.)

The sandstone outcrop at Stranger Creek in Section 36, Township 10 South, Range 21 East is in contact with the stream and could be present below the bed of the stream. The outcrop is visible between the elevations of approximately 820 to 860 feet, m.s.l. The elevation of the surface at the wellfield ranges from approximately 895 feet to 905 feet, m.s.l. No stratigraphic well logs are available at this time for the District's wells, but water use reports have consistently shown that the wells have depths ranging from 126 to 145 feet. If these are accurate, then the bottom of the wells are at an elevation of approximately 755 to 780 feet m.s.l., 40 to 70 feet below the floodplain of Stranger Creek. A nearby drilling log in Section 34 (between the wellfield and the outcrop) shows the Tonganoxie Sandstone to be present between 780 and 830 m.s.l. It appears that the sandstone outcrop, being higher in elevation that the Tonganoxie Sandstone aquifer less than 2 miles away, is the Ireland Sandstone. No information is available to determine if the two sandstone members are hydrologically connected. As the Tonganoxie Sandstone deepens to the southwest, there is some possibility that the recharge of the aquifer comes from Stranger Creek and its alluvium.

Based on the reported well depths, aquifer elevation calculations, observed outcrops of sandstone and published reports showing confined aquifer conditions at the wellfield, it has been decided that the protection area should include the area in the immediate vicinity of the wellfield. If new information becomes available to directly connect Stranger Creek surface water to the recharge of the aquifer at a specific location, consideration will be given to expanding the chosen protection area.

The protection area for Well Nos. 1, 2, 3, 4 & 5 comprises 4.58 square miles. The Source Water Assessment completed by the Kansas Department of Health and Environment on November 21, 2003, designated an assessment area of 14.02 square miles.

It is believed that identified protection activities established in the designated source water protection areas will contribute protection benefits. Maps of the Leavenworth RWD No. 9 Source Water Assessment Area and the Source Water Protection Area may be found in <u>Appendix 1</u>.

1. Source Water Assessment and Source Water Protection Area (cont.)

The following narrative describes the local factors and circumstances unique to the Source Water Protection Area:

Leavenworth RWD No. 9 has five wells under their four water rights. None of the wells are classified as being in a battery of wells. Only the most senior of the appropriations (File No. 19,460) is a certified water right. The remaining appropriations (File Nos. 43,487; 43,488 & 43,489) still have time available in which to perfect the authorized quantities. The four water rights authorize the diversion of 111.000 million gallons per year (m.g.y.) at a maximum rate of diversion of 281 gallons per minute (g.p.m.). Depths reported by the district for the wells are 125 - 145 feet. The United States Geological Survey (USGS) designates the area in which the wells are located as Hydrologic Unit Code (HUC) 102701040404, named the Tonganoxie Creek - Stranger Creek Subwatershed of the Lower Kansas River Subbasin. The Source Water Protection area also includes parts of HUC 102701040403, the Jarbalo Creek - Stranger Creek Subwatershed and HUC 102701040407, the Little Stranger Creek - Stranger Creek Subwatershed, both also in the Lower Kansas River Subbasin.

The district owns the land on which all of the wells, the iron/manganese filter plant, the shop and the chlorination building are located. Copies of the ownership documents are located in the Water Rights and Water Well Landownership Appendix, Appendix 9.

2. CONTAMINANT SOURCE INVENTORY

The pollutant source inventory was developed using the checklist found at Appendix 2. Analysis of the protection areas was accomplished with a drive-through survey of the protection areas. The drive-through survey and inventory was conducted by Douglas S. Helmke, P.G., and Kenneth A. Kopp, P.G., Kansas Rural Water Association on June 8, 2016.

Kansas Source Water Assessment Program Plan - Contaminant Source Inventory
Name of Public Water Supply: Rural Water District No. 9, Leavenworth County
Water Supply Diversion Points: Well Nos. 1, 2, 3, 4 & 5
Inventory Prepared by: Douglas S. Helmke, P.G. & Kenneth A. Kopp, P.G. - K.R.W.A.
Date Inventory Completed: June 8, 2016

Code	Description	Present	Comments
7531*	Auto Body Repair & Paint Service	x	Zone C
7538	Auto Truck Repair Serv ice	x	Zone C - Motorcycle Conversion Shop
7542	Car Wash	x	Zone B
211	Cattle Farm	x	Zone C
0	Drinking Water Treatment	x	Zone A & B
AF	Electric Power Lines	x	Zones A, B & C
AH	Farmstead	x	Zone C
5541	Gasoline Service Station	x	Zone B (Testing occurring this day)
9100	Government Office Building	x	Zone C
BF	Gravel Road	x	Zones A, B & C
BH	Grazing Livestock	x	Zones A, B & C
G	Health Services–offices of physicians, dentists, etc.	x	Zone C
BN	Native Grass Land (not CRP)	x	Zones A, B & C
1389	Oil of Gas Well	x	Zones B & C (Historical)
4600	Pipeline (Petroleum, Chemical, etc.)	x	Zone C (Natural Gas Compressor Station)
BQ	Pond	x	Zones B & C
4220	Public Warehouse	x	Zone C
F	Range & Pasture	x	Zones A, B & C
N	Rural Homestead	x	Zone C
4952	Sanitary Sewer	x	Zones B & C
N	Septic Tank--lateral field	x	Zone C
1521	Single-Family Housing Construction	x	Zone B
AP	Telephone Lines	x	Zones B & C
742	Veterinary Services–Specialties	x	Zone C
4221	Warehouse	x	Zone C
BA	Wells	x	Zones B & C
Other	Orthotics Manufacturing	x	Zone C
Other	Post Office	x	Zone C
Other	Emergency Medical Response Station	x	Zone C
Other	Bank	x	Zone C
Other	Metal Specialty Warehouse	x	Zone C

2. Contaminant Source Inventory (cont.)

In the Kansas Source Water Assessment Program, the assessment areas were divided into three zones: Zone A, Zone B and Zone C. These zones were developed for the purpose of determining assessment scores. In theory, the presence a contaminant source in Zone A has a greater risk than a similar contaminant source in Zone B, etc. The zones for water systems using groundwater were defined in this manner:

Zone A = Land within 100 feet of the wells
Zone B = Land within 2,000 feet of the wells
Zone C = Land within 2 miles of the wells

A general description of the contaminant sources found in the protection area, with emphasis on Zones A and B, as shown in the latest Source Water Assessment, is as follows:

-Within 100 feet of the District's wells (Zone A) are:

1. Native Grass, some Grazed.
2. District Facilities.
3. Existing and Future Single Family Subdivision Lots.
4. Proposed 206th Parkway Transportation Corridor.
5. Electric Power Lines.

-Within 2,000 feet District's wells (Zone B), not repeating the items in Zone A, are:

1. Subdivisions with Single Family Homes and Duplexes.
2. Sanitary Sewers.
3. Single Family Homes with Septic Systems, some with Wells.
4. Major Traffic Corridor (US Highway 24/40).
5. Abandoned Oil Well.
5. Gravel Roads.
6. Telephone Lines.
7. Gasoline Station with Other Retail and Car Washing.
   (Underground Storage Tank Integrity Testing being done on June 8, 2016.)
8. Ponds.

Within the protection area, 32 categories of potential pollutant sources were identified. The inventory worksheet identifying the potential pollutant sources may be found in Appendix 2.

Not appearing in the source water assessment were two sites that were investigated as possible contaminated sites. The contaminated site (Stewart Property, Project Code C405272336) at 20736 Parallel Road was found to have buried material described as having a tar-like consistency. Also found was a small area where waste treated lumber was burned. Approximately 88 tons of soil was removed and the site was considered to be resolved in April of 2009. Petroleum leases in Section 34, Township 10 South, Range 21 East were on file with the Leavenworth County Register of Deeds from the 1960's and earlier, but KDHE did not locate any abandoned oil wells. KDOT's 2008 US Highway 24/40 Corridor Study shows the possible location of an oil well in Section 34.

2. Contaminant Source Inventory (cont.)

The second potential contamination site (Williams Natural Gas, Project Code C405270971) at 20031 207th Street is also in Section 34. Sampling of soil and an impoundment was done in 1991 by an EPA contractor to determine the presence of PCB's, VOC's and SVOC's. None of the samples had contamination of the target constituents exceeding contamination criteria. This site was considered to be resolved on October 30, 1998.

3. WATER QUALITY PROTECTION MEASURES

Leavenworth RWD No. 9 has identified measures to assure protection of the quality of its source of water. These Water Quality Protection Measures are described in Appendix 3 of this document.

4. SUSCEPTIBILITY ANALYSIS

The purpose of a susceptibility analysis is to identify risks. It is a systematic procedure for determining the likelihood that a public water supply's raw water will contain contaminants at concentrations of concern. Using this information, a water system can direct water quality protection efforts in the most effective manner, thereby reducing contamination risks to its drinking water source.

The Source Water Protection Planning Committee used the susceptibility analysis procedure developed by the Kansas Department of Health and Environment for use in the Kansas Source Water Assessment Program. The following is a quote from the Kansas Source Water Assessment Report that describes in part the susceptibility analysis process:

> *"This analysis was based on a decision tree framework consisting of a series of yes and no questions. These questions considered the proximity of contaminant sources to the water supply intake, the type of contaminant, and the application of pollution prevention or water quality protection practices to sources of contamination. As the evaluator moved through the analytical framework, susceptibility points were accumulated based on the presence of contaminant sources in the assessment area (AA)."*
>
> *"After all the questions were answered, the susceptibility likelihood score (SLS) was calculated for each contaminant of concern category. The SLS was determined by counting the number of contaminant risk factors found to occur in the delineated AA and applying a multiplier to this number. Because the number of contaminant category risk factors is not equal, the multiplier is used to establish a common scale for the SLS of each contaminant category."*

4. Susceptibility Analysis (cont.)

The process described above was used to determine the susceptibility of the District's wells. For this activity, the protection areas for each well or group of wells was separated into three zones: Zone A – 100 foot radius around the wells; Zone B – 2000 foot radius around the wells; Zone C – 2 mile radius around the wells. The decision tree procedure of questions was used to assess the circumstances pertinent to each zone and the scores were recorded using the Kansas Department of Health and Environment's Automated Source Water Assessment Tool (ASWAT).

The resulting SLS scores for the District's wells do not indicate whether the wells are at high or low risk to contamination, but rather the scores are intended to help the water system identify the types of contaminants that are most likely to impact the wells. With this information in hand, the water system can then direct water quality protection efforts towards addressing (and hopefully lowering) the highest contamination risks to a well. All risk factors should be addressed in a source water protection plan, but the use of a susceptibility analysis helps focus the protection activities.

The decision tree procedure and ASWAT scoring used to tally the Susceptibility Likelihood Score (SLS) for the District's wells may be found in Appendix 4 of this document. The Susceptibility Likelihood Score (SLS) for the wells used by Rural Water District No. 9, Leavenworth County, are as follows:

Susceptibility Likelihood Score (SLS)						
Susceptibility Likelihood Score - SLS	**A**	**B**	**B***	**C**	**C***	**D**
Leavenworth RWD 9 (Assessment Area 26)	44	45	48	52	48	55
SLS Range	Low	Low	Low	Mid	Low	Mid

Contaminant Risk Factors
A – Microbiological
B – Inorganic Compounds (IOC's)
B* – Nitrates
C – Synthetic Organic Compounds (SOC's)
C* – Pesticides
D – Volatile Organic Compounds (VOC's)

The Susceptibility Likelihood Score (SLS) can range from 0 to 100. The greater the number, the greater the susceptibility of the water supply to contamination by the contaminant of concern. While the SLS is intended to reflect the relative susceptibility of the water supply to contamination by a particular contaminant group, there is no quantitative or value scale intended. Therefore, an SLS below a certain value is not intended to represent no problem to the water supply. There is also no intent to develop an overall or single "susceptibility score" for the water supply. The SLS is most useful for helping the public water supply direct water quality protection actions towards a contaminant category of concern. For example if the SLS for microbiological contamination is high relative to volatile organic compounds, water supply protection planners would conclude that attention should be directed towards microbiological contaminant sources rather than VOC sources.

4. Susceptibility Analysis (cont.)

Based on the Susceptibility Likelihood Scores shown above, there is no one category of contamination threat that appears to be significantly greater than any of the others to the District's water supply. All efforts to reduce the risks from all contaminant sources will be beneficial, including those not addressed by the assessment tool.

In the opinion of the Source Water Protection Planning committee, the most significant potential risks to the quality and quantity of the source water to Leavenworth Rural Water District No. 1, ranked highest to lowest, are:

1. Abandoned Water Wells.
2. Proposed Parkway Construction.
3. Subdivision Encroachment.
4. Proposed Developments with water wells (cross contamination and backflow to aquifer).
5. Abandoned Oil Wells.

A listing of other potential pollutant sources that may pose a risk can be found in Appendix 3.

5. INFORM PUBLIC OF SOURCE WATER PROTECTION PLAN

In accordance with the 1996 Safe Drinking Water Act Amendments, the results of the Source Water Assessment portion of the Rural Water District No. 9, Leavenworth County, Source Water Protection Plan have previously been made public. The Source Water Assessment requirements are:

> delineation of the protection area, an inventory of the potential contaminant sources, and a susceptibility analysis to determine the risk of contamination to the water source.

The Kansas Department of Health and Environment has provided this information to the public on their website at:

http://www.kdheks.gov/nps/swap/download/LEAVENWORTHCORWD9.pdf

The District will provide information to the public regarding the Source Water Protection Plan in the following manner:

> Upon approval of the Source Water Protection Plan, a summary will be prepared for the water systems patrons. The summary will be posted to the District's web site with the Consumer Confidence Report. Availability of these documents will be announced on customer water bills.

6. SOURCE WATER PROTECTION STRATEGY

The Source Water Protection Strategy describes the actions necessary to minimize the risk to the quality of the source water utilized by Leavenworth RWD No. 9.

1. The following actions will be taken to implement Water Quality Protection Measures:

    a. The Leavenworth County Sheriff, the Stranger Township Fire Department, the Leavenworth County Conservation District, the Leavenworth County USDA Offices, the Leavenworth County Extension Office, the Leavenworth County Commissioners, and the Leavenworth County Departments of Emergency Management, Public Works, Planning and Zoning, and Geographic Information Systems (GIS), Stranger Township, the Mid-America Regional Council (MARC) and the City of Tonganoxie will be contacted and informed of the location of the Leavenworth RWD No. 9 Source Water Protection Area and the development of the Source Water Protection Plan.

    b. A program to educate landowners of the dangers of abandoned and poorly maintained water wells and to promote the plugging of these hazards will be established with the Leavenworth County Conservation District, K-State Research & Extension, and the Leavenworth County Planning and Zoning Department. Also included in this program will be cross-connection prevention education.

    c. Objections to the proposed 206th Parkway route as found in the 2008 US 24/40 Corridor Study will be filed with the Kansas Department of Transportation, Leavenworth County, the City of Tonganoxie and the Mid-America Regional Council (MARC) expressing the unsuitability of placing a traffic corridor through the water district's wellfield and treatment plant facility.

    d. The District will attempt to work with the City of Tonganoxie to protect the shared source of water by restricting the drilling of water wells within all new subdivisions proposed in the protection area.

    e. The Leavenworth County Sheriff Department will be asked to regularly patrol the protection area to prevent vandalism and any other illegal activities. Regular first responder training and appreciation events will be scheduled at the treatment plant and wellfield. The District will work with the Sheriff Department to establish a National Drug Take Back site in Tonganoxie.

    f. Landowners in the protection area will be invited to share information and knowledge of petroleum production history that occurred within the protection area, which will be shared with the Kansas Corporation Commission.

g. Kansas Rural Water Association will be asked to evaluate the progress of the water right perfection of File Nos. 43,487; 43,488 & 43,489 before December 31, 2018.

6. Source Water Protection Strategy (cont.)

2. The following actions will be taken to assure continued maintenance of Water Quality Protection Measures presently in place:

   a. Each year the Source Water Protection Plan will be re-evaluated. (This will occur at about the same time of the year that the water systems Consumer Confidence Reports are due.) At this time, progress and continued completion of the protection goals will be evaluated. If any new potential pollutant sources are identified, the potential risk they may pose to the water supply will be evaluated and the plan revised to reflect the change.

   b. Efforts will be made to maintain good communication with the landowners and the partners providing assistance within the protection area, providing beneficial information concerning recommended Water Quality Protection Measures.

   c. Water analytical reports will be closely monitored, evaluated and compared to previous years' results to make sure there is not an increase in any inorganic or organic substances that could indicate a possible contamination problem.

   d. Water levels at a specific well will be measured monthly to help understand the seasonal and annual elevation changes of the groundwater table.

3. The following actions will be taken to assure that persons responsible for future potential pollutant sources are aware of the expectations / requirements of the Leavenworth RWD No. 1 Source Water Protection Plan:

   a. The source water will be tested regularly and the reports reviewed and compared to insure no significant change to water quality. The results will be made available to the customers and area landowners through the Consumer Confidence reports.

   b. Efforts will be made to stay alert to any future activities that could potentially effect the water quality of Leavenworth RWD No. 9's groundwater supply.

   c. Efforts will be made to educate new landowners concerning the recommended Water Quality Protection Measures by mailing information concerning the Source Water Protection Plan once a year. This will be done at the same time that the Consumer Confidence Report is made available to all water users. Information concerning educational materials and resources available through the conservation district, extension office, the county planning and zoning departments, etc., will be provided.

7. EMERGENCY WATER SUPPLY PLAN AND WATER CONSERVATION PLAN

Appendix - 1.

Maps of Source Water Assessment Area,
Source Water Protection Area,
and Water Well Drilling Logs

Appendix - 2.

Contaminant Source Inventory

Appendix - 3.

Recommended Water Quality Protection Measures

Index of Recommended Water Quality Protection Measures

Less Developed Rural Land
1. Forest Land
2. Wetland

Land Cover And Crop
3. Land Cover & Crop (dryland)
4. Land Cover & Crop (irrigated)
5. Pasture (Tame & Range)
6. Conservation Reserve Program (CRP)
7. Irrigation Well Pump Site
8. Chemigation System
9. Tail Water Pit

Livestock
10. Dairy- Drylot
11. Dairy- Pasture
12. Dog Kennel
13. Cattle- Feedlot
14. Cattle- Pasture
15. Hog- Feedlot
16. Hog- Barn
17. Horses- Pasture
18. Horses- Barn
19. Poultry- Barn
20. Sheep- Pasture

Farmstead and Household
21. Abandoned Water Well
22. Farmstead Equipment Maintenance
23. Farmstead Feed Mill
24. Farmstead Feed and Hay Storage
25. Farmstead Fertilizer Storage
26. Farmstead Fuel Storage
27. Farmstead Grain Storage
28. Household Wastewater (septic tank, lateral field)
29. Household Wastewater (lagoon)
30. Household Wastewater (city sewer)
31. Landscape Maintenance
32. Farmstead and Temporary Livestock Confinement
33. Animals (pets)
34. Farmstead Pesticide Storage
35. Farmstead Silage
36. Solid Waste Storage
37. Water Well in Use
38. Abandoned Farmstead

Transportation and Utilities
39. Railroad Tracks
40. State/Federal Highway
41. City Streets (paved and gravel)
42. County & Township Roads (paved and gravel)
43. Electrical Substation and Power Lines

Pipelines and Pump Stations
44. Pump Station- Raw surface water
45. Pump Station- Petroleum
46. Pump Station- Sewer
47. Natural Gas Pipelines
48. Petroleum Pipelines (crude)
49. Petroleum Pipelines (refined product)
50. Sewer Lines

Airports
51. Airport Fuel Storage
52. Airport Pesticide Applicator
53. Airport Maintenance Areas
54. Airport- Onsite Sanitary Wastewater

Recreation Area
55. Fair Ground
56. City Park
57. Camping Area (primitive)
58. Camping Area (modern)
59. Golf Course
60. Gun Club
61. Sports Complex

Municipal Waste Treatment
62. Municipal Wastewater: Lagoon
63. Municipal Wastewater: Mechanical
64. Wastewater: Land Application
65. Wastewater: Biosolids Storage
66. Wastewater: Biosolids Application
67. Injection Well
68. Sanitary Landfill
69. Composting
70. Abandoned Dump
71. Solid Waste Transfer Station

Institutions and Businesses
72. Cemetery
73. Church
74. Hospital
75. Motel/Hotel

76. Nursing Home
77. Prison
78. Restaurant
79. School
80. Agricultural Center- Onsite Sanitary Wastewater
81. Agricultural Center- Water Well in Use

Index of Recommended Water Quality Protection Measures (cont.)

82. Agricultural Center Fuel Sales
83. Agricultural Center Equipment Repair
84. Agricultural Center Fertilizer Sales
85. Agricultural Center Fertilizer Application Service
86. Agricultural Center Pesticide Sales
87. Agricultural Center Pesticide Application Service
88. Agricultural Center Feed Mill
89. Agricultural Center Grain Elevator
90. Farm Equipment Dealer- Onsite Wastewater
91. Farm Equipment Dealer- Water Well in Use
92. Farm Equipment Dealer- Fuel Storage & Sales
93. Custom Packing Plant
94. Sale Barn
95. Seed Processor
96. Truck Wash
97. Veterinary Clinic
98. Auto Repair Shop
99. Beauty Shop
100. Car Wash
101. Dry Cleaner
102. Fuel Service Station
103. Funeral Home
104. Hardware Store
105. Photography/Print Shop
106. Small Engine Repair
107. Welding Shop

Industrial

108. Food Processor
109. Pharmaceutical Plant
110. Meat Processor
111. Metal Fabrication
112. Metal Plater
113. Petro-Chemical Refinery
114. Research Laboratory
115. Salvage/Recycler
116. Industrial Facility- Onsite Sanitary Wastewater
117. Industrial Facility- Water Well in Use

Mineral Extraction

118. Coal Mine
119. Oil or Gas Well
120. Rock Quarry
121. Geophysical Exploration Test Holes
122. Mineral Extraction- Onsite Sanitary Wastewater
123. Mineral Extraction- Water Well in Use

Recommended Water Quality Protection Measures

1. Forest Land
When possible leave in undisturbed state. Maintain good woodland conditions. Avoid or minimize woodland grazing. Control gully erosion. Use pesticides carefully.

2. Wetland
When possible leave in undisturbed state. Maintain in good wetlands condition. Avoid or minimize wetlands grazing. Use pesticides carefully.

3. Land Cover & Crop (dryland)
Follow Kansas Catalog of NPS Pollution Control Practices for Cropland Production - Nutrient Management and Pesticide Application.

4. Land Cover & Crop (irrigated)
Follow Kansas Catalog of NPS Pollution Control Practices for Cropland Production - Nutrient Management and Pesticide Application. Use only the amount of water the crop needs.

5. Pasture (Tame & Range)
Follow Kansas Catalog of NPS Pollution Control Practices for Cropland Production - Nutrient Management and Pesticide Application

6. Conservation Reserve Program (CRP)
When possible leave in undisturbed state. Maintain according to State and Federal laws regulations concerning CRP lands.

7. Irrigation Well Pump Site
Maintain site in such away that no fuels or other contaminants may enter the soil. When possible, maintain a vegetative buffer strip between the well site and crop.

8. Chemigation System
Follow applicable State and Federal laws and regulations concerning proper operation and maintenance of Chemigation Systems. In particular, attention should be give to proper operation of anti-pollution devices.

9. Tail Water Pit
Construct and maintain according to State and Federal laws and regulations. Follow Kansas Catalog of NPS Pollution Control Practices for Cropland Production-Nutrient Management and Pesticide Application.

10. Dairy- Drylot
Operate and maintain according to applicable State and Federal waste management laws and regulations. Follow Kansas Catalog of NPS Pollution Control Practices-Waste Management and Pesticide Application.

11. Dairy- Pasture
Operate and maintain according to applicable State and Federal waste management laws and regulations. Follow Kansas Catalog of NPS Pollution Control Practices-Waste Management and Pesticide Application.

12. Dog Kennel

Operate and maintain according to applicable State and Federal waste management laws and regulations. Follow Kansas Catalog of NPS Pollution Control Practices-Waste Management and Pesticide Application.

13. Cattle- Feedlot
Operate and maintain according to applicable State and Federal waste management laws and regulations. Follow Kansas Catalog of NPS Pollution Control Practices-Waste Management and Pesticide Application.

14. Cattle- Pasture
Operate and maintain according to applicable State and Federal waste management laws and regulations. Follow Kansas Catalog of NPS Pollution Control Practices-Waste Management and Pesticide Application.

15. Hog- Feedlot
Operate and maintain according to applicable State and Federal waste management laws and regulations. Follow Kansas Catalog of NPS Pollution Control Practices-Waste Management and Pesticide Application.

16. Hog- Barn
Operate and maintain according to applicable State and Federal waste management laws and regulations. Follow Kansas Catalog of NPS Pollution Control Practices-Waste Management and Pesticide Application.

17. Horses- Pasture
Operate and maintain according to applicable State and Federal waste management laws and regulations. Follow Kansas Catalog of NPS Pollution Control Practices-Waste Management and Pesticide Application.

18. Horses- Barn
Operate and maintain according to applicable State and Federal waste management laws and regulations. Follow Kansas Catalog of NPS Pollution Control Practices-Waste Management and Pesticide Application.

19. Poultry- Barn
Operate and maintain according to applicable State and Federal waste management laws and regulations. Follow Kansas Catalog of NPS Pollution Control Practices-Waste Management and Pesticide Application.

20. Sheep- Pasture
Operate and maintain according to applicable State and Federal waste management laws and regulations. Follow Kansas Catalog of NPS Pollution Control Practices-Waste Management and Pesticide Application.

21. Abandoned Water Well
Identify and properly plug all abandoned wells through a coordinated effort with landowners, cost share programs such as the County Conservation District Non-Point Source Program and the Public Water Supply.

22. Farmstead Equipment Maintenance
Use good practices for handling, recycling and disposal of equipment parts and fluids, so no contaminants may enter the soil.

23. Farmstead Feed Mill

Avoid long term spillage of grain on the ground. Use care when using pesticides to prevent them from entering the soil.

24. Farmstead Feed and Hay Storage
When possible, avoid storage of feed or hay on the ground. When storing on the ground, protect from rain and/or store at different sites each year. Use care when using pesticides to prevent them from entering the soil.

25. Farmstead Fertilizer Storage
Store fertilizer in such a manner that any spills are contained and prevented from entering the soil.

26. Farmstead Fuel Storage
Visually monitor above ground tanks for leaks. Comply with applicable State and Federal laws and regulations for large aboveground and underground fuel storage tanks.

27. Farmstead Grain Storage
Avoid long term spillage or storage of grain on the ground. Use care when using pesticides to prevent them from entering the soil.

28. Household Wastewater (septic tank, lateral field)
Install and maintain septic system according to Kansas Department of Health and Environment regulations and local codes.

29. Household Wastewater (lagoon)
Install and maintain lagoon according to Kansas Department of Health and Environment regulations and local codes.

30. Household Wastewater (city sewer)
Install and maintain lines according to Kansas Department of Health and Environment regulations and local codes.

31. Landscape Maintenance
Follow Kansas Catalog of NPS Pollution Control Practices for Cropland Production-Nutrient Management and Pesticide Application. Prevent fuels, solvents, or paints from entering the soil.

32. Farmstead and Temporary Livestock Confinement
Follow Kansas Catalog of NPS Pollution Control Practices-Waste Management and Pesticide Application. Clean out confinement area regularly.

33. Animals (pets)
Follow Kansas Catalog of NPS Pollution Control Practices-Waste Management and Pesticide Application. Clean out confinement area regularly.

34. Farmstead Pesticide Storage
Follow Kansas catalog of NPS Pollution Control Practices for Proper Pesticides Storage, Handling and Mixing. Handle pesticides in such a manner that it is not allowed to enter the soil at the storage site. Follow label directions.

35. Farmstead Silage
Protect from rain and runoff. In areas with shallow aquifers avoid storage in unlined ground storage bunkers.

36. Solid Waste Storage
Contain all wastes in such a manner that no waste materials have an opportunity to enter the soil.

37. Water Well in Use
Properly protect and maintain the well and wellhead area according to Kansas Department of Health and Environment standards and recommendations

38. Abandoned Farmstead

Follow guidelines and recommended protection measures for associated land use activities, properly plug any abandoned wells as listed elsewhere. Use proper practices for handling, recycling and disposal of fluids, heavy metals and other contaminants.

39. Railroad Tracks
Maintain railroad tracks in good condition. Contact the Kansas Department of Health and Environment immediately in the event of an accidental spill or derailment.

40. State/Federal Highway
Use good practices for use and handling of de-icers, pesticides, and road construction materials. Use good erosion control practices.

41. City Streets (paved and gravel)
Use good practices for use and handling of de-icers, pesticides, and road construction materials. Use good erosion control practices.

42. County & Township Roads (paved and gravel)
Use good practices for use and handling of de-icers, pesticides, and road construction materials. Use good erosion control practices.

43. Electrical Substation and Power Lines
Use good practices for herbicide application and brush control. Follow Kansas Catalog of NPS Pollution Control Practices for proper pesticide handling and mixing.

44. Pump station- raw surface water
Maintain Pump Station site in such a manner that no contaminants may enter the soil or be washed away from the site.

45. Pump Station- petroleum
Operate and maintain according to applicable State and Federal laws and regulations. Inspect regularly to ensure proper operation. Maintain Pump Station site in such a manner that no contaminants may enter the soil or be washed away from the site.

46. Pump Station- sewer
Operate and maintain according to applicable State and Federal laws and regulations. Inspect regularly to ensure proper operation. Maintain Pump Station site in such a manner that no contaminants may enter the soil or be washed away from the site.

47. Natural Gas Pipelines
Operate and maintain according to applicable State and Federal laws and regulations. Periodically inspect pipelines for leaks. Maintain pipelines in good condition. Follow Kansas Catalog of NPS Pollution Control Practices for proper handling and mixing of weed and brush control pesticides.

48. Petroleum Pipelines (crude)
Operate and maintain according to applicable State and Federal laws and regulations. Periodically inspect pipelines for leaks. Maintain pipelines in good condition. Follow Kansas Catalog of NPS Pollution Control Practices for proper handling and mixing of weed and brush control pesticides.

49. Petroleum Pipelines (refined product)
Operate and maintain according to applicable State and Federal laws and regulations. Periodically inspect pipelines for leaks. Maintain pipelines in good condition. Follow Kansas Catalog of NPS Pollution Control Practices for proper handling and mixing of weed and brush control pesticides.

50. Sewer Lines

Operate and maintain according to applicable State and Federal laws and regulations. Smoke test sewer system to locate leaks. Maintain pipelines in good condition.

51. Airport Fuel Storage
Visually monitor above ground tanks for leaks. Comply with applicable State and Federal laws and regulations for large aboveground and underground fuel storage tanks.

52. Airport Pesticide Applicator
Operate and maintain according to applicable State and Federal laws and regulations. Follow Kansas Catalog of NPS Pollution Control Practices for Proper Pesticides Storage, Handling and Mixing. Handle pesticides in such a manner that it is not allowed to enter the soil at the storage site. Follow label directions.

53. Airport Maintenance Areas
Use approved practices for handling, recycling and disposal of equipment parts, fluids, and fuels, so no contaminants may enter the soil

54. Airport- Onsite Sanitary Wastewater
Operate and maintain according to Kansas Department of Health and Environment laws and regulations and local codes. Use system for sewage disposal only.

55. Fair Ground
Maintain grounds in such a manner that all wastes are disposed of properly. Limit use of fertilizers and pesticides when possible.

56. City Park
Maintain park in such a manner that all wastes are disposed of properly. Limit use of fertilizers and pesticides when possible.

57. Camping Area (primitive)
Provide facilities with proper containment of wastes for later disposal according to Kansas Department of Health and Environment regulations and local codes.

58. Camping Area (modern)
Construct, maintain, and operate waste disposal systems according to Kansas Department of Health and Environment regulations and local codes.

59. Golf Course
Follow Kansas Catalog of NPS Pollution Control Practices for Cropland Production - Nutrient Management and Pesticide Application.

60. Gun Club
Limit area exposed to spent lead shot. Limit use of fertilizers and pesticides when possible.

61. Sports Complex
Maintain area in such a manner that all wastes are disposed of properly. Limit use of fertilizers and pesticides when possible.

62. Municipal Wastewater: Lagoon
Operate and maintain according to applicable State and Federal laws and regulations.

63. Municipal Wastewater: Mechanical
Operate and maintain according to applicable State and Federal laws and regulations.

64. Wastewater: Land Application
Operate and maintain according to applicable State and Federal laws and regulations.

65. Wastewater: Biosolids Storage
Operate and maintain according to applicable State and Federal laws and regulations.

66. Wastewater: Biosolids Application
Operate and maintain according to applicable State and Federal laws and regulations.

67. Injection Well
Operate and maintain according to applicable State and Federal laws and regulations.

68. Sanitary Landfill
Operate and maintain according to applicable State and Federal laws and regulations.

69. Composting
Operate and maintain according to applicable State and Federal laws and regulations.

70. Abandoned Dump
Maintain and monitor according to State and Federal laws and regulations.

71. Solid Waste Transfer Station
Contain all wastes in such a manner that no waste materials have an opportunity to enter the soil. Maintain according to KDHE guidelines and regulations.

72. Cemetery
Maintain awareness of potential to contaminate groundwater supplies with heavy metals and various contaminants. Limit use of fertilizer and pesticides.

73. Church
Limit use of fertilizer and pesticides on lawn. Dispose of waste according to State laws and local codes.

74. Hospital
Properly dispose of biological and chemical waste in accordance with State and Federal laws and regulations. Limit use of fertilizer and pesticides on lawn.

75. Motel/Hotel
Limit use of fertilizer and pesticides on lawn. Dispose of waste according to State laws and local codes.

76. Nursing Home
Properly dispose of biological and chemical waste in accordance with State and Federal laws and regulations. Limit use of fertilizer and pesticides on lawn.

77. Prison
Limit use of fertilizer and pesticides on lawn. Dispose of waste according to State laws and local codes.

78. Restaurant
Limit use of fertilizer and pesticides on lawn. Dispose of waste according to State laws and local codes.

79. School
Limit use of fertilizer and pesticides on lawn. Dispose of waste according to State laws and local codes.

80. Agricultural Center-Onsite Sanitary Wastewater

Install and maintain onsite wastewater system according to Kansas Department of Health and Environment regulations and local codes. Use system for sewage disposal only.

81. Agricultural Center-Water well in use
Properly protect and maintain the well and wellhead area according to Kansas Department of Health & Environment standards and recommendations.

82. Agricultural Center Fuel Sales
Visually monitor above ground tanks for leaks. Comply with applicable State and Federal laws and regulations for large aboveground and underground fuel storage tanks.

83. Agricultural Center Equipment Repair
Use good practices for handling, recycling and disposal of equipment parts and fluids, so no contaminants may enter the soil.

84. Agricultural Center Fertilizer Sales
Store bulk fertilizer according to State and Federal laws and regulations. Handle fertilizer in such a manner that it is not allowed to enter the soil at the storage site.

85. Agricultural Center Fertilizer Application Service
Conduct soil test before application of fertilizer. Apply fertilizer according to crop nutrient requirements. Follow Kansas Catalog of NPS Pollution Control Practices for Cropland Production-Nutrient Management and Pesticide Application.

86. Agricultural Center Pesticide Sales
Store all pesticides according to State and Federal laws and regulations. Handle pesticides in such a manner that it is not allowed to enter the soil at the storage site. Follow label directions.

87. Agricultural Center Pesticide Application Service
Operate and maintain according to applicable State and Federal laws and regulations. Follow Kansas Catalog of NPS Pollution Control Practices for Proper Pesticides Storage, Handling and Mixing. Handle pesticides in such a manner that it is not allowed to enter the soil at the storage site. Follow label directions.

88. Agricultural Center Feed Mill
Avoid long term spillage of feed on the ground. Use care when using pesticides to prevent them from entering the soil.

89. Agricultural Center Grain Elevator
Avoid long term storage or spillage of grain on the ground. Use care when using pesticides to prevent them from entering the soil.

90. Farm Equipment Dealer- Onsite Wastewater
Install and maintain onsite wastewater system according to Kansas Department of Health and Environment regulations and local codes. Use system for sewage disposal only.

91. Farm Equipment Dealer- Water Well in Use
Properly protect and maintain the well and wellhead area according to Kansas Department of Health & Environment standards and recommendations.

92. Farm Equipment Dealer Fuel Storage & Sales
Visually monitor above ground tanks for leaks. Comply with applicable State and Federal laws and regulations for large aboveground and underground fuel storage tanks.

93. Custom Packing Plant
Dispose of all waste according to State and Federal laws and regulations.

94. Sale Barn
Operate and maintain according to applicable State and Federal waste management laws and regulations. Follow Kansas Catalog of NPS Pollution Control Practices- Waste Management and Pesticide Application.

95. Seed Processor
Maintain and operate in a manner that prevents any pesticides or processing chemicals from entering the soil.

96. Truck Wash
Dispose of wash water according to State and Federal laws and regulations and local codes.

97. Veterinary Clinic
Dispose of all biological and chemical waste in accordance to State and Federal laws and regulations and local codes.

98. Auto Repair Shop
Use good practices for handling, recycling and disposal of equipment parts, fuels, and solvents. Prevent contaminants from entering the soil.

99. Beauty Shop
Prevent perm solutions or dyes from entering the soil.

100. Car Wash
Dispose of wash water according to State and Federal laws and regulations and local codes.

101. Dry Cleaner
Dispose of all dry cleaning waste according to State and Federal laws and regulations. Prevent solvents and spotting chemicals from entering the soil.

102. Fuel Service Station
Visually monitor above ground tanks for leaks. Comply with applicable State and Federal laws and regulations for large aboveground and underground fuel storage tanks.

103. Funeral Home
Prevent biological and chemical materials from entering the soil.

104. Hardware Store
Prevent paints, solvents, fuels, and other contaminants from entering the soil.

105. Photography/Print Shop
Prevent solvents and processing chemicals from entering the soil.

106. Small Engine Repair
Use good practices for handling, recycling and disposal of equipment parts, fuel and solvents. Prevent contaminants from entering the soil.

107. Welding Shop
Use good practices for use, handling, recycling and disposal of solid wastes, fuels, and solvents. Prevent contaminants from entering the soil.

108. Food Processor
Dispose of all waste according to State and Federal laws and regulations.

Appendix C
Kansas Geological Survey
Bulletin 86, Part 5 &
Bulletin 134, Part 3

Kansas Geological Survey Bulletin 86, Part 5

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1.0 Abstract

Study of lowermost deposits of the Virgilian Series (upper Pennsylvanian) in Leavenworth, Wyandotte, and Douglas Counties, northeastern Kansas, indicates localized development of sediment classed as belonging to the Tonganoxie sandstone member of the Stranger formation, which is the lowermost subdivision of the Douglas group in this region. The Tonganoxie rests disconformably on eroded upper Missourian strata consisting of evenly bedded shales and limestones.

The Tonganoxie sandstone mainly occupies and fills a wide, shallow, southwest-trending valley carved in the pre-Virgilian rocks. This valley, named Tonganoxie Valley, has a maximum width of nearly 20 miles and depth of 90 to 100 feet.

Four types of deposits are recognized in the Tonganoxie sandstone: (a) basal conglomerate, (b) sandstone, (c) shale, and (d) coal. The lithologic characters are stratigraphic relations of each of these types are described and interpreted. The filling of the Tonganoxie Valley is judged to have been accomplished by a southwest-flowing low-gradient river, named Tonganoxie River. In part, erosion and deposition in this area are concluded to have been contemporaneous.

2.0 Introduction

The purpose of this report is to show the origin, environment of deposition, and stratigraphic relations of the Tonganoxie sandstone in northeastern Kansas. The results of detailed sedimental and stratigraphic studies bearing on these problems are presented.

The Tonganoxie sandstone is the basal unit of the Upper Pennsylvanian Virgilian Series in parts of eastern Kansas. In the area studied, it consists mainly of a basal sandstone, overlain by shale and a thin coal bed. Evidence of several sorts, outlined in this paper, indicates that in country adjacent to the Missouri River, this sandstone was deposited in a broad river valley, some 14 to 20 miles wide, which extended southwestward from northwestern Missouri across northeastern Kansas. The sandstone is nonmarine and of fluviatile origin. Also, it is judged that the river which deposited the sand and associated finer sediments was very nearly at grade. The name Tonganoxie River is proposed for this Pennsylvanian river and the name Tonganoxie Valley is assigned to the valley in which sediment belonging to the Tonganoxie sandstone of this area was deposited. These names are used in the report.

A regional disconformity occurs at the base of the Virgilian Series throughout Kansas. The Tonganoxie Valley, 80 to 95 feet deep, was formed by erosion of the underlying Pedee and Lansing groups of late Missourian age. North and south of Tonganoxie Valley, the disconformity intersects formations of the Pedee group, whereas in the Tonganoxie Valley, it cuts deeply into units of the Lansing group.

2.1 Location of the Area

Strata assigned to the Tonganoxie sandstone member of the Stranger formation, Douglas group, crop out in northeastern Kansas in a belt 0.25 to 14 miles wide, extending from northeastern Leavenworth County to southern Douglas County (Pl. 1). This area lies within Ts. 8 to 14 S. and Rs. 19 to 23 E. The towns of Leavenworth and Vinland approximately define the northern and southern limits of the area included in this study. Other towns in the area are Basehor, Hodge, and Tonganoxie.

2.2 Method of Study

The months of June and July 1949 and various subsequent weekends up to May 1950 were spent in Douglas, Leavenworth, and Wyandotte Counties examining available outcrops of the Tonganoxie sandstone. Topographic maps and aerial photographs were used for mapping. Collected samples were analyzed in the laboratory, using size analysis, heavy mineral separation, thin sections, and insoluble residues. Studies with binocular and petrographic microscopes were made where necessary. Well logs and other subsurface data were examined in an attempt to extend this study beyond the area of outcrop.

2.3 Topography of the Area

The bedrocks of northeastern Kansas, including the Tonganoxie sandstone area, comprise alternating sandstone, shale, and limestone of Pennsylvanian age. These beds dip slightly north of west, approximately 25 feet to the mile. Elevations above sea level range from 750 feet along Missouri River, at the east margin of the area studied, to 1,100 feet on the upland at the west margin of the area. Erosion has produced a series of cuestas whose east-facing fronts trend northeastward. The outcrop area is bounded at the west by a conspicuous escarpment capped by the Oread limestone. This formation rises 75 to 150 feet above the lowland east of it, which is underlain by rocks of the Douglas group. Erosion of the Oread escarpment has produced outliers which make prominent hills in the area. Blue Mound, in Douglas County, and Jarbalo Mound, in Leavenworth County, are excellent examples (Pl. 1). Throughout the area, the Haskell limestone member of the Stranger formation forms local low escarpments and outliers. These rise 10 to 30 feet above adjacent areas which are underlain by the shales and sandstones of the Stranger formation. Along Missouri River, various members of the Stanton limestone form small low east-facing escarpments. On the dip-slope plains between the Oread and Haskell escarpments and between the Haskell and Stanton escarpments, the Ireland and Tonganxoie sandstones have been eroded into low mound-like hills. Where pre-Ireland erosion has cut into the Tonganoxie sandstone and the Ireland sandstone is in contact with sandstone beds of the Tonganoxie, larger hills occur, reflecting increased thickness of sandstone. This condition exists south and west of Lansing in Leavenworth County. Glacial till has somewhat masked the escarpments in the northern part of the area.

Missouri River on the north and east and Kansas River on the south control drainage of the area. In the past, critical relief has been such that stream drainage reached grade and flood plains developed, while interfluve areas remained broad, flat, and relatively undissected. Rejuvenation has brought about minor intrenchment of all drainage. Missouri and Kansas Rivers and their main tributaries now seem to have adjusted themselves and are near or at grade, but minor tributaries still are undergoing adjustments.

2.4 Acknowledgments

Writing and field work were done under the direction of Professor H. A. Ireland, at the University of Kansas. Much assistance was given by Dr. R. C. Moore and Dr. J. M. Jewett, members of the Kansas Geological Survey, and by various staff members of the Department of Geology at the University of Kansas. Field studies were facilitated by the cooperation of various citizens of Douglas, Leavenworth, and Wyandotte Counties, who permitted gathering of data from water wells, coal mines, and outcrops. I express thanks to all of these persons.

The State Geological Survey of Kansas supplied available maps and permitted use of stratigraphic sections, well logs, aerial photographs,, and unpublished field notes. Transportation and field expenses which were furnished by the Survey made this work possible.

The geologic map was compiled from unpublished geologic maps of the State Geological Survey of Kansas and by J. M. Patterson (1933), and from field work by me.

3.0 Stratigraphy

Pennsylvanian strata in the northeastern Kansas area studied consist of upper Missourian rocks belonging to the Lansing and Pedee groups and lower Virgilian units assigned to the Douglas group (Table 1). The Douglas group is separated from beds of the underlying Missourian Series by a widespread disconformity. Detailed studies were confined to the Tonganoxie sandstone, the basal member of the Stranger formation of the Douglas group. Except for the Tonganoxie sandstone, the following summary is compiled from Moore (1949). Minor changes which apply to the area under discussion have been made.

Table 1. Sequence of upper Pennsylvanian rocks in eastern Kansas.

- Pennsylvanian System
  - Virgilian Series
    - Wabaunsee group
    - Shawnee group
    - Douglas group
      - Lawrence shale
        - Amazonia limestone
        - Ireland sandstone
- Local disconformity
      - Stranger formation
        - Robbins shale
        - Haskell limestone
        - Vinland shale
        - Westphalia limestone
        - Tonganoxie sandstone
- Regional disconformity
  - Missourian Series
    - Pedee group
      - Iatan limestone
      - Weston shale[1]
    - Lansing group
      - Stanton limestone
        - South Bend limestone[1]
        - Rock Lake shale[1]
        - Stoner limestone[1]
        - Eudora shale[1]
        - Captain Creek limestone

[1]Locally absent as result of post-Missourian pre-Virgilian erosion.

3.1 Missourian Series

Various strata of the Lansing and Pedee groups of the Missourian Series underlie the Tonganoxie sandstone throughout the area. Knowledge of these strata is necessary in order to understand their relationship to Tonganoxie deposition. The stratigraphic units are discussed in ascending order.

3.1.1 Lansing Group

3.1.1.1 Stanton limestone

3.1.1.1.1 Captain Creek limestone member--The Captain Creek limestone is the oldest unit cut by the erosion surface on which the Tonganoxie sandstone rests. The Captain Creek limestone is composed of gray to dark-gray massive and evenly bedded limestone. The individual beds are more than 8 inches thick. In most exposures, the limestone has prominent vertical joints. *Enteletes pugnoides* Newell is abundant in northeastern Kansas and a robust fusulinid, *Triticites neglectus* Newell, occurs commonly on the bedding planes. Along Kansas River, the member ranges, from 4.5 to 5.5 feet in thickness.

3.1.1.1.2 Eudora shale member--The Captain Creek limestone is overlain by the Eudora shale. The lower part is black and fissile, but the upper part is light gray or greenish gray in most places. This black shale is an excellent stratigraphic marker. Megascopic fossils are rare in the Eudora shale of northeastern Kansas. The Eudora shale averages 6 feet in thickness.

3.1.1.1.3 Stoner limestone member--This limestone overlies the Eudora shale and is light bluish gray to nearly white; it weathers very light gray or creamy white. Beds of the Stoner limestone weather into thin wavy layers with thin shale partings, although on freshly quarried surfaces it has an appearance somewhat like that of the Captain Creek limestone. To the north it contains abundant *Triticites* of the *T. irregularis* type. In uneroded sections this member is 11 to 15 feet thick.

3.1.1.1.4 Rock Lake shale member--This shale overlies the Stoner limestone. The lower part is gray to greenish-gray clay shale, but in places it contains very thin silty calcareous partings. Some beds display prominent ripple marks. The upper Rock Lake shale is very sandy in places and locally grades into cross-bedded siltstone or sandstone. Marine fossils distinguish this sandy phase from the Tonganoxie sandstone in places where pre-Tonganoxie erosion has removed the South Bend limestone. Locally, this member contains remains of land plants, reptile bones, fish, and marine invertebrates. The thickness ranges from 5 to 10 feet.

3.1.1.1.5 South Bend limestone member--The South Bend limestone is the uppermost member of the Stanton limestone. It lies conformably upon the Rock Lake shale and conformably beneath the Weston shale. It is a dark-gray to blue fine-grained limestone which occurs in beds more than 3 inches thick. The brachiopod *Meekella striatocostata* (Cox) and a fusulinid similar to *Triticites moorei* Dunbar and Condra are the most common fossils. The thickness is 2 to 3 feet.

3.1.2 Pedee Group

The Pedee group consists of the Weston shale, below, and the Iatan limestone, above. This group conformably overlies the upper beds of the Lansing group and disconformably underlies beds of the Douglas group. Throughout much of Platte County, Missouri, and in the Kansas River Valley, the disconformity cuts out the Pedee group and extends downward into the Stanton limestone. Iatan limestone is present only locally to the north and south of these areas. Lower Douglas beds occupy the stratigraphic position of the Weston shale and Iatan limestone where the latter are missing.

3.1.2.1 Weston shale

The Weston shale includes strata between the top of the Stanton limestone and base of the Iatan limestone. Where the Iatan is missing, the top of the Weston shale is in contact with lower beds of the Douglas group.

The Weston deposits consist mostly of rather uniform dark-blue to bluish-gray marine shale containing several zones of sub-cylindrical ironstone concretions which lie parallel to the bedding planes. The thickness of the Weston shale is about 55 feet at Beverly Junction, Missouri, and about 70 feet at Vinland, Kansas. Post-Missourian erosion has removed most of the Weston shale in the intervening area.

3.1.2.2 Iatan limestone

The Iatan limestone overlies the Weston shale conformably and is overlain disconformably by basal deposits of the Douglas group. In the vicinity of Leavenworth, the limestone is light bluish gray to white, both on fresh and weathered surfaces. The bedding is somewhat uneven and indistinct, imparting a massive appearance, Brachiopods, bryozoans, and crinoid fragments are the most common fossils.

Northeast of Vinland, in Douglas County, it seems that prolonged exposure during early Virgilian time greatly altered the appearance of the Iatan limestone. Here the Iatan is 0.5 to 3 feet thick and is weathered blue gray, light brown, or brown to reddish brown. Incrustations, dense nodules, and thin platy beds, separated by what seems to be residual material, are evidence of solution and downward movement of calcium carbonate which has been redeposited at lower levels. The appearance of the Iatan points to development of a soil during part of early Virgilian time, prior to deposition of the overlying beds.

3.2 Virgilian Series

3.2.1 Douglas Group

The rocks of the Douglas group are divided into two formations: the Stranger (lower) and the Lawrence (upper).

3.2.1.1 Stranger formation

The Stranger formation consists of nonmarine and marine beds of the lower part of the Douglas group, extending upward to the disconformity at the base of the Lawrence formation. In north-eastern Kansas, the top of the Haskell is defined as the upper boundary of the Stranger formation, because the Robbins shale member (uppermost Stranger of some areas) commonly is absent or cannot be identified there.

> 3.2.1.1.1 Tonganoxie sandstone member--The Tonganoxie sandstone includes all strata from the disconformity at the base of the Stranger formation upward to the top of the Upper Sibley coal or the base of the Westphalia limestone member. It consists of a thin basal conglomerate, a sandstone, a shale, and at the top, a coal (Upper Sibley coal). Since the character and origin of the Tonganoxie member are the subject of this paper, this part of the Stranger formation will be

discussed in detail subsequently. The Tonganoxie member ranges in thickness from 4 to 100 feet in the northeastern Kansas area.

3.2.1.1.2 Westphalia limestone member--In northeastern Kansas, a carbonaceous laminated dark-blue limestone has been identified tentatively as equivalent to the Westphalia limestone of southern Kansas. This dark-blue limestone is widespread throughout the area, occurring 3 to 4 inches above the top of the Upper Sibley coal. A calcareous zone marks its position where the limestone is not well developed. The limestone contains abundant small gastropods and ostracodes in northern Leavenworth County. Ostracodes are the only invertebrate fossils found in this bed in Douglas County, but plant remains are common almost everywhere.

3.2.1.1.3 The Westphalia limestone of southern Kansas is characterized by the presence of abundant fusulinids. Faunally and lithologically, the dark-blue limestone occurring persistently next above the Tonganoxie sandstone in northeastern Kansas seems to be a brackish water deposit. Because it occupies the same stratigraphic position as the type Westphalia limestone, the dark-blue limestone is reasonably interpreted as the near-shore equivalent of the off-shore fusulinid-bearing Westphalia limestone of southern areas. The gastropods found in the presumed Westphalia of Leavenworth and adjacent counties may be fresh-water forms. In the areas where the Upper Sibley coal is poorly developed, the bed identified as Westphalia limestone makes an excellent stratigraphic marker for defining the top of the Tonganoxie sandstone member. The Westphalia in northeastern Kansas ranges from 0.3 to 1 foot in thickness.

3.2.1.1.4 Vinland shale member--This shale conformably, and in some places disconformably, overlies the Upper Sibley coal and the Westphalia limestone. It contains variable thicknesses of clayey to sandy shale and sandstone. Except locally, the Vinland deposits are entirely marine. The shale is blue gray and light brown. The sandstone and siltstone beds are light brown to brown. Near the town of Tonganoxie, along U. S. Highway 40 (SE cor. sec. 2, T. 11 S., R. 21 E.), and 2.5 miles south of Lawrence (Cen. E. line sec. 25, T. 13 S., R. 19 E.), the Vinland contains silty and massive sandstones up to 12 feet thick, which occur in the top part of the member. In other places where these silts and sandstones occur at the base of the Vinland shale, the underlying Upper Sibley coal and Westphalia limestone commonly are missing. Excellent plant fossils, but no invertebrates, were found in the lower sandstone zones. The upper sandstone and shale grade into the overlying marine Haskell limestone. The thickness of the Vinland shale in northeastern Kansas ranges from 7 to 25 feet.

3.2.1.1.5 Haskell limestone member--The Haskell member is a very persistent limestone which lies conformably on the Vinland shale member. The lower beds of the Haskell are sandy and contain abundant pelecypods. In northeastern Kansas, there are local thin coquinoidal beds composed of fragments of brachiopods, pelecypods, and crinoids. At some places fusulinids are abundant. The main part of the Haskell is a bluish-gray blocky fine-grained limestone. The Haskell is 2 to 4 feet thick at most outcrops.

3.2.1.1.6 Robbins shale member--Throughout most of Leavenworth and Douglas Counties, the Ireland sandstone rests directly on the Haskell limestone or on older strata, but south of Lawrence, near Baldwin, the Ireland sandstone rests on the Robbins shale. Here, the Robbins shale is a gray argillaceous silty shale which contains a zone of ellipsoidal phosphatic concretions at the base. These concretions contain ammonoid cephalopods and fish brain casts. Near Baldwin, the Robbins shale is 1 to 5 feet thick, but southward it thickens to 100 feet,

3.2.1.2 Lawrence formation

The Lawrence formation includes strata from the top of the Haskell limestone to the base of the Oread formation. The disconformity at the base of the Ireland sandstone member marks the lower boundary of the Lawrence formation. Where the Robbins shale is absent or not recognized, and the Ireland seemingly rests conformably upon the Haskell limestone, the top of the Haskell limestone is designated as the base of the Lawrence formation.

3.2.1.2.1 Ireland sandstone member--The disconformity at the base of the Ireland sandstone locally cuts through the Robbins shale, Haskell limestone, and Vinland shale into the Tonganoxie sandstone. Where the latter is thin, the disconformity at the base of the Ireland may cut through the Tonganoxie into the Weston shale or the Stanton limestone. The Ireland sandstone is light to reddish brown, typically containing disseminated iron compounds, which impart a speckled appearance upon weathering. The sandstones are thin-bedded to massive and in places cross-bedded. Where the Ireland rests on deeply eroded Haskell limestone, the sand is cemented by calcium carbonate. Heavy minerals are common throughout the Ireland sandstone. The thickness of the Ireland sandstone ranges from 3 to 80 feet in northeastern Kansas.

3.2.1.2.2 Amazonia limestone member--This limestone, which is found elsewhere in the upper part of the Lawrence formation, is not recognized in the Leavenworth and Douglas County area.

4.0 Study of the Tonganoxie Sandstone

4.1 Previous Work

Early workers (Bennett, 1896; Hall, 1896; Haworth, 1896), in their sections across Kansas, described the basal sandstone of the Lawrence shale as resting upon strata now classified as beds of the Pedee group. Hinds and Greene (1915) described the basal sandstone as a wide channel fill, unconformably overlying various formations now classed as parts of the Lansing and Pedee groups. A study of the physical characteristics of the sandstone by Moore (1931) indicated a flood-plain type of deposit. Patterson (1933) compiled much information on the lithology and stratigraphic relations of the sandstone, known then as the Stranger sandstone and as the basal member of the Stranger formation. The sandstone was named Tonganoxie sandstone in 1934 (Moore, Elias, and Newell). Moore (1936) summarized all information available in 1936 and described lithology, stratigraphic relations, the pre-Tonganoxie erosion surface, and a possible origin and environment of deposition of the Tonganoxie sandstone. Bowsher and Jewett (1943) published results of studies on coal beds of the Stranger formation and described many characteristics of the Tonganoxie sandstone.

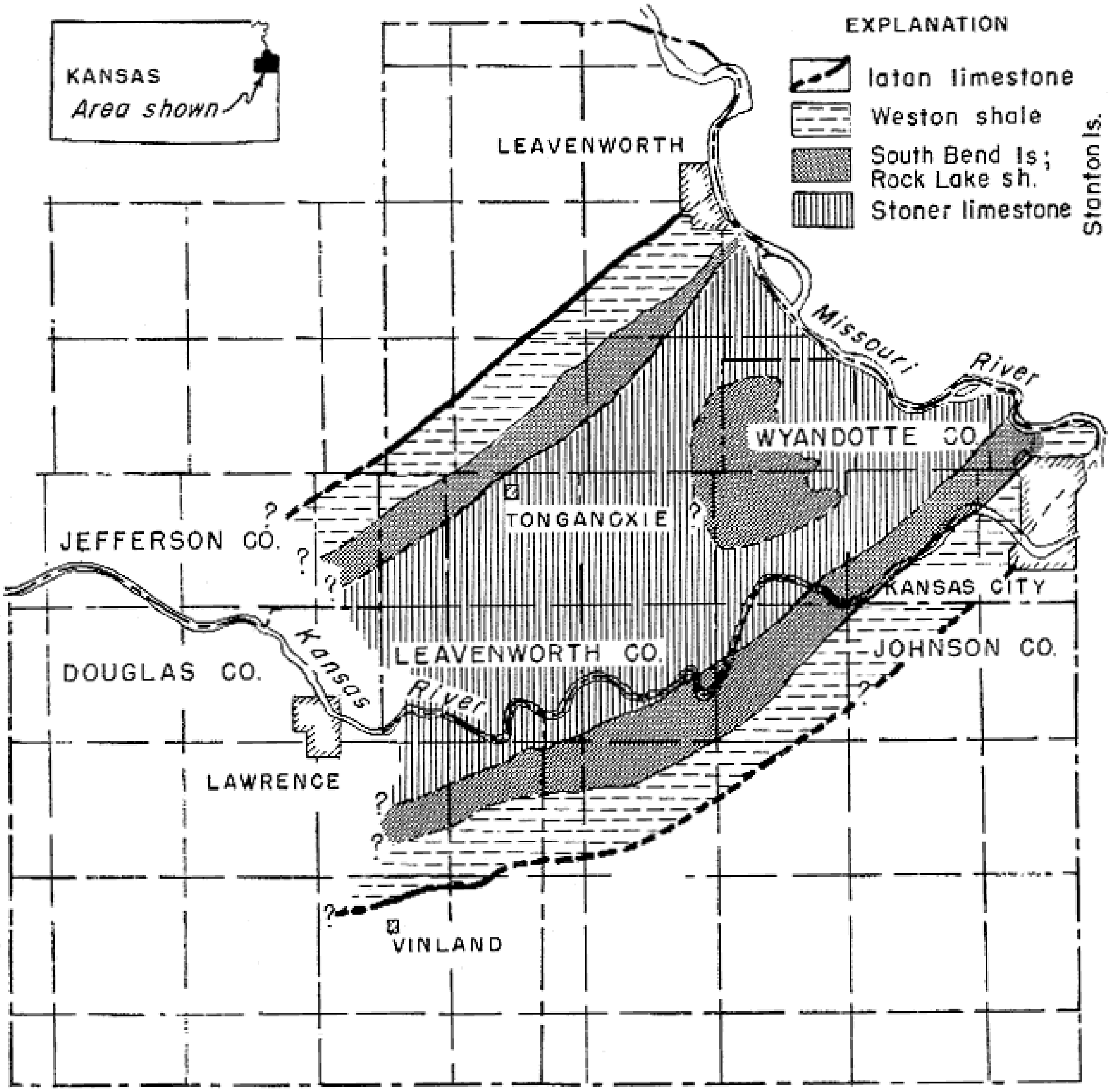
4.2 General Statement

The Tonganoxie sandstone represents the filling of a large southwest-trending valley, here termed the Tonganoxie Valley, a major feature of the regional disconformity which separates the Pedee group or older beds (Missourian) from the overlying Douglas group (Virgilian). A generalized paleogeologic map of the floor and sides of this Pennsylvanian valley is shown in Figure 1, and a cross section of the valley is given in Figure 3. Both of these illustrations indicate the presence of late Missourian strata extending along the floor and sides of the valley. This is determined from observations of the rocks which occur next below the Tonganoxie sandstone in various places. The pattern shown by the strata was formed by the cutting of the Tonganoxie Valley into the relatively flat-lying Stanton limestone and formations of the Pedee group. The valley floor in various places is directly underlain by the Stoner limestone, Rock Lake shale, or South Bend limestone (the three upper members of the Stanton limestone). The sides of the valley are formed by the Weston shale and the divides are held up by the Iatan limestone (formations of the Pedee group). Unreliable subsurface data prevented tracing of the valley beyond the Tonganoxie sandstone outcrop area.

Present outcrops closely parallel the old Tonganoxie Valley (Pl. 1), because the north-northeast regional strike nearly coincides with the trend of the valley and because post-Pennsylvanian erosion has stripped away Virgilian (and possibly Permian and Cretaceous) deposits which covered this region before development of the present land surface. In the past, knowledge of the stratigraphy and sedimentation of the Tonganoxie sandstone has been retarded by the failure to recognize that the present outcrop is approximately parallel to the old Tonganoxie Valley and is not at right angles to the direction of the source of sediment.

The depth of erosion of the Tonganoxie Valley can be ascertained in two ways; by compiling thicknesses of eroded formations from measured sections in near-by areas, and by measuring the maximum thickness of the Tonganoxie valley fill (Tonganoxie sandstone).

Figure 1--Generalized geologic map of the disconformity at the base of the Tonganoxie sandstone.



The thickness of stratigraphic units which were removed during erosion of the Tonganoxie Valley are: Stoner limestone, 4 feet; Rock Lake shale, 8 feet; South Bend limestone, 10 feet; Weston shale, 60 feet; and Iatan limestone, 2 feet. Only in a few places has erosion cut to the top of the Captain Creek limestone. These are average thicknesses which add up to 84 feet; 90 feet is an approximate figure for the maximum depth of valley erosion.

No complete sections of the Tonganoxie sandstone are exposed and the thickness, therefore, is determined from composite sections. Thicknesses of 85 feet for the sandstone unit and 20 feet for the shale unit indicate 85 feet of valley fill. Due to numerous variations in the thickness of the conglomerate and the coal units and variations in the depth of valley erosion, a maximum thickness of 80 to 100 feet of valley fill is a better estimate. On divides adjacent to the valley, the Upper Sibley coal is found 3 to 10 feet above the Iatan limestone. This indicates that the Tonganoxie sandstone filled the entire valley and overlapped the divides slightly. The figures of 80 to 100 feet of maximum valley fill and 80 to 95 feet of maximum valley erosion are comparable.

4.3 Lithology of the Tonganoxie Sandstone

The Tonganoxie sandstone contains four distinct lithologic units, which (in ascending order) include conglomerate, sandstone, shale, and coal.

4.3.1 Conglomerate Unit

The constituents of the conglomerate unit are: (1) pebbles of limestone, siltstone, and claystone; (2) reworked invertebrate fossils; (3) plant fragments; (4) quartz sand and silt; and (5) limonite, clay calcite, and siderite cement.

Spaces around the pebbles are filled in by quartz sand and silt, plant material, and shale. A few shale and sandstone partings occur locally. Limonite, clay, calcite, and traces of siderite cement the conglomerate into a hard mass.

The limestone, siltstone, and claystone pebbles range in diameter from 5 to 50 mm, 20 mm being average. The limestone and siltstone pebbles are well rounded and the claystone pebbles are compressed. They are poorly sorted and show no clearly marked orientation denoting currents which distributed them. Limestone pebbles are light brown, gray, blue gray, dense, and fine-grained. On weathered surfaces, iron oxides give a reddish color to the pebbles. The siltstone pebbles, although well rounded, are slightly elongated. This is due in part to derivation from thin-bedded siltstone layers and in part to a small amount of compaction. The siltstone pebbles show various shades of brown and red, due to staining by limonite and hematite.

The siltstone pebbles, together with the compressed claystone pebbles, are identical in color and lithology to the associated siltstone and shale of the Tonganoxie sandstone. Their origin can be attributed to reworking of beds of the Tonganoxie member, as discussed later.

Abundant plant fossils occur throughout the conglomerate, seemingly at random, either as carbonized material, molds, or imprints. Some plant fragments are 4 feet long and have compressed diameters of 5 inches.

The conglomerate unit occurs widely at the base of the Tonganoxie sandstone, where it rests on various members of the Stanton limestone and locally on the Weston shale. The thickest, best-developed conglomerate occurs in the northeastern part of the Tonganoxie Valley. A good outcrop can be seen along U.S. Highway 73, 0.5 mile north of Victory Junction, in southern Leavenworth County. In many small areas, the conglomerate is missing, as might be expected in a valley-fill type of deposit. Where the conglomerate is absent, the sandstone unit of the Tonganoxie member rests directly on Missourian rocks.

4.3.2 Sandstone Unit

4.3.2.1 Texture--The sandstone unit comprises almost three-quarters of the sediment of the Tonganoxie member. Colors generally range from light to dark brown. Iron oxide occurs throughout as a stain and as cementing material, imparting a variety of colors to the sandstone. Mechanical analyses of two representative samples are given in Table 2. The sand is composed largely of quartz grains ranging in size from one-sixteenth to one-fourth mm. Grains more than one-fourth mm in diameter are scarce and consist mostly of mica flakes. From 10 to 40 percent of the sandstone consists of quartz silt. The proportions of silt, very fine sand, and fine sand vary both laterally and vertically. Muscovite is present throughout. Results of sieve analyses, shown in Table 2, bear out the field observation that as the proportion of larger size sand grains increases, the amount of muscovite decreases; and, conversely, as the proportion of larger size sand grains decreases, the amount of muscovite increases. Although not shown in Table 2, the muscovite flakes having largest diameter occur among the coarser sands. This relationship of amount and size of mica flakes to coarseness of the sand reflects the competency of currents which transported the material, and is therefore a significant feature of the sandstone. A considerable amount of muscovite is present on the bedding planes of the siltstones and imparts a lamellar appearance; carbonaceous material produces the same effect in other siltstone beds.

Table 2--Representative analyses of the Tonganoxie sandstone.

Size	Percent sand by weight	Percent mica by volume
Festooned cross-bedded sandstone		
0.50 - 0.25 mm		Trace large flakes
0.25 - 0.125 mm	44.40	1.0
0.125 - 0.0625 mm	42.20	0.3
Below 0.0625 mm	13.40	Trace
Very fine silty sandstone (thin-bedded)		
0.50 -0.25 mm	0.87	90.0
0.25 -0.125 mm	33.00	25.0
0.125 - 0.0625 mm	22.60	20.0
Below 0.0625 mm	43.53	20.0

4.3.2.2 Composition--Quartz constitutes more than 95 percent of the sand grains, which are angular to subangular. Binocular examination and petrographic study of thin sections reveal that on many grains angularity has been accentuated by secondary quartz growth. Many such grains, exhibiting small crystal faces, have uniform extinction under crossed nicols.

Muscovite, clay, limonite, and a few grains of tourmaline comprise most of the remaining 5 percent of the detrital material. Small amounts of chlorite occur, which probably represent minor amounts of original biotite (Lee and Payne, 1944, p. 90). Muscovite in sufficient quantity to form 25 percent of the detrital material occurs in some beds. Argillaceous layers and the valley shale remnants within the sandstone unit are composed largely of clay minerals. Light-brown interstitial clay is universally present, and serves as a weak cement. Limonite occurs in small grains and as cementing material. Tourmaline is rare; grains of this mineral were found only after large quantities of Tonganoxie sediment had been separated in bromoform. Plant material and ironstone concretions occur in zones indiscriminantly distributed through the sandstone unit. Where the basal conglomerate is absent and the sandstone unit rests on limestones of the Stanton formation, the sandstone is cemented by calcite and is gray rather than brown.

4.3.2.3 Stratification--Deposition of the sandstone unit produced three types of stratification: (1) festooned cross-bedded siltstone and sandstone; (2) massive-bedded siltstone and sandstone; and (3) thin-bedded argillaceous siltstone, sandstone, and silty shale. The composition of these types is essentially identical, except for the greater amount of fine material in the thin-bedded type.

Festooned cross-bedding was first described by Knight (1929) in the Fountain and Casper formations of Wyoming. It consists of numerous cut and fill structures, each cut being an elongate trough which is closed at the upstream end and open at the downstream end. The fill consists of oblique crescentic laminae which occupy the trough from. its head to downstream end, thus forming a narrow elongate cross-laminated lens. In the Casper formation and also in the Tonganoxie sandstone, such cross-bedded lenses occur in nested groups, each lens truncating the subjacent and adjacent lenses, and in turn truncated by the superjacent lenses. The overall appearance is that of a nested group of cut and fill structures. The Tonganoxie beds exhibiting festooned stratification rest on eroded members of the Stanton limestone. The festooned cross-bedding of the Tonganoxie sandstone is not as well developed and is on a smaller scale than that described by Knight. The oblique laminae are shorter, and presumably owing to weaker current action during Tonganoxie sedimentation, large cut and fill structures, which Knight interpreted as marine cross-bedding, did not develop.

The trough-shaped channels containing the oblique laminae are as much as 20 feet long and are 6 to 8 feet wide. The laminae, which are 0.5 to 3 inches thick, have dip angles of as much as 30 degrees. Generally these laminae are 2 to 6 feet in length. All oblique laminae are concave upward, truncated at the top, and tangent to the base of the lens which they form. Many of the oblique laminae of sandstone and siltstone alternate with thin micaceous and carbonaceous silty to shaly laminae.

Directions of dip of the cross-bedded oblique laminae range from north through west to south. Since cross beds produced by river currents generally dip downstream, the most common direction of dip indicates the down-valley trend. This most common dip direction of the Tonganoxie oblique laminae is west-southwest to southwest. Therefore, the axis of the Tonganoxie Valley is judged to have extended in this direction.

The massive-bedded type of stratification consists of siltstones and sandstones which contain excellent examples of the sedimentary phases described by Gilbert (1914). These are (1) thin beds of the first phase of smooth traction, (2) cross beds of the first dune-rippled phase, and (3) thin beds representing a return to first phase smooth traction.

The massive-bedded stratification grades downward and laterally into festooned stratification and upward and laterally into the thin-bedded type. An excellent example of massive bedding can be seen along a creek in Douglas County, just north of the Cen. E. line sec. 26, T. 13 S., R. 21 E.

The thin-bedded type of stratification is best developed along margins of the Tonganoxie Valley. Throughout the area, this type occurs at the top of the sandstone unit and grades into the overlying shale unit. This stratification is characterized by thinness of the beds and their high content of mica and carbonaceous material, Abnormally thick sections of shale, to 60 feet thick, occur locally in the Tonganoxie member. (Fig. 3, sec. C-C', column 2). The lower part of these shales grades laterally into the sandstone unit of the Tonganoxie, but the upper part of the shales belongs to the shale unit. Since the lower shales are stratigraphic equivalents of the sandstone unit and seem to have been deposited contemporaneously with the sands of the sandstone unit, they are here termed "valley shales." These valley shales occur as isolated remnants in the Tonganoxie Valley.

The valley shales are even-bedded, blue gray to dark blue, and contain zones of ironstone concretions. Interbedded with the shales are numerous thin siltstone and sandstone beds with well-developed ripple marks. Some thin coals (Lower Sibley) are contained in the valley shale.

The sandstone unit of the Tonganoxie thins from 65 feet in the main channel area to 5 feet along the margin of the Tonganoxie Valley. As shown in Figure 2, the festooned cross-bedded and massive-bedded siltstones and sandstones occur in the lower and central parts of the valley where the sandstone unit is thickest and grade laterally and upward into the thin-bedded sandstone type which characterizes the margins of the valley (Fig. 3, sec. C-C').

4.3.3 Shale Unit

The shale unit of the Tonganoxie grades upward from and overlies sediments of the thin-bedded type throughout the Tonganoxie Valley. It consists of two distinct phases, silty shale and clay shale. The silty shale is highly micaceous and ranges in color from light brown to dark red or brown. Fine carbonaceous material and fossilized plant fragments are abundant throughout. No marine fossils have been observed.

The clay shale is light bluish gray to dark blue and contains minor amounts of mica. The shale is sticky to firm, and in many zones fracture surfaces exhibit slickensides. The shale is even-bedded, individual layers reaching an inch in thickness. Bands of hollow and solid ironstone concretions are common. Plant fragments are especially abundant in shale beneath the thin coal beds and in equivalent intervals where accumulation of plant material was insufficient to form a coal bed.

The shale unit is commonly silty where it overlies the festooned cross-bedded sandstone of the valley and where the lower part of the overlying Vinland shale is sandy. The thickness of the shale unit ranges from 10 to 25 feet.

Figure 2--Diagrammatic cross section showing relation of Tonganoxie sandstone to Tonganoxie Valley.

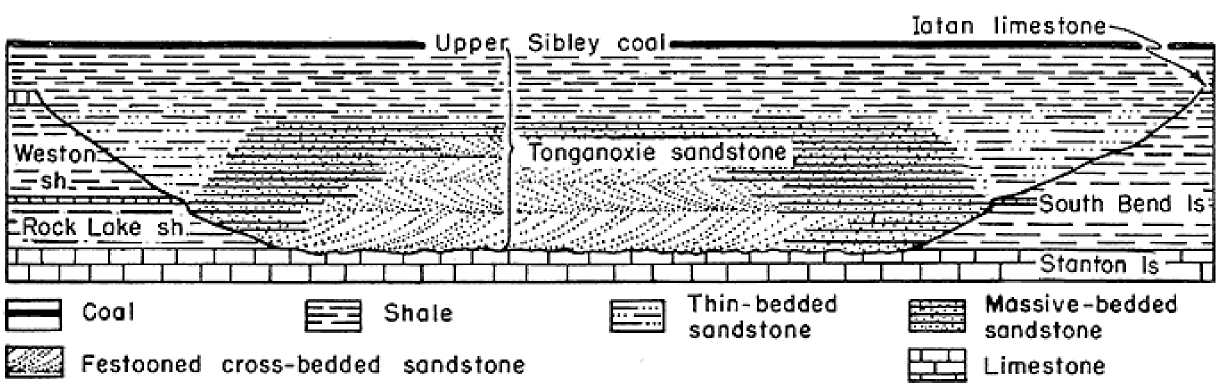
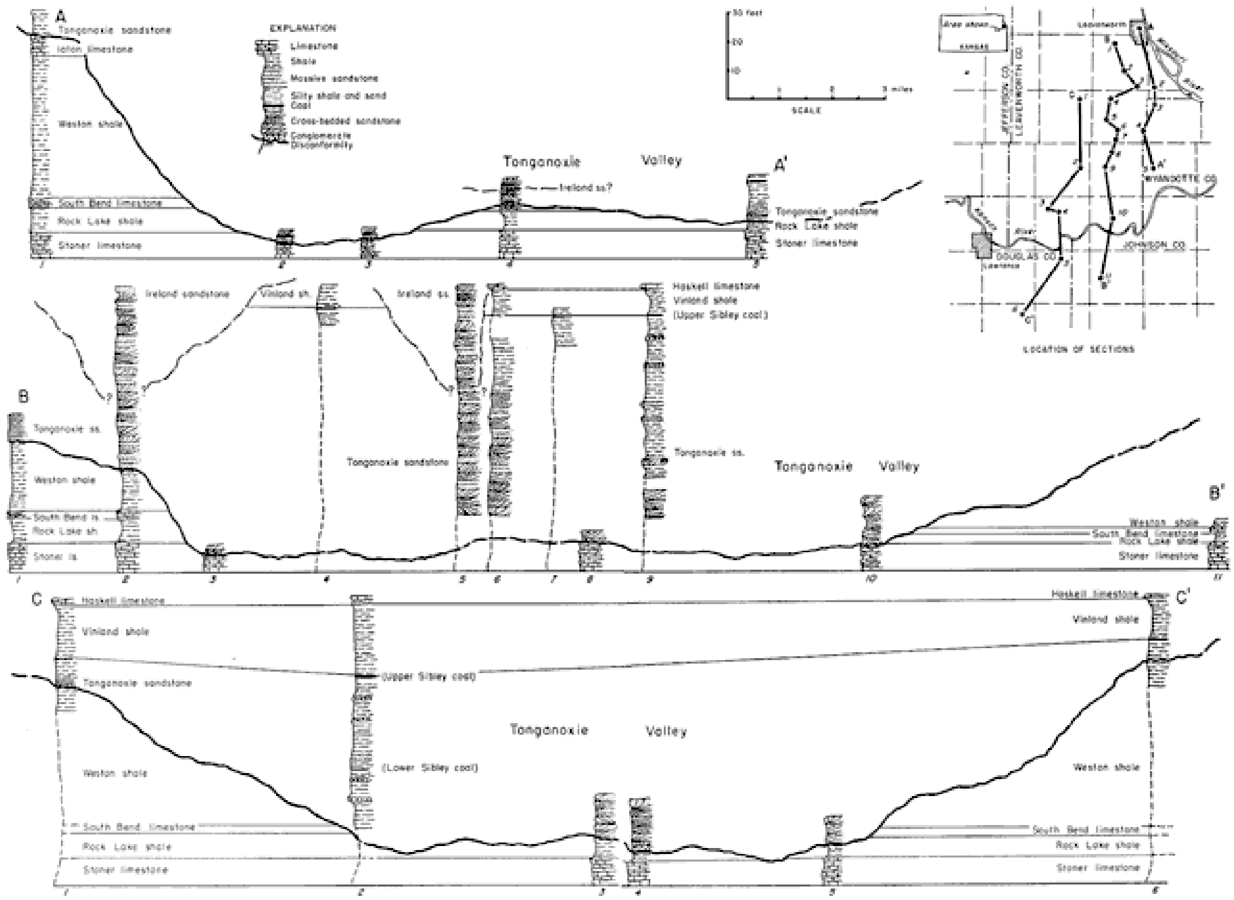


Figure 3--Diagrammatic cross section showing relation of Tonganoxie sandstone to Tonganoxie Valley.



4.3.4 Coal Unit

The Upper Sibley coal is designated as the coal unit of the Tonganoxie member. This coal bed is the uppermost stratum of the Tonganoxie and can be correlated throughout the Tonganoxie Valley. The Upper Sibley coal maintains a fairly constant stratigraphic position across the valley from north of Leavenworth to Vinland, in Douglas County (Pl. 1). Identification of the lateral continuity is strengthened by the presence of the overlying dark-blue limestone, which is correlated with the Westphalia limestone.

The Upper Sibley coal varies in thickness. At some places the coal is represented by a thin shale containing plant fossils. Elsewhere, the coal is a fairly pure bed which increases in thickness to an observed maximum of 20 inches near the town of Tonganoxie. The average thickness is about 8 inches. Stems, leaves, and trunks are preserved either as molds or as carbonized material; limbs and trunks exhibit leaf scars and limb attachment marks. The plant molds are found at the basal contact of the coal. Upper and lower parts of the coal have shale partings but the central part is generally a well-developed coal, free from clay. No underclay has been observed and roots or trunks were not observed in place. Ironstone and rare calcareous and pyrite concretions occur widely under the coal zone. The percolation of ground water through the coal has somewhat altered the subjacent shale.

The upper part of the Upper Sibley coal grades through 3 to 4 inches of calcareous carbonaceous shale into a carbonaceous argillaceous laminated limestone which has been correlated with the Westphalia limestone of southern Kansas (Moore, 1949). In northern Leavenworth County, abundant small high-spired gastropods occur in the gradational beds and in the lower part of the Westphalia limestone. Excellent impressions of tree trunks, limbs, and leaves are preserved throughout the limestone. Where the Upper Sibley coal is not identifiable or is absent, the base of the Westphalia limestone can be used as the upper stratigraphic boundary of the Tonganoxie sandstone.

Other bituminous coal beds occur below the Upper Sibley in the shale and sandstone units of the Tonganoxie sandstone. In general, these beds are thin and laterally not extensive. Except for the Lower Sibley coal, correlation from area to area is difficult.

The Lower Sibley coal is contained in valley shales which are lateral equivalents of the sandstone unit. Since these valley shales are isolated remnants surrounded by sandstones of the sandstone unit, correlation of the Lower Sibley coal is based on stratigraphic position. Valley shales containing the Lower Sibley coal are exposed on the Sumner farm in the NW cor. sec. 24, T. 11 S., R. 21 E. and at Blue Mound (Douglas County) on the S. line sec. 21, T. 13 S., R. 20 E.

Within the sandstone unit, the thin coal beds are preserved mostly in local lenticular remnants of valley shale, but such occurrences are not common. A thin local bed occurs north of Bonner Springs at the Cen. S. line sec. 17, T. 11 S., R. 23 E. The stratigraphic relationship is shown on Figure 3 (column 5, sec. A-A').

4.4 Relations of the Tonganoxie Sandstone to Overlying Beds

Normally in northeastern Kansas, the Upper Sibley coal is stratigraphically overlain by the Westphalia limestone, Vinland shale, Haskell limestone, and Ireland sandstone. However, the Ireland sandstone in most localities rests disconformably on the Haskell limestone and older strata. Locally throughout the area, erosion which is recorded by the disconformity reached the sandstone unit of the Tonganoxie member; subsequent deposition of the Ireland resulted in a very thick section of sandstone. Therefore, an understanding of the relation of the Ireland and Tonganoxie sandstones is important to study of geology in the area.

Haworth (1894, p. 122), in naming the Lawrence shale, miscorrelated the limestone now called Haskell with the Iatan limestone. Hall (1896), Haworth (1896), and Hinds and Greene (1915) recognized only one sandstone body in the section. Hall and Haworth recognized the shallow-water characteristics of the basal sandstone member of this sequence but did not observe the large stratigraphic erosional surface on which the sandstone was deposited. Later detailed stratigraphic work by members of the State Geological Survey of Kansas revealed upper and lower sandstone bodies, resting unconformably on older formations and in places one on the other. The upper sandstone (above the Haskell limestone) was named Ireland (Moore, 1932) and was classified as the basal member of the Lawrence shale. The lower sandstone (below the Haskell limestone and above the true Iatan), locally in contact with various members of the Stanton limestone, was named Tonganoxie sandstone (Moore, Elias and Newell, 1934) and was regarded as the basal member of the Stranger formation.

The Ireland sandstone rests disconformably upon the Stranger formation in most localities. Lithologically, the Ireland sandstone is indistinguishable from the basal member of the Stranger formation, the Tonganoxie sandstone. The Ireland generally is more reddish, owing to its higher iron oxide content, but this distinction cannot be used over wide areas. In places, the pre-Ireland erosion and the deposition of the Ireland sandstone directly on the sandstone unit of the Tonganoxie resulted in thick sections of sandstone which have been mapped previously as Tonganoxie sandstone. Examples are in the vicinity of Hodge, Leavenworth County. Combined sections of Ireland and Tonganoxie sandstone 100 to 150 feet thick occur locally throughout the area. A few of these thick sandstone sections contain a conglomerate of siltstone and mud balls cemented by clay and calcium carbonate. The conglomerate probably marks the contact between the two sandstone bodies. An excellent example of such a conglomerate is seen in an outcrop west of the railroad track along the N. line sec. 36, T. 10 S., R. 22 E. Well-defined Ireland sandstone is found to the west of this outcrop, the Haskell limestone is absent, and the obviously greater abundance of disseminated iron in the sandstone above the conglomerate indicates that the conglomerate probably marks the contact between the Ireland and Tonganoxie sandstones.

Laterally, the lower part of the Ireland sandstone may be found at the same stratigraphic level as shales of the Tonganoxie sandstone member and seems to grade into them. Failure to recognize the upper sandstone as Ireland and the shales as Tonganoxie has retarded understanding of the origin and environment of both the Tonganoxie and Ireland sandstones.

Field work has shown that in practically all sections where the Haskell limestone is present, the Upper Sibley coal occurs 7 to 18 feet below its base. Where sandstone occupies this interval the Haskell limestone is absent. Absence of the Haskell limestone and the Upper Sibley coal in near-by areas and the presence of sandstone at the same stratigraphic horizon definitely identify the sandstone as Ireland. This points to deep post-Haskell erosion prior to deposition of Ireland sandstone.

4.5 Sedimentary Origin and Environment of the Tonganoxie Sandstone

4.5.1 General Statement

As shown in Figures 1 and 3, the Tonganoxie sandstone occupies a southwest-trending valley, 14 to 20 miles wide and 80 to 100 feet deep. The prevalent southwesterly dip of laminae in the festooned cross-bedded sandstone indicates that the Tonganoxie River flowed from northeast to southwest.

4.5.2 Disconformity

The regional disconformity at the base of the Virgilian Series, of which the disconformity at the base of the Tonganoxie sandstone is a part, denotes a time of widespread retreat of the Pennsylvanian sea in the midcontinent region. Post-Missourian folding in the southwestern part of the midcontinent suggests that the regional disconformity was not due entirely to a eustatic change of sea level. With retreat of the sea, erosion cut the Tonganoxie Valley and produced the disconformity which coincides with the floor of the valley.

Reconnaissance work north and south of the Tonganoxie Valley has revealed no similar erosional valley. In these areas, the disconformity seemingly occurs in the midst of a shale sequence which overlies the Iatan limestone and underlies or is part of the Vinland shale. In localities where the Iatan limestone is absent, the disconformity is between the Weston shale and the overlying Vinland shale.

While erosion, unaccompanied by local sedimentation, proceeded north and south of the Tonganoxie Valley, erosion and concurrent deposition took place in the valley. As thickness of sediment in the

Tonganoxie Valley increased and as the sea encroached, erosion of the valley ceased, but north and south of the valley it continued. Accordingly, the part of the disconformity which is marked by the base of the Tonganoxie sandstone is not precisely equivalent in time value to the disconformity elsewhere. Also, the sediment which ultimately came to be deposited over the divide areas north and south of the valley was laid down after the Tonganoxie Valley had been filled. This indicates that in regional correlation, the Tonganoxie sandstone is a little older than sediments overlying the disconformity in areas outside the valley.

4.5.3 Tonganoxie Valley

The Tonganoxie Valley is interpreted as having been cut by a basinward-flowing river which, owing to retreat of the sea, was forced to cross an emerged sea bottom. Faunal and sedimental evidence indicates that the Pennsylvanian seas were shallow. Consequently, the initial dip of the sediments (dip of the profile of equilibrium) was very gentle and small vertical changes in sea level uncovered or submerged large areas. The gradients of rivers flowing over such emerged sea bottoms evidently were low, but sufficient to permit excavation of shallow valleys.

The ratio of 14 to 20 miles of valley width to 80 to 100 feet of valley depth indicates that the Tonganoxie River was near grade and that minor fluctuations in current velocity could result in either erosion or deposition.

4.5.4 Erosion and Deposition in the Tonganoxie Valley

Initial deposition of the Tonganoxie sandstone is judged to have been contemporaneous with erosion in the Tonganoxie Valley. (1) The Tonganoxie Valley is very shallow compared to its width, indicating that the river must have been close to grade and that valley erosion was primarily lateral rather than downward. It is probable that a river carving such a shallow wide valley would be depositing at one place and eroding at another, all at the same time. (2) The basal conglomerate seems to be of local origin (as discussed below). (3) Festooned cross-bedded sandstone occurs in the areas of deepest erosion and inferred strongest currents, and thin-bedded sandstones occur where erosion was least. (4) Valley shale deposits seemingly were contemporaneous with the sandstone unit.

Present large streams, which are near or at grade, are continually reworking their flood-plain and channel deposits. During times of floods, valley widening and deepening take place in the channel and deposition occurs on the flood plain. As the channel shifts, sediment is removed from parts of the flood plain and redeposited elsewhere. Such valley sedimentation is contemporaneous with valley erosion and does not represent deposition subsequent to carving of the entire valley.

4.5.5 Sources of Sediment

The immediate sources of Tonganoxie sediments may be sought in sandy and silty near-shore and alluvial facies of earlier Pennsylvanian sediments to the east and north of the area, or in pre-Pennsylvanian terranes such as occur in the Ozark dome, Wisconsin Highlands, or the Appalachian region.

The sandstones and siltstones of the Tonganoxie are composed largely of angular quartz grains. Other detrital minerals are scarce, except muscovite. No rounded frosted sand grains of the St. Peter type have been observed. It seems probable that the Tonganoxie siltstones and sandstones represent reworked micaceous sediments of Pennsylvanian age which were exposed by the retreat of the sea and were transported westward from the upstream parts of the Tonganoxie River system.

Most of the limestone pebbles are lithologically similar to the Stanton and Iatan limestones. This suggests that the pebbles were derived from these formations, probably at places not far distant from the deposits of conglomerate. The poor sorting of the pebbles and the intermixture of pebbles with water-worn brachiopods, crinoid fragments, and some fusulinids also indicate that the pebbles were of a local detritial origin.

4.5.5.1 Deposition of the conglomerate unit--The cutting of the Tonganoxie Valley indicates that during erosive periods the river acquired a load from its channel to supplement the sand, silt, and clay transported from farther east. The Tonganoxie Valley area of northwestern Missouri and northeastern Kansas was underlain by limestones and shales of the Missourian Series. Little sand or silt was available for river load. Consequently, the traction load of the river was augmented by fragments of locally derived limestone and shale. These fragments were seemingly too large for the usual competency of the river; they were shifted from place to place as the valley formed and were concentrated as the basal conglomerate of the Tonganoxie sandstone.

4.5.5.2 Deposition of the sandstone unit--The sediment of the Tonganoxie sandstone shows that the Tonganoxie River was transporting fine micaceous sand, silt, and clay which were deposited in the channel and on the flood plain of the Tonganoxie Valley. The main channel area of the Tonganoxie Valley is shown by the location of extensive deposits of festooned cross-bedded and massive-bedded siltstones and sandstones.

To my knowledge, festooned cross-bedding has not been observed in modern sediments or produced in the laboratory. It has not been reported widely from the older sediments. Presumably, it results from alternate cutting and filling of troughlike channels by strong shifting currents.

Clay accumulated in the local lakes and swamps of the flood plain while silt and sand were deposited in the channel areas. The clay material became valley shales. The ripple-marked siltstone and sandstone beds within the valley shales may represent times of minor flooding when current action was strong. Some plant material accumulated in the valley shale material, as is shown by the presence of the Lower Sibley coal. Later channel migration failed to remove the valley shale deposits and they remain as remnants of formerly more extensive deposits surrounded by the festooned cross-bedded and massive-bedded siltstones and sandstones of the sandstone unit.

4.5.5.3 Deposition of the shale unit--The gradual change in lithology from the thin-bedded strata of the sandstone unit into the overlying shale unit represents a change in depositional environment. This change seems to reflect reduction of the river gradient and slow encroachment of the sea from the west. Beds tentatively identified as brackish water in origin, overlain by marine strata, occur widely above the Tonganoxie sandstone. This sequence of strata is interpreted to represent progress toward marine conditions and establishment of marine conditions in the area. The initiation of the marine invasion was probably contemporaneous with deposition of the shale and coal units and partly may have been responsible for the reduction of river gradient.

The association and lithology of the shale unit suggest that deposition took place in broad shallow lakes, swamps, and on the partly inundated flood plain of the Tonganoxie Valley. The blue-gray to dark-blue color of the iron-bearing shales indicates that the water table was high and that the environment was primarily one of reduction, rather than oxidation. The high content of carbonaceous material in the shales also suggests that reducing conditions prevented complete oxidation of the organic matter. Iron was precipitated in the swamps and lakes, probably as iron carbonate, forming ironstone concretions. Where colloidal clay was present, clay ironstone beds formed.

No invertebrate fossils have been found in the shale unit. Although the environment seems to denote reducing conditions, there is no evidence of pyrite, marcasite, black shales, and other signs of "foul bottom" conditions. If the shale unit had been deposited in a marine environment, occurrence of marine invertebrates should furnish proof.

Deposition of uppermost beds of the shale unit terminated existence of the Tonganoxie Valley. The shale material filled the valley and overlapped the divides (Fig. 3, sec. C-C'). Deposition of the shale unit was followed by accumulation of the material of the Upper Sibley coal over what had been the Tonganoxie Valley and in small areas north and south of the divides.

4.5.5.4 Deposition of the coal unit--Characteristics of the Upper Sibley coal and associated sediments have been studied in order to determine the origin and environment of deposition of the coal. The following are significant features of the Upper Sibley coal.

1. The coal zone can be recognized within the Tonganoxie Valley and on the marginal divide areas, but in many places the coal is absent and a carbonaceous shale represents the zone.

2. Sections of the coal bed show no clay or silt in the middle part.

3. Plant material, consisting of stems, limbs, trunks, and leaves, was the parent material of the coal.

4. Plant remains are well preserved in subjacent and superjacent strata and show no signs of having been transported by currents.

5. Subjacent shales are well bedded but plant material is not parallel to the bedding planes.

6. Subjacent shales are nonmarine.

7. Underclay has not been observed.

8. Fossils, tentatively identified as fresh to brackish-water forms, occur in overlying beds, but no definitely marine fossils have been found.

9. Subjacent and superjacent strata grade into coal.

Bowsher and Jewett (1943, p. 38) suggest that coals of the Stranger formation possibly may have been produced from detrital plant material which accumulated in a marine littoral environment. Coals of such allochthonous origin would have to have been brought into' place by currents. Moore (1940) states that at least 15 to 20 feet of vegetable matter is required to furnish material for 8 to 12 inches of coal. If this is true, the average 8-inch thickness of the Upper Sibley coal represents approximately 15 feet of vegetable material. It seems to me that fluctuations in currents during the time required for deposition of the 15 feet of vegetable material at least occasionally would have brought in silts and clays. The lack of interbedded silt or clay in the Upper Sibley coal suggests that the coal is not detrital. The coal does grade upward and downward into plant-bearing clay shale but the central part is free from clay.

The leaves, stems, limbs, and trunks preserved in the Lower and Upper Sibley coals, and in the subjacent and superjacent gradational shales, show no signs of having been transported from their place of growth. Fragile leaves and stems are preserved intact. Bark with leaf and limb attachment scars is preserved on the trunks. There is no abrasion or other evidence indicating their transportation as detritus.

Physical similarities of the Upper Sibley coal to the Lower Sibley coal also indicate a.common origin. On the basis of its stratigraphic relations, the Lower Sibley coal seems definitely to be nonmarine. The Lower Sibley coal is preserved in valley shale remnants which grade laterally into definitely nonmarine beds of the sandstone unit, and is overlain by the nonmarine shale unit of the Tonganoxie sandstone.

I am of the opinion that the Lower and Upper Sibley coals are of continental autochthonous origin. There is a possibility that some of the very thin local beds in the sandstone and shale units may have been derived from previously formed peat or coal beds which were reworked and redeposited, but physical charactristics of the coal beds give the impression that original peat and plant material which later formed the coal accumulated in situ.

Considering the Tonganoxie sandstone as a depositional unit, the Upper Sibley coal seems an integral nonmarine member of a depositional sequence or cycle. The sequence of nonmarine sandstone, followed by nonmarine shale, and finally by coal, indicates a reduction of current action in the area and the final filling of the Tonganoxie Valley by organic deposits. Marine sediment of the overlying Vinland shale represents completion of marine flooding and beginning of the marine part of a cyclothem.

4.5.6 Tonganoxie Sandstone and Cyclic Deposition

The conditions of deposition of the Tonganoxie sandstone may explain the absence of the nonmarine sand, shale, and coal units of certain cyclothems in the Pennsylvanian sections in Kansas.

Upper Pennsylvanian cyclic deposition in Kansas primarily expresses sea level fluctuations. Marine and nonmarine deposition closely followed the shifting shore lines. During most of late Pennsylvanian time in northeastern Kansas, the shore line was farther east. Erosion has removed the eastern, dominantly nonmarine, facies of most of the Pennsylvanian cyclothems. These missing facies contained the nonmarine units of cyclothems which are represented by marine beds in Kansas. Deposition of the Tonganoxie sandstone marked a time when the eastern nonmarine facies extended well into Kansas. Successive stratigraphic sections to the west should reveal that the Tonganoxie sandstone grades into marine sediments. Where the equivalent of the Tonganoxie sandstone is marine, a stratigraphic section would lack the nonmarine sand, shale, and coal units of a cyclothem.

Stratigraphic sections which include sediments of the Tonganoxie Valley and its overlying deposits contain the nonmarine sandstone, shale, coal, and marine units of a cyclothem. Stratigraphic sections outside the valley contain only the marine units of this cyclothem, although uppermost parts of the nonmarine unit may be present. Sections of the latter type may lead one to believe that the nonmarine units should be found only farther east, whereas actually, the nonmarine units are restricted to a near-by valley.

5.0 Economic Geology

The Tonganoxie sandstone is the most important aquifer in the area under discussion. Nearly all well water for stock and domestic use is obtained from this sandstone. The town of Tonganoxie obtains its water supply from this sandstone in wells east of the town.

The festooned cross-bedded and massive-bedded deposits in the center of the old Tonganoxie Valley have greater porosity and permeability than the thin-bedded sandstone near the old valley margins. Wells drilled at short distances north or south of the old Tonganoxie Valley encounter no Tonganoxie sandstone. In those areas, the Ireland is the most important aquifer near the surface, although locally it is absent also.

Porosity and permeability are best developed in the basal conglomerate, where ground water has dissolved parts of the limestone pebbles and the calcium carbonate matrix. Ground water moves freely along the contact where the conglomerate rests on limestones of the Stanton formation. Poor wells completed above the Upper Sibley coal or in the shale unit of the Tonganoxie sandstone could be improved by deepening to the conglomerate of the Tonganoxie in order to take advantage of the greater porosity of this zone.

Care should be exercised in drilling wells in the upland areas where thick sections of the Ireland and Tonganoxie sandstones occur. In these areas the valley walls of existing streams are steep and thick sections of the sandstones are exposed; ground water drains into the streams through the highly porous sandstone, causing the water table to become appreciably lower during dry weather. Wells in these areas should be deepened to the basal contact of the Tonganoxie sandstone in order to obtain ground water which moves laterally along the surface of the underlying impermeable strata.

The thin coals of the Tonganoxie sandstone have been mined in the past, but such ventures are generally not profitable commercially, except under unusual circumstances such as conditions produced by a war. The coal resources of the Stranger formation (Douglas group) are discussed by Bowsher and Jewett (1943).

The Tonganoxie sandstone is an extensive possible source of fine quartz sand and silt, although the high iron and mica content may limit its use. The poor degree of cementing makes the sandstone very easy to quarry and large deposits with only a thin overburden are present.

6.0 Summary

The following is a summary of the major results obtained in this study.

1. The Tonganoxie sandstone consists mainly of nonmarine beds of sandstone, shale, and coal which are considered to be the nonmarine units of a cyclothem. The Tonganoxie sediments are divided into four units: conglomerate, sandstone, shale, and coal. Three types of stratification are observed in the sandstone unit: (a) festooned cross-bedded sandstone and (b) massive-bedded siltstones and sandstones in the center of the old Tonganoxie Valley, and (c) thin-bedded sandstone along the valley margins. The festooned cross-bedded and massive-bedded sandstones grade laterally and upward into the thin-bedded sandstones. The thin-bedded sandstone grades upward into the shale unit, which grades vertically into the coal unit.

2. The Tonganoxie sandstone is confined to a valley extending southwestward across northeastern Kansas. Only slight marginal overlap of the upper part of the shale and coal units occur on adjacent divide areas.

3. The Lower Sibley coal is preserved in valley shale remnants of former extensive flood-plain deposits.

4. Excessive thicknesses of sandstone (more than 65 feet) are due to combined thicknesses of the Ireland and Tonganoxie sandstones.

5. Sediments composing the Tonganoxie sandstone were derived from the east and deposited by a southwest-flowing river.

6. The mica of the Tonganoxie is detrital and not authigenic.

7. The Tonganoxie sandstone may be the time equivalent of sandstones of the same name elsewhere in Kansas, but the immediate source of sediments and the depositing rivers probably were not the same.

8. The disconformity at the base of the Tonganoxie sandstone does not represent precisely the same time interval as the regional disconformity outside the Tonganoxie Valley.

9. The Tonganoxie is older than beds overlying the regional disconformity in most places elsewhere.

10. The stratigraphic relations and conditions of deposition of the Tonganoxie sandstone may explain the absence of certain cyclothem units in Kansas.

11. The alignment of the present outcrop is approximately parallel to the old Tonganoxie Valley and is not at a right angle to the direction of the source of sediment.

12. Greater porosity and permeability for ground water prevails in the basal conglomerate and in the festooned cross-bedded and massive-bedded sandstones than in the thin-bedded sandstones and the shale unit of the Tonganoxie sandstone. The sandstone is not encountered in various wells drilled outside the old Tonganoxie Valley.

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Sandstones of the Douglas and Pedee Groups in Northeastern Kansas

by Donald T. Sanders

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Abstract

Sandstones of the Douglas and Pedee Groups (Upper Pennsylvanian) in northeastern Kansas occupy definite channel-like trends, which are interpreted as being ancient river valleys. Isolith maps of sandstones above and below the Haskell Limestone show major features of this drainage pattern and indicate that little or no sandstone is present in much of the area. The deepest channel (i.e., trend of thickest sandstone) above the Haskell Limestone trends in an irregular westerly direction across Wabaunsee, Osage, and Franklin counties, and main sandstone deposition below the Haskell Limestone was in a deep channel extending southwestward through Douglas, Franklin, Osage, Coffey, Lyon, and Greenwood counties. Sandstone as much as 160 feet thick was found in each of these stratigraphic units.

A few samples of Ireland and Tonganoxie Sandstone, the most important units in the sequence, were analyzed, and all samples were found to have similar physical characteristics. Fine to very fine sand is predominant in both sandstones, but the Ireland contains a larger percentage of silt. Subangular to angular quartz grains make up 90 to 95 percent of the volume of all samples, the remainder being composed of muscovite, some tourmaline, and rare chlorite grains. Permeability is uniformly low, although both of these sandstones are important aquifers in northeastern Kansas.

Results of this study should aid in locating new sources of ground water and possibly in developing underground storage reservoirs for surface water.

Introduction

Purpose and Scope of Investigation

This investigation was undertaken in order to map and describe the aggregate distribution and thickness of sandstones in the Douglas and Pedee Groups, of late Pennsylvanian age, in the subsurface of northeastern Kansas, and to study their physical characteristics. It is believed that results of this study will have value in locating ground water for domestic, municipal, or industrial use.

Owing to the nature of subsurface data available in this part of Kansas, and for greater clarity in mapping, the sandstones of the Douglas-Pedee stratigraphic sequence have been arbitrarily divided into two groups, those above the Haskell Limestone member of the Stranger Formation (Pl. 1) and those below the Haskell Limestone (Pl. 2). Each of these subdivisions contains, in certain parts of the area studied, a major sandstone unit (Ireland Sandstone above and Tonganoxie Sandstone below) as well as several comparatively local sandstone phases of various shale units.

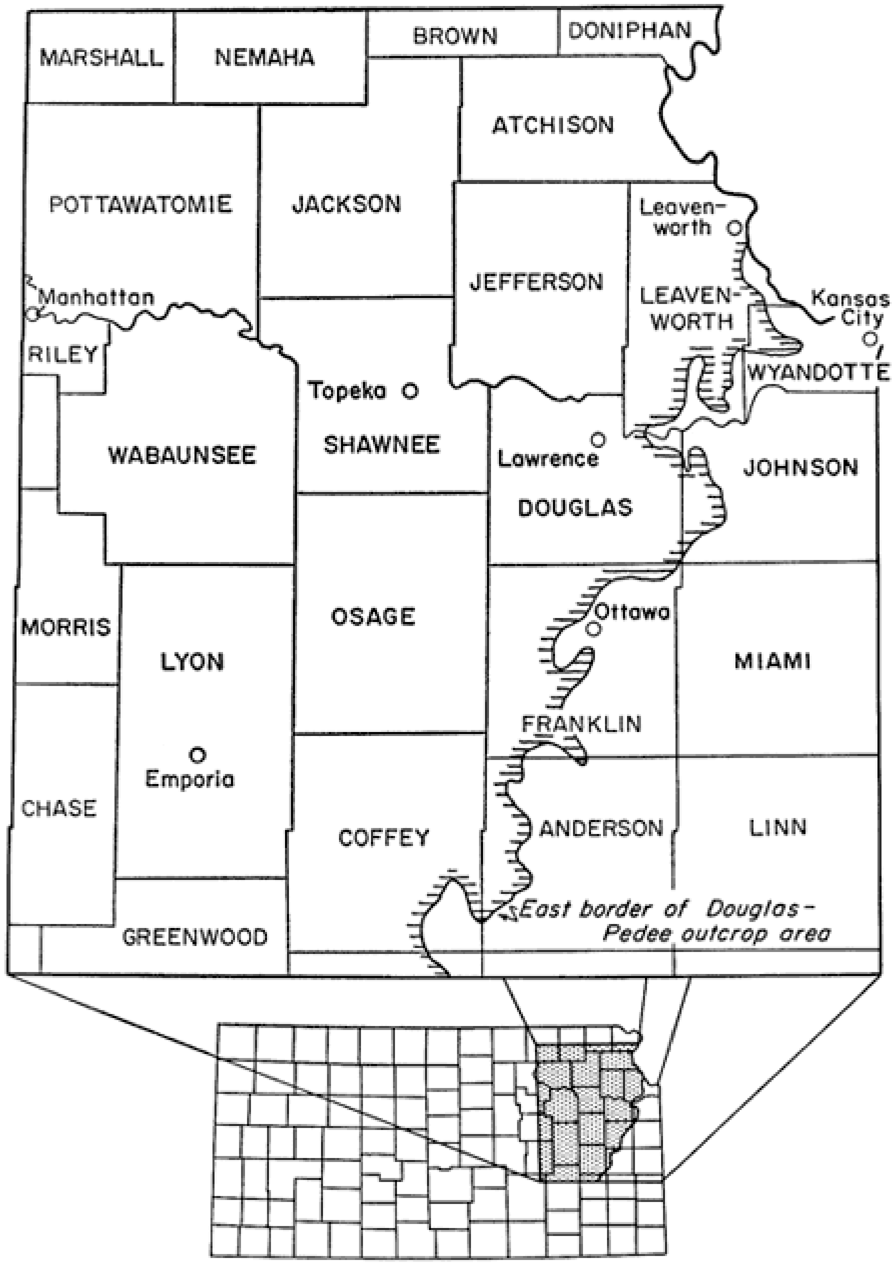
Although very few sandy zones were found in the Pedee Group, and none of these was continuous over much of the area, the Douglas and Pedee Groups were studied as a unit because of the difficulties encountered in attempting to separate them in the subsurface. In much of the area studied, their contact is one of shale upon shale, virtually impossible to recognize on well logs. Thus the only reliable stratigraphic horizons everywhere usable as upper and lower limits of the sequence studied are the base of the Oread Limestone (which overlies the Douglas Group) and the top of the Stanton Limestone (which underlies the Pedee Group).

Original plans included an investigation of only the Ireland Sandstone member of the Lawrence Formation, with the objective of mapping its distribution and thickness in northeastern Kansas and interpreting its origin and depositional environment. It soon became obvious, however, that available subsurface data were quite inadequate for such a detailed study, and that any conclusions concerning origin and environment of deposition would have little validity. It was decided, therefore, to change emphasis to a more generalized investigation of all sandstones in the Douglas and Pedee Groups.

Extent of Area

The area discussed in this report includes approximately 9,000 square miles in northeastern Kansas (Fig. 1). The northern boundary is the north side of T. 4 S., the western boundary is the west side of R. 8 E., and the southern boundary is the south side of T. 23 S. The eastern boundary is delineated by the Kansas-Missouri state line approximately as far south as the city of Leavenworth, Kansas, and by the eastern border of the Douglas-Pedee outcrop area from Leavenworth to T. 23 S., R. 16 E.

Figure 1--Index map showing location of area discussed in this report.



Methods of Study

During October and November of 1956, selected sections of rocks in the Douglas and Pedee Groups were measured and samples of Ireland and Tonganoxie sandstone were taken for laboratory analysis. Locations from which samples were obtained, although few, were chosen in an attempt to obtain representative specimens with regard to both lateral variation and stratigraphic position. The samples selected for analysis were divided into two parts, one for permeability tests and the other for size analysis and microscopic examination.

Subsurface data were obtained by the examination of logs of somewhat more than 1,000 oil wells and water wells in the area studied. All logs used are in the files of the State Geological Survey of Kansas. Where drilling has been relatively intense, as in northern Greenwood County, many logs were eliminated, and only those believed to be reliable were used. In areas of little drilling activity, where too much selectivity would have led to almost complete lack of control, only the obviously poor logs were omitted. Well samples were studied as an aid to interpretation of logs from some of the more problematical areas.

Electric logs or, to a lesser degree, radioactivity logs, were judged to be most reliable and were used wherever available. Logs of the Kansas Sample Log Service, plotted on the basis of sample analysis, were used where possible in preference to drillers logs, which were relied upon only where more dependable types were not accessible.

Previous Work

Literature on the Pennsylvanian rocks of Kansas is extensive; many of the sandstones in the Pennsylvanian and Permian sections have been studied (Bass, 1934, 1936; Cadman, 1927; Charles, 1927; Cheney, 1929; Mudge, 1956; Pierce and Courtier, 1935; Rich, 1923, 1926; Rubey and Bass, 1925; Tarr, 1934). Environmental significance of the sandstones, in Kansas and elsewhere, and their relation to cyclical deposition, have been discussed by Moore (1929, 1931, 1950), Reger (1931), Stout (1931), Wanless (1931), Wanless and Shepard (1936), Weller (1930, 1931), and others.

Patterson (1933) described the Douglas Group as it crops out in Douglas and Leavenworth counties, Kansas. Rich (1933), after studying coal fragments found in the base of the Ireland Sandstone in northwestern Franklin County, estimated that a time span of "some millions of years" is represented by the pre-Ireland disconformity. Bowsher and Jewett (1943), in describing coal resources of the Douglas Group in northeastern Kansas, discussed stratigraphic relations of the coal beds. Lins (1950), from a study of outcrops in northeastern Kansas, concluded that the Tonganoxie Sandstone was deposited in the valley of a large southwestward-flowing river.

Strata of the Douglas and Pedee Groups have been described in several publications of the State Geological Survey of Kansas and other organizations, but until now no attempt has been made to map their regional distribution and thickness in this part of the state.

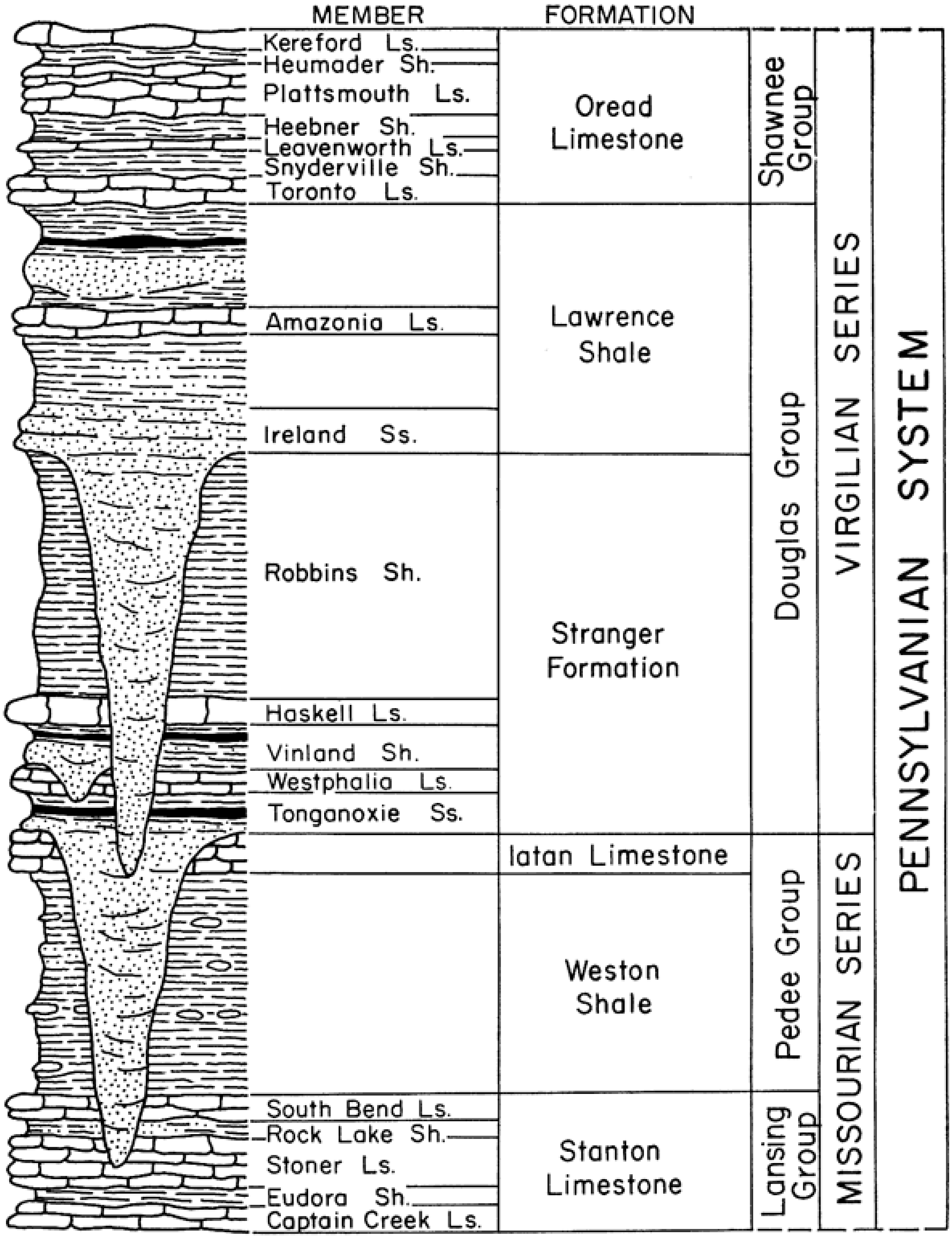
Acknowledgments

I wish to express my thanks to Dr. H. A. Ireland of the Department of Geology, University of Kansas, who supervised this study and made many helpful suggestions and criticisms. Mr. Wallace Lee gave advice on interpretation of well logs and preparation of the structure contour map. Mr. Floyd W. Preston and Mr. Kevin R. Jones, of the Department of Petroleum Engineering, University of Kansas, made available the equipment in the petroleum engineering laboratory. Part of the drafting was done by Miss Marilyn Eaton. Mr. George DeVries Klein made sieve and pipette analyses of a sample of Ireland Sandstone.

Stratigraphy

Rocks belonging to the Pedee and Douglas Groups (Fig. 2) are late Missourian and early Virgilian in age, respectively, the boundary between the two series being placed at the unconformity below the basal sandstone (Tonganoxie) of the Douglas Group (Moore, 1932, p, 88). The following description of these strata, presented in ascending order, is taken mostly from Moore (1949) and Moore and others (1951). Minor modifications applicable to the area studied, as observed in well logs and at the outcrop, have been added. Included in the description, for reference, are the Stanton and Oread Limestones, which respectively underlie and overlie the Douglas-Pedee sequence.

Figure 2--Generalized stratigraphic section (adapted from Moore and others, 1951).



Missourian Series

Lansing Group

Stanton Limestone

The Stanton Limestone, which directly underlies Douglas-Pedee strata, contains three limestone and two shale members. The upper member, South Bend Limestone, is easily distinguishable on electric well logs and serves as a good subsurface marker bed. On most drillers logs the whole formation is denoted as limestone, making its top readily apparent. Although the formation ranges in thickness from 10 to 90 feet throughout its area of outcrop, it was found to be consistently about 50 feet thick in the area of this investigation.

Captain Creek Limestone member--The Captain Creek Limestone is massive or even-bedded, granular to dense, and dark gray to bluish gray. Common fossils are the brachiopod *Enteletes pugnoides* and the fusulinid *Triticites neglectus*. The member is characteristically about 5 feet thick along Kansas River, and in the area studied, as indicated on electric logs, thickness of the member ranges from 5 feet to 15 feet in the south. Acording to Lins (1950, p. 112), the pre-Tonganoxie erosion surface in places cuts down as low as the Captain Creek Limestone, but this relationship was not observed during the present study. The oldest unit seen to be directly overlain by the Tonganoxie Sandstone in the subsurface is the Stoner Limestone member of the Stanton Limestone (Fig. 2).

Eudora Shale member--The Eudora Shale is dark gray to black and fissile in the lower part, clayey and greenish to bluish gray in the upper part. It contains few megascopic fossils in this part of Kansas. In the subsurface this member was found to maintain a thickness of 5 to 10 feet.

Stoner Limestone member--The Stoner Limestone is composed of thin, wavy beds mostly separated by thin shale partings. It is fine grained and light bluish gray to nearly white. Fossils are not common generally, but in northern exposures *Triticites* are abundant. Typically this is the thickest member of the Stanton Limestone, ranging from about 20 to 30 feet throughout the area of study. Tonganoxie Sandstone (Fig. 2) rests on the Stoner Limestone where pre-Tonganoxie erosion in this area has cut most deeply into older strata.

Rock Lake Shale member--The Rock Lake Shale is mostly reddish to yellowish brown, but greenish-gray clay shale is common in the lower part. The upper part tends to be sandy, and locally is represented by massive sandstone. Both marine and non-marine fossils are present. Thickness of the Rock Lake Shale ranges from 5 to 15 feet throughout the area, increasing somewhat in places where the sandstone occurs. In areas of deep pre-Tonganoxie erosion this member may be absent.

South Bend Limestone member--The top of the South Bend Limestone represents the lower limit of the Douglas-Pedee stratigraphic sequence (Fig. 2). The South Bend member is composed of dark-gray fine-grained limestone, but contains sandy limestone and, locally, sandy shale at the base. Common fossils include fusulinids and the brachiopod *Meekella*. The thickness is consistently about 5 feet, although in parts of the area where pre-Tonganoxie erosion was comparatively deep the limestone has been partly or completely removed. In such places the base of the Tonganoxie Sandstone serves as the lower boundary of the Douglas-Pedee sequence, although where this occurs the entire Pedee Group has been removed by the same erosion.

Pedee Group

The Pedee Group, comprising the Weston Shale and Iatan Limestone, is the lower of the two groups with which this report is concerned. Over much of the area studied it was partly or wholly removed during the time of emergence and erosion that preceded deposition of the lower sandstone member (Tonganoxie) of the overlying Douglas Group. Where present, the Pedee Group conformably overlies the Stanton Limestone and, as shown by its relation to the Tonganoxie Sandstone, disconformably underlies rocks of the Douglas Group (Fig. 2). Its thickness has a large range, owing to this same disconformity. Maximum thickness is almost indeterminate in the subsurface, even where the basal sandstone of the Douglas Group is absent, because the upper formation (Iatan Limestone) of the Pedee Group either was not deposited in much of the area or does not show up clearly on well logs. Those logs showing a limestone that is probably the Iatan indicate an average thickness of approximately 60 feet for the group in this area. Moore and others (1951, p. 78) give 90 feet as the average thickness in outcrops, and Moore (1949, p. 120) also states that exposures of as much as 200 feet have been observed in southern Kansas.

Weston Shale

Weston Shale is the name given the lower and thicker formation of the Pedee Group. It is mostly dark-blue to bluish-gray clay shale, and locally contains thin fossiliferous limestone beds. Also present, especially toward the south, are some beds of shaly and even-bedded sandstone. Some well logs examined indicate a sandstone body, in most places not more than 20 feet thick, near the base of the formation, but no definite pattern of occurrence is discernible. Limonitic concretions are characteristic of the Weston Shale in many outcrops, and marine fossils have been found in places. Where the formation has not been subjected to post-Pedee erosion it may attain a thickness of nearly 200 feet, but the greatest thickness noted with certainty in the subsurface is approximately 45 feet.

Iatan Limestone

The Iatan Limestone, at the top of the Pedee Group, seems to be discontinuous over much of the area included in this investigation. In many places where it probably is present, it has not been definitely indicated on well logs. Where the Iatan is absent the Weston Shale is disconformably overlain by sandstone or shale of the lower Douglas Group. The Iatan Limestone is light bluish gray to white, and very fine grained to dense. It has a massive appearance, owing to indistinctness of bedding planes. Although not abundantly fossiliferous, the formation locally contains fusulinids, brachiopods, bryozoans, crinoid fragments, and small corals. Where the Iatan Limestone is present its thickness ranges from about 4 to 22 feet.

Virgilian Series

Douglas Group

The Douglas Group, upper of the two groups that are the subject of this report, disconformably overlies rocks of the Pedee Group. It is conformably overlain by the Oread Limestone of the Shawnee Group, except possibly in southern Douglas County (Moore and others, 1951, p. 69). The disconformity at the base of the Douglas Group forms the Missourian-Virgilian boundary in Kansas as defined by Moore (1932, p. 88). Rocks of this group are mostly shale and sandstone, but relatively minor beds of limestone, coal, and conglomerate are included.

Total thickness of the Douglas Group has considerable range and is determined over most of the area by the depth to which post-Pedee erosion has cut into older strata (Fig. 2). Where the basal Tonganoxie Sandstone member was not deposited, determination of thickness of the Douglas Group in the subsurface is extremely difficult. On the basis of what reliable information is available from subsurface data, its average thickness in this area is probably about 180 feet. Maximum thickness, where the most extensive deposits of Tonganoxie Sandstone occur, is about 340 feet. Moore (1949, p. 127) states that "the thickness of the group ranges from about 50 feet in southeastern Nebraska to nearly 700 feet in southern Kansas." The combined thickness of the Douglas and Pedee Groups in the area investigated was seen to increase more or less regularly from about 100 feet in southeastern Marshall County to about 340 feet in southern Coffey County and northwestern Franklin County, indicating a general thickening of the clastic deposits of these groups toward the southeast.

The Douglas Group includes the Stranger Formation below and the Lawrence Shale above.

Stranger Formation

The Stranger Formation comprises one sandstone member, two shales members, and two comparatively thin limestone members. The middle member (Vinland Shale) is generally sandy and locally grades into a massive sandstone of appreciable thickness, which lies disconformably on older rocks. The base of the Stranger Formation is marked by the disconformity below the Tonganoxie Sandstone member. The top of the formation, too, is defined by a disconformity, this one produced by post-Stranger erosion after which a sandstone (Ireland) similar in character to the Tonganoxie Sandstone was widely deposited (Fig. 2). Because in much of the area these disconformities cut deeply into underlying strata, though not necessarily in the same localities, the thickness of the Stranger Formation differs greatly from place to place. Where the post-Stranger erosion is not deep and where pre-Stranger erosion has allowed Tonganoxie Sandstone to occupy the stratigraphic position of older rocks, the thickness of the Stranger Formation may exceed 200 feet. Because the presence of Ireland Sandstone is necessary for recognition of the top of the Stranger Formation on well logs, and because the Ireland Sandstone was deposited on the eroded surface of Stranger beds, the actual maximum thickness of the Stranger Formation in the subsurface can only be estimated. The Stranger Formation is absent in the few areas where post-Stranger erosion has cut into strata of the underlying Pedee Group, as in southeastern Douglas County.

Tonganoxie Sandstone member--The Tonganoxie constitutes most of the sandstone below the Haskell Limestone in the Douglas-Pedee deposits (Plate 2), and its lithologic characteristics will be discussed in detail in a later section of this report. Generally, this member is made up of massive crossbedded sandstone or (less typically) thin-bedded shaley sandstone, and sandy to clayey shale; it includes several thin and discontinuous coal beds in the upper part. The sandstone is fine grained and light brown or tan at the outcrop and light gray in well samples; the shale (Lins, 1950, p. 124) is either silty and light brown to reddish brown, or clayey and light bluish gray to dark blue. The two most persistent coal beds have been named Upper and Lower Sibley. In some outcrops the basal portion of the member is made up of a conglomerate composed mostly of small limestone pebbles, quartz sand, silt, and limonite or clay cement. Plant remains are present in the sandstone and conglomerate.

In northeastern Kansas thickness of the Tonganoxie, where post-Stranger erosion has not cut into the member, may attain 160 feet, depending on relief of the pre-Tonganoxie erosion surface upon which the sandstone was deposited.

Westphalia Limestone member--The Westphalia, although not definitely recognized north of T. 19 S. (Moore and others, 1951, p. 73), has been tentatively identified farther north by Lins (1950, p. 115) as "a carbonaceous laminated dark blue limestone," which occurs 3 to 4 inches above the Upper Sibley coal. In southern exposures it is characterized by the presence of fusulinids. Like the Iatan Limestone of the Pedee Group, it can be identified on very few well logs, and is assumed to be discontinuous over most of the region studied. Maximum thickness of the limestone recognized by Lins is only 1 foot and the member has been completely removed in areas where post-Stranger erosion was most extensive.

Vinland Shale member--The Vinland is gray, clayey, calcareous, and sandy, and locally grades into massive light-brown to tan sandstone of considerable thickness. In areas where this sandstone attains maximum development, the base of the member is marked by a slight disconformity. Marine fossils are abundant in most outcrops, a characteristic zone near the top containing many remains of clams (*Myalina*). Thickness of the Vinland Shale, where it has not been removed by post-Stranger erosion as in southeastern Douglas County and northwestern Franklin County, is probably as much as 50 feet in this area. An exact figure is difficult to establish from subsurface data because of the discontinuous nature of the underlying Westphalia Limestone.

Haskell Limestone member--The Haskell is bluish gray and fine grained and is a single massive bed in most outcrops. Fossils include algae, fusulinids, and brachiopods. Where not removed by post-Stranger erosion, the member attains a thickness of 10 feet. It is extremely persistent throughout northeastern Kansas and is easily recognizable on most well logs. It occurs approximately in the middle of the Douglas-Pedee sequence and between the two major sandstone bodies (Fig. 2). For these reasons it was chosen as the dividing marker between the groups of sandstones mapped on Plates 1 and 2.

Robbins Shale member--The Robbins Shale, which conformably overlies the Haskell Limestone and disconformably underlies the Lawrence Shale, is gray to yellowish gray and in many places includes a zone of phosphatic concretions near the base. Many of these concretions contain ammonoid cephalopods and casts of fish brains. Because of the disconformity above this member, it is absent where the erosion has cut into older strata, but is as much as 100 feet thick in southern Kansas. The thickness of the Robbins Shale in the subsurface is difficult to determine where the overlying sandstone is not present, because the contact then becomes one of shale upon shale.

Lawrence Shale

The Lawrence Shale is the uppermost formation included in the present study. It is composed predominantly of blue-gray and yellowish shale and tan to light-brown fine-grained sandstone, but contains comparatively thin limestone and coal beds in some areas. A basal conglomerate can be seen in some outcrops. The Ireland Sandstone member is widespread and grades upward from sandstone at the base of the formation into thin-bedded shaly sandstone or sandy shale. Above this in parts of northeastern Kansas, although most readily recognizable farther south, is the Amazonia Limestone member. The Amazonia Limestone or equivalent zone is overlain by a sequence of tan to greenish-gray clayey or sandy shale, which in some localities grades laterally into massive, fine-grained, tan to light-brown sandstone. Locally this shale-sandstone sequence becomes fairly thick and may, as indicated on logs of wells in parts of southern Pottawatomie County, extend from the base of the Oread Formation to a horizon well below the zone of the Amazonia Limestone. Also present in the upper part of the Lawrence Shale in most outcrops are thin coal beds (chiefly the Upper and Lower Williamsburg coals) and a characteristic layer of maroon clay shale.

Thickness of the Lawrence Shale, like that of the Stranger Formation, is dependent upon the downward extent of erosion responsible for the disconformity at its base. The greatest thickness observed during the study is approximately 170 feet. Where the Ireland Sandstone member is missing or very thin, the Lawrence Shale may have a thickness of only 40 feet. The exact position of its base is indeterminable on well logs that do not show Ireland Sandstone and also in places where the Ireland members rests on Tonganoxie Sandstone; hence in may parts of the area an accurate determination of its thickness is impossible.

Ireland Sandstone member--Inasmuch as the Ireland Sandstone is the most important sand body of the Douglas Group occurring above the Haskell Limestone (Plate 1), its lithologic characteristics are discussed in detail in a later section of this report. Only general features are presented here. The member rests disconformably on various strata of the Stranger Formation or, locally, where post-Stranger erosion was deepest, as in southeastern Douglas County and northwestern Franklin County, it is in contact with rocks of the Pedee Group (Fig. 2). The Ireland and Tonganoxie sandstones look identical in outcrops and in most places can be distinguished only by stratigraphic position. Like the Tonganoxie Sandstone, the Ireland is composed of fine-grained light-brown or tan massive sandstone, mostly crossbedded, which grades both vertically and laterally into thin-bedded silty or shaly sandstone. In places a limy conglomerate occurs at the base. Plant remains have been found in the thin-bedded material, and the basal conglomerate may contain coal fragments. Thickness of the Ireland Sandstone is as much as 160 feet in parts of the area investigated. Owing to the indistinct nature of the upper part of the member and the disconformity at its base, an exact figure is difficult to detemine.

Amazonia Limestone member--The Amazonia Limestone, which lies 25 to 30 feet below the Oread Limestone, is typically light gray, hard, and dense. Like the Iatan and Westphalia Limestones previously described, it is discontinuous in northeastern Kansas and shows up poorly on well logs. Where recognized in this part of the state, it is, in most exposures, a coquinoidal, fragmental bed of reddish brown tinge. It is not normally fossiliferous, but several kinds of marine fossils have been found locally. The Amazonia member is as much as 13 feet thick in outcrops, gradually thinning to a featheredge in southern Kansas. Where recognizable on well logs its average thickness is somewhat less than 10 feet.

Shawnee Group

Oread Limestone

The base of the Oread Limestone marks the upper limit of the Douglas Group (Fig. 2). The formation contains four limestone and three shale members. Its lowest member, the Toronto Limestone, although not present locally, can be recognized easily on most electric logs and serves as a good subsurface datum. The formation is recorded on almost all drillers logs and can be correlated easily. Its thickness ranges from 45 feet in the type area at Lawrence, Kansas, to about 100 feet in southern Kansas, the increase being due mainly to southward thickening of the Snyderville Shale member. In the area studied, the Oread Limestone ranges in thickness from about 40 feet in the north to about 80 feet in the south.

Toronto Limestone member--The Toronto Limestone is massive and brownish gray, weathering to a characteristic deep brown. Common fossils are fusulinids, corals, and small brachiopods. In the outcrop area it is locally absent in southern Douglas County and elsewhere and is indistinct in part of southern Kansas. In the subsurface, too, it seemingly is missing in small parts of the area investigated, though in general it has wide continuity. Thickness of the Toronto in northern Kansas ranges from 8 to 12 feet, and in the area studied it averages about 10 feet.

Snyderville Shale member--In northern Kansas the Snyderville is mostly structureless gray to bluish-gray clay, but there is some red shale. In southern Kansas the member is sandy and in places contains sandstone and impure limestone. Marine fossils, especially the brachiopod *Chonetes*, are found in the unit. Its thickness increases greatly toward the south, from an average of 12 feet in the north to about 75 feet in southern Kansas. In the area studied it was found to range from about 5 to 20 feet. In places where the Toronto is absent, Snyderville Shale will be found in contact with Lawrence Shale.

Leavenworth Limestone member--The Leavenworth Limestone occurs as a dark bluish-gray, dense, massive bed having a uniform thickness between 1 and 2 feet. It commonly contains fusulinids and brachiopods. Owing to its relative thinness, it is not easily recognizable on many electric well logs, and is indicated on only an occasional drillers log.

Heebner Shale member--The Heebner, although mostly black platy shale, also includes calcareous clay and dark bluish-gray shale near the top and some gray or yellow clay shale at the bottom. Small brachiopods are found near the top, and the black shale contains conodonts. Abundant gastropods can be found locally in the basal yellow shale. Thickness of the Heebner Shale is consistently 5 to 7 feet. It forms an excellent subsurface datum because the black shale is easily recognized in samples and makes a distinctive "kick" on electric logs and especially on radioactivity logs.

Plattsmouth Limestone member--The Plattsmouth member is composed of light-bluish-gray, dense, wavy-bedded limestone. Common fossils are fusulinids, corals, bryozoans, brachiopods, and some mollusks. Chert nodules are characteristic of the member in northern outcrops. In most places it is the thickest member of the Oread Limestone, averaging approximately 20 feet thick in northeastern Kansas, but thinning southward.

Heumader Shale member--The Heumader Shale is mostly dark gray but in places is bluish or greenish gray. It is clayey to silty, becoming sandy in southern Kansas. Marine fossils, especially mollusks, are common. Its thickness is generally less than 5 feet.

Kereford Limestone member--The Kereford Limestone is widespread in northeastern Kansas but is not recognized in the southern part of the state. Its lithology is not everywhere the same, in places being oölitic or fine grained and flaggy and elsewhere massive and dense. Locally it is shaly. Its color is generally dark bluish gray. Fossils include algae, fusulinids, other marine invertebrates, and locally, remains of land plants. Where present it may be as much as 40 feet thick. The member is not definitely discernible on many well logs, seeming to merge into the Plattsmouth Limestone because of the thinness of the intervening Heumader Shale member.

Sandstones of the Douglas and Pedee Groups

Results of Laboratory Studies

Data on texture, composition, and permeability of the Ireland and Tonganoxie Sandstones were obtained from seven outcrop samples and one well sample. Although not enough samples were analyzed to warrant definite conclusions, it was felt that useful information could be derived from results of this preliminary laboratory work. Size analyses were made by the standard methods outlined in Krumbein and Pettijohn (1938) and Twenhofel and Tyler (1941). Composition was determined by examination of disaggregated samples under the binocular microscope. Permeability was measured by means of a variable-head discharging water permeameter (Fishel, in Wenzel, 1942, p. 59-63) and, for comparison of results, an air permeameter.

The localities from which samples of Ireland Sandstone were obtained for analysis are plotted on Plate 1, and the location numbers there correspond to the sample numbers used in Figure 3. Similarly, localities from which samples of Tonganoxie Sandstone were obtained are indicated on Plate 2, location numbers corresponding to sample numbers in Figure 4. Table 1 shows exact position of these localities, listed by section, township, and range.

Table 1--Location of sample-collection localities.

Sample number	Location	County
1	SW SW NE sec. 33, T. 8 S., R. 22 E.	Leavenworth

2	Cen NL NE sec. 36, T. 10 S., R. 22 E.	Leavenworth
3	SE NE NE sec. 14, T. 13 S., R. 20 E.	Douglas
4	SW SW sec. 27, T. 13 S., R. 19 E.	Douglas
5	Cen EL NW sec. 3, T. 15 S., R. 19 E.	Douglas
6	SE SE NW sec. 11, T. 17 S., R. 18 E.	Franklin
7	SW NE SW sec. 14, T. 17 S., R. 19 E.	Franklin

Texture and Composition

In general aspect the Ireland and Tonganoxie sandstones are similar, and in outcrops, except possibly for minor local differences, they seem to be identical. Both are predominantly fine to very fine, and they have essentially the same composition. The few analyses made for this report show some differences in physical characteristics that may be significant, but detailed study of many samples will be necessary to establish their validity for correlation.

The predominant size grade of particles of Ireland and Tonganoxie sandstone varies, as would be expected, according to where the samples were obtained in relation to maximum amount of sand deposition. Samples of thin-bedded or shaly sandstone from channel borders are mostly very fine sand or silt, whereas those taken from massive, crossbedded exposures within the deeper channel trends contain a large percentage of fine or even medium sand (Fig. 3, 4; Table 2).

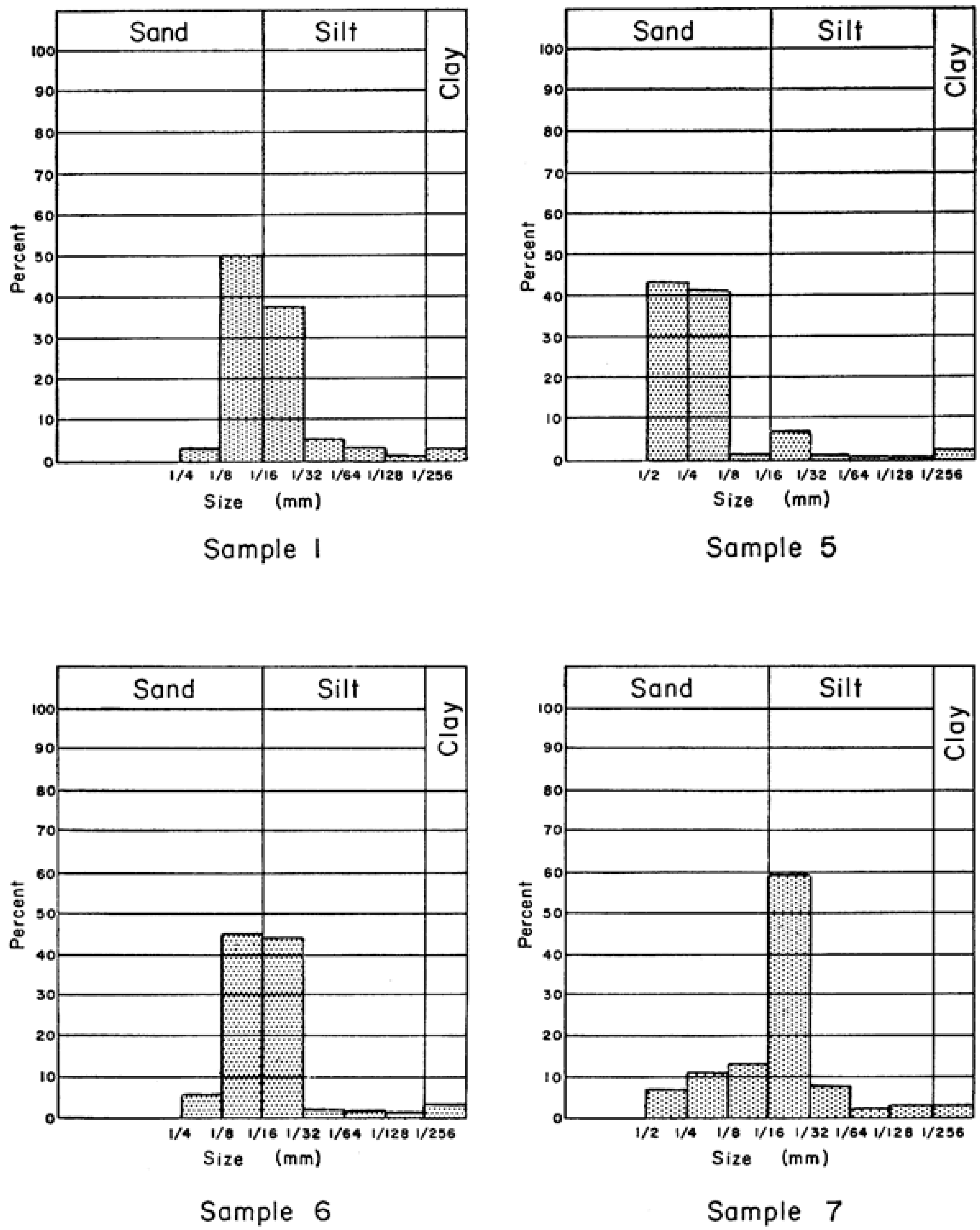
Table 2--Wentworth's size classification (after Krumbein and Sloss, 1951, p. 71).

Grain diameter (mm)	Size grade
4-2	Granule
2-1	Very coarse sand
1-1/2	Coarse sand
1/2-1/4	Medium sand
1/4-1/8	Fine sand
1/8-1/16	Very fine sand
1/16-1/32	Coarse silt
1/32-1/64	Medium silt
1/64-1/128	Fine silt
1/128-1/256	Very fine silt
Less than 1/256	Clay

In Figure 3 it is seen that 50 percent of Sample 1, from northern Leavenworth County where the lower part of the Lawrence Shale is composed of thin-bedded, shaly sandstone, falls within the 1/8 to 1/16 mm grade (very fine sand) and that most of the remainder is coarse silt. On the other hand Sample 5, from an exposure of massive channel sandstone in southern Douglas County, is much coarser, being made up almost entirely of medium and fine sand. Sample 6, from an outcrop of massive channel sandstone in western Franklin County, is in contrast to Sample 5. The histogram of Sample 6 shows a size distribution much like that of Sample 1, and would seem to indicate that Sample 6 represents a lens of very fine sand

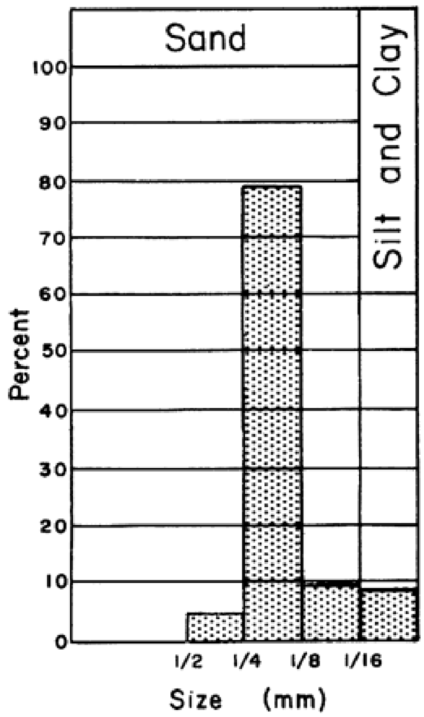
and coarse silt within the main channel deposit. Sample 7, which is predominantly silt, came from very thinly laminated and even-bedded sandstone at an exposure on U. S. Highway 50 about 1 mile south of Ottawa, Franklin County.

Figure 3--Histograms showing size analyses of samples of Ireland Sandstone.

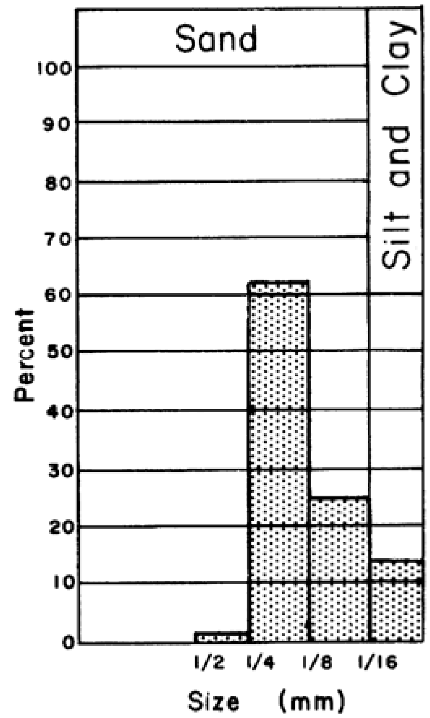


Samples 2A and 2B, histograms of which are shown in Figure 4, were obtained from an outcrop in sec. 36, T. 10 S., R. 22 E., in eastern Leavenworth County (Plate 2). Lins (1950, p. 129), in discussing this outcrop, has suggested the presence here of both Ireland and Tonganoxie sandstones separated by a pebble conglomerate, which cuts across the exposure. Sample 2A was collected from a point 4 feet above this conglomerate, and Sample 2B from a point 2.5 feet below it. The presence of both sandstones in this locality is improbable, however, for Plate 1 shows that little or no Ireland Sandstone is present in the subsurface of western Leavenworth County, and no major Ireland channel is trending toward the area where Samples 2A and 2B were collected. On the other hand, this locality is well within the projected trend of main Tonganoxie deposition, which is discussed below. Further, the histogram of Sample 2A (which, if Lins were correct, would be Ireland Sandstone) is similar to other histograms of Tonganoxie Sandstone in Figure 4 and is dissimilar to histograms of Ireland Sandstone in Figure 3.

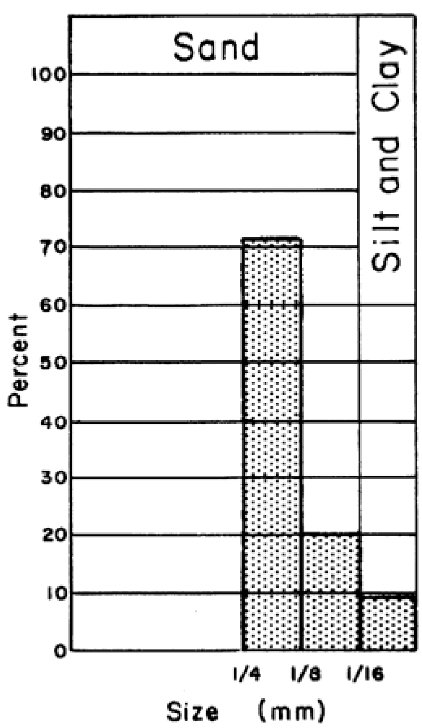
Figure 4--Histograms showing size analyses of samples of Tonganoxie Sandstone.



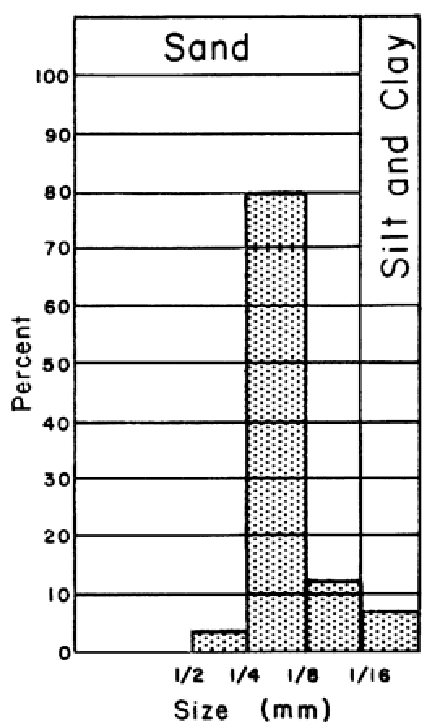
Sample 2A



Sample 2B



Sample 3



Sample 4

Sample 3 was collected from an exposure of massive Tonganoxie channel sandstone, which can be seen along Wakarusa River in sec. 14, T. 13 S., R. 20 E., Douglas County. It contains virtually no sand grains greater than 1/4 mm in diameter, although the 1/4 to 1/8 mm grade (fine sand) constitutes more than 70 percent of the sample. Sample 4 is a well sample from sec. 27, T. 13 S., R. 19 E., also within the main channel trend, and has a size distribution almost identical to that of Sample 2A. Both of these samples are extremely well sorted, having almost 80 percent of total volume in the 1/4 to 1/8 mm size range.

In comparing Figures 3 and 4 it is seen that with the exception of Sample 7, analyses of Ireland Sandstone indicate that it is less well sorted than Tonganoxie Sandstone. All four samples of Tonganoxie Sandstone contain much more fine sand (1/4 to 1/8 mm) than other size grades, and all contain comparatively little silt and clay. Their average silt and clay content is only about 9 percent, too little to warrant pipette analysis after sieving, whereas all samples of Ireland Sandstone contain a large percentage of particles in this category. All samples of Tonganoxie Sandstone were obtained from massive, crossbedded layers within main channel trends, whereas two Ireland samples came from thin-bedded or shaly rock.

All samples analyzed were found to have essentially the same overall composition. It is estimated that subangular to angular quartz grains account for 90 to 95 percent of the volume of all size grades of each sample. Some rounded and frosted grains were observed in the larger sizes (greater than 1/4 mm in diameter). The remaining 5 to 10 percent is predominantly thin flakes of muscovite, but includes a few irregular crystals of tourmaline and, rarely, amorphous chlorite grains. The only significant variation observed, both from sample to sample and between size grades of the same sample, is in relative quantity of muscovite. In contrast to Ireland Sandstone specimens, in which most muscovite is 1/4 to 1/8 mm in diameter, the greatest distribution of this mineral in Tonganoxie Sandstone seems to be in the 1/8 to 1/16 mm range. This cannot be regarded as a definite conclusion, however, for only four samples of each member were analyzed, and in Sample 2B (Tonganoxie) the greatest precentage of muscovite was found in the 1/2 to 1/4 mm grade. It was noted that more muscovite is present in samples of thin-bedded, silty sandstone than in samples of massive, crossbedded sandstone from main channel areas. This corroborates an observation made by Lins (1950, p. 121), with regard to Tonganoxie Sandstone, that "as the proportion of larger size sand grains increases, the amount of muscovite decreases; and, conversely, as the proportion of larger size sand grains decreases, the amount of muscovite increases."

Cement is predominantly clay or limonite in outcrops, where it coats the quartz grains and imparts a brownish color to the rock. Subsurface samples, however, are light gray to ahnost white and they react readily with hydrochloric acid, showing the presence of calcium carbonate cement. Ireland Sandstone in surface exposures may contain slightly more iron, as stated by Lins (1950, p. 129), which would account for its somewhat darker color in some outcrops. This difference is not recognized everywhere, however, and can be used only locally.

Permeability

Table 3 gives the coefficient of permeability in meinzer units of four samples each of Ireland and Tonganoxie sandstone that were collected from the same outcrops as the samples discussed in the preceding section. Results with the air permeameter were obtained by measuring the time required for a known quantity of air, at known pressure, to pass through a small core of sandstone. Two cores were cut from each sample, one parallel to the bedding and one perpendicular. Results with the variable-head water permeameter were obtained by measuring the time required for a given quantity of water to drain through a cylinder filled with disaggregated sand.

Table 3--Coefficients of permeability (meinzer units) of samples of Ireland and Tonganoxie Sandstone.

Sandstone member	Sample number	Air method		Water method
		Parallel to bedding	Perpendicular to bedding	
Ireland	1	*	*	24
	5	65	53	73
	6	120	107	132
	7	3	*	*
Tonganoxie	2A	103	53	149
	2B	54	29	57
	3	147	58	47
	4	*	*	31
*No sample, or sample unsuitable for testing.				

Even though tests with the water permeameter and air permeameter were made with disturbed and undisturbed samples, respectively, the results correspond closely. Note that values obtained with disturbed samples in the water permeameter are in most cases similar to those obtained in the air permeameter from cores cut parallel to stratification. As would be expected, cores cut parallel to the bedding are more permeable than those cut perpendicular to the bedding.

The coefficient of permeability, like predominant size grade, seems to depend upon where samples were obtained with respect to main channel deposition. Samples 1 and 7, both very silty and thin bedded and collected from localities marginal to main depositional trends, have extremely low coefficients of permeability. In comparison, Samples 5 and 6 (Ireland Sandstone) and 2A, 2B, and 3 (Tonganoxie Sandstone), all composed of massive, crossbedded sandstone from main channels, are much more permeable. Sample 4 seems anomalous in this respect, in that it was obtained from a well that penetrates the main Tonganoxie channel. No cores were available for analysis with the air permeameter, however, and it is possible that false readings were obtained with the water permeameter.

The values given in Table 3 are the same order of magnitude as coefficients of permeability obtained by means of pumping tests of wells that get water from Douglas sandstones in northeastern Kansas. Such tests have given results ranging from 50 to 300 meinzer units (H. G. O'Connor, personal communication). Although these values are low compared to many aquifers (e.g., Pleistocene gravels in this area may have permeability coefficients of 6,000 or more), the sands yield adequate supplies for domestic, stock, or small town wells.

Thickness and Distribution

Sandstone is not everywhere present in the Douglas and Pedee Groups. Plates 1 and 2 show that the sand bodies occur in several broad trends of diverse orientation and there is little or no sand in large areas between these trends, which are judged to be ancient river channels filled with sand before deposition of overlying strata. Knowledge of the location and thickness of these channel deposits is, of course, of utmost importance in any a.ttempt to use the Douglas-Pedee sandstones as sources of ground water.

It should be emphasized that areas of sand shown on Plates 1 and 2 do not necessarily represent, in any given locality, the existence of a single sand body. Because of the nature of the sandstones themselves, which may grade either laterally or vertically into shale, and the inadequacy of subsurface data for detailed correlation, only net sand thickness was mapped. For example, an isolith (i.e., equal lithology) value of 50 feet on the map may theoretically indicate the presence of one 50-foot sandstone bed, five 10-foot beds, or any other combination resulting in an aggregate sand thickness of 50 feet, the thickness of any intervening strata of different lithology being ignored. In practice, however, the isolith values shown on Plates 1 and 2 are controlled chiefly by the presence or absence of Ireland or Tonganoxie Sandstone, respectively, so that at least one major sandstone unit can be expected wherever a thickness of more than 20 feet is indicated on the maps. (For details of the contruction of isolith maps, see Low, in LeRoy, 1950, p. 941-951.)

Sandstones Above Haskell Limestone

Two main sandstones have been recognized in the Douglas Group above the Haskell Limestone. The most important of these, with regard to both thickness and areal extent, is the Ireland Sandstone member of the Lawrence Shale. The other is an unnamed sandstone that occurs locally above the Amazonia Limestone member. Aggregate thickness and distribution of these sandstones, along with other sand lenses above the Haskell Limestone, are shown on Plate 1. Ireland Sandstone deposition is assumed to account for at least the trends of greatest sand thickness as indicated on the map. Supporting this assumption is the observation that in northwestern Franklin County, where isolith values are especially large, Ireland Sandstone is very thick and massive in outcrops (Laughlin, 1957, p. 17, Fig. 6A, and Pl. 1).

Plate 1 shows that sandstones above the Haskell Limestone occur in two main trends, or channels, and in subsidiary channels in several places. The deepest channel (i.e., the trend of greatest sandstone deposition) follows an irregular, predominantly westward course across the center of the area. The maximum thickness is shown to be slightly more than 100 feet throughout its length, although in areas where control is poor, as in eastern Wabaunsee County, it may be either more or less. Extrapolation of the 100-foot isolith line through these areas is felt to be justified, however, because in both western Wabaunsee County and southeastern Osage County, wells have penetrated 100 feet or more of sandstone, and they are located in such a way as to indicate continuation of the trend through the intervening area. Further, on each side of this extrapolated channel, well logs indicate a definite thickening of sand deposits toward the area outlined by the 100-foot isolith line.

The other main channel is formed by the union of two smaller ones in northern Jackson County and extreme southeastern Nemaha County. This trend then continues southwestward across Jackson County into Wabaunsee County, where it joins the deeper channel. This second channel is neither as wide nor as deep as the first one, although a well in T. 8 S., R. 14 E., penetrated 90 feet of sandstone.

In southern Douglas County and northwestern Franklin County the existence of a very thick sandstone section is indicated by subsurface data and confirmed by surface exposures. The relation of this deposit to the main channel, which seemingly is farther south, is obscured by the fact that Douglas-Pedee strata crop out in the vicinity and have been removed everywhere to the east. Seemingly this deposit represents a tributary channel that enters the area from northeast or east of Douglas County and joins the main channel in Franklin County. The log of one well that penetrates this trend in sec. 2, T. 16 S., R. 17 E., records 160 feet of Ireland Sandstone, the thickest section in the area of study. The erosion that produced this exceptionally deep channel is believed to have removed a considerable thickness of previously deposited Tonganoxie Sandstone. Reasons for this conclusion are presented below in discussing major trends of Tonganoxie deposition.

The southwestern part of the area is characterized by many small channels of slight depth and width. The largest of these is formed by the joining of two trends in central Lyon County, whence they extend northeastward and meet the main channel in western Osage County.

Plate 1 shows the location of several wells the logs of which indicate a thickness of sandstone much greater than that in adjacent areas. Examples include a well near the boundary between Jefferson and Leavenworth counties, where most well logs record no sandstone above the Haskell Limestone, and one in sec. 31, T. 20 S., R. 10 E., where the electric log indicates more than 100 feet of sandstone in a locality of generally thin sandstone deposition. Each of these anomalous logs was re-examined and found to present no reason for rejection. Accordingly the data were plotted as recorded and isolith lines were drawn to fit as nearly as possible into areal trends. It seems reasonable to conclude that at least most of these features are the result of local scouring and filling, and are too small to have been penetrated by more than one or two wells.

Sandstones Below Haskell Limestone

As has been explained earlier, almost all sandstone below the Haskell Limestone is restricted to the lower part of the Douglas Group, only a few well logs indicating the presence of thin sand bodies in the underlying Pedee Group. The Tonganoxie member of the Stranger Formation is the most important of two main sandstones recognized in this part of the section, and it is assumed te control at least the thicker trends shown on Plate 2. The other sandstone is locally present in the Vinland Shale member of the Stranger Formation. Plate 2 shows the distribution and net thickness of these sandstones, along with the minor lenses that occur in places in the Pedee Group.

On Plate 2 it can be seen that the main trend of sandstone deposition extends southwestward from Douglas County to Greenwood County, roughly parallel to the outcrop of Douglas-Pedee strata. The greatest thickness of sandstone is in western Coffey County, where a well in sec. 18, T. 21 S., R. 14 E., penetrated 160 feet of sandstone. Several other logs, mostly from wells in Greenwood County and southeastern Lyon County, indicate sand thickness in excess of 140 feet. In Douglas and Franklin counties, too, where thick deposits of Tonganoxie Sandstone are known in surface exposures, subsurface data show more than 120 feet of sandstone in places. This trend seems to be the southwestward subsurface continuation of the "Tonganoxie Valley" recognized by Lins (1950, p. 117, 131, Fig. 1) from studies of exposures of Tonganoxie Sandstone in northeastern Kansas. Its width, which on the basis of subsurface data ranges from 12 to 20 miles, is comparable to the 14 to 20 miles postulated by Lins.

In northwestern Franklin County and east-central Osage County, transecting the main Tonganoxie channel described above, is an area where subsurface data are interpreted as indicating that no Tonganoxie Sandstone exists. Comparison of Plates 1 and 2 shows that in this same area an exceptional thickness of Ireland Sandstone was deposited. Thus it may be inferred that pre-Ireland erosion, while cutting the channel in which Ireland Sandstone was later deposited, removed Tonganoxie Sandstone that previously had been laid down in this locality.

The other major trend of sandstone deposition shown on Plate 2, joining the main Tonganoxie Valley in southeastern Lyon County, is seemingly a coalescence of several minor channels, and in places it attains considerable net thickness. In the extreme north-central part of the area a thickness of at least 80 feet of sandstone is indicated by well logs, although here precise mapping is impossible because of poor control. Wells that have penetrated 100 feet of sandstone are present within each of two subparallel channels in northwestern Wabaunsee County, although here, unlike the main Tonganoxie channel described above, sandstone does not occur as a single massive bed.

On Plate 2, as on Plate 1, are shown a few isolated occurrences of sandstone in areas where logs from nearby wells indicate no sand deposition. Examples are found in T. 9 S., R. 19 E., and in T. 20 S., R. 15 E. These features, like those represented on Plate 1, are interpreted as local scour-and-fill deposits.

Structure and Depth from Surface

Rocks of the Douglas and Pedee Groups dip gently to the northwest at an average rate of about 20 feet per mile over most of the area studied. Figure 5 shows that along the outcrop the altitude of the top of the Douglas Group ranges from 900 to 1,100 feet and that in the subsurface, where Douglas-Pedee strata are overlain by younger deposits, it decreases more or less uniformly toward the northwest. The Nemaha Anticline, which is "a major post-Mississippian element that crosses Kansas from Nemaha County to Sumner County and extends into Nebraska and Oklahoma" (Jewett, 1951, p. 146), interrupts this trend in the northwestern part of the area. Here the top of the Douglas Group rises in a short distance from an altitude of about 100 feet above sea-level to well over 600 feet, and then resumes a gentle westward dip. This anticlinal trend, which has a northeast-southwest direction, leaves the area in northern Morris County. In southern Morris County and northern Chase County the top of the Douglas Group is slightly below sea level, its minimum elevation within the area. The small westward-trending anticline in T. 19 S., R. 8 E., is probably an eastward extension of the Elmdale Dome, which is farther west in central Chase County.

Figure 5--Structure map of northeastern Kansas contoured on top of Douglas Group.

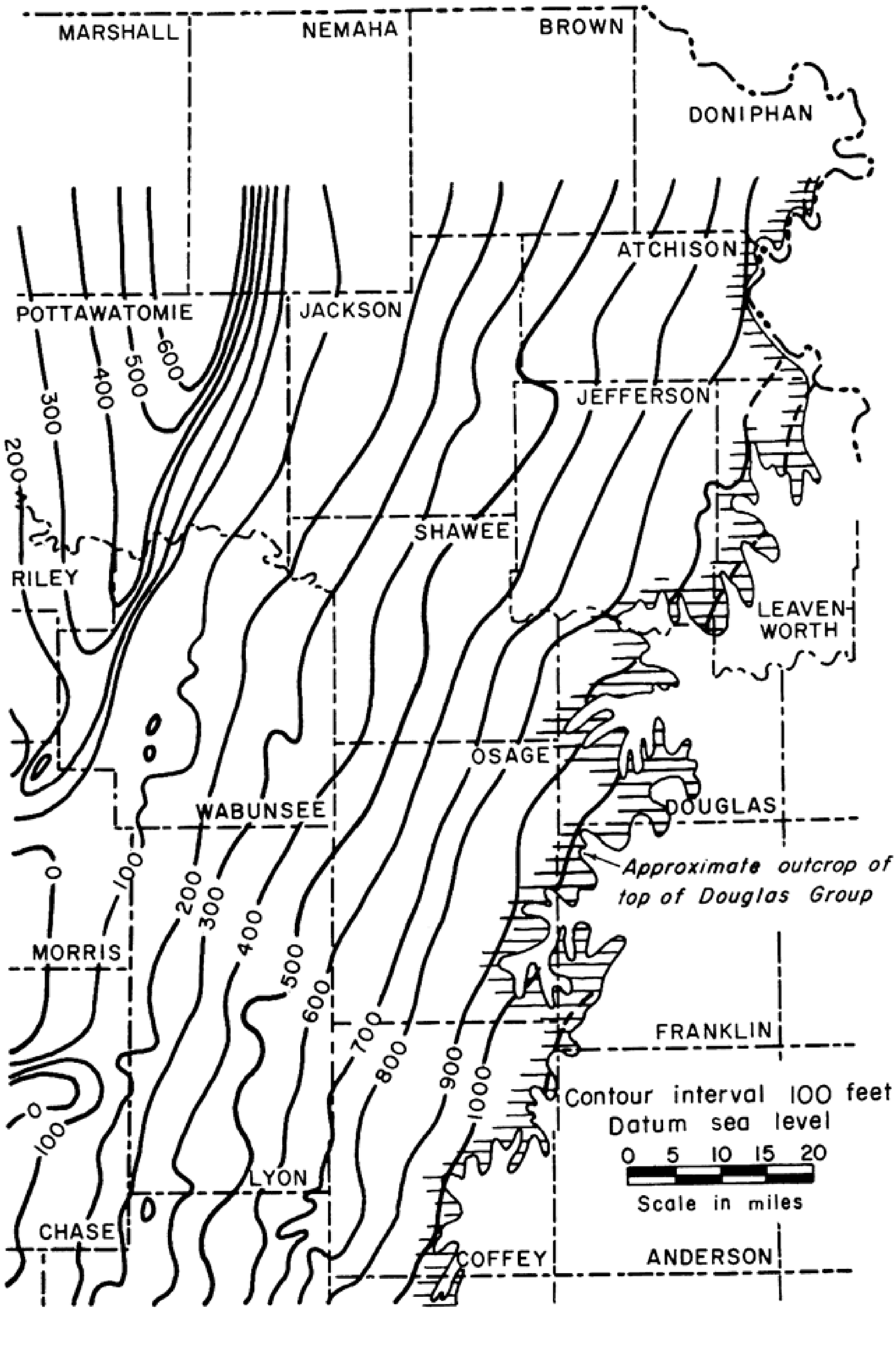

MARSHALL
NEMAHA
BROWN
DONIPHAN
ATCHISON
POTTAWATOMIE
JACKSON
JEFFERSON
SHAWEE
RILEY
LEAVEN-
WORTH
OSAGE
WABUNSEE
DOUGLAS
Approximate outcrop of
top of Douglas Group
MORRIS
FRANKLIN
Contour interval 100 feet
Datum sea level
0 5 10 15 20
Scale in miles
LYON
CHASE
COFFEY
ANDERSON
200
300
400
500
600
0
100
200
300
400
500
600
700
800
900
1000
0
100

Figure 5 is included in the present report mainly to offer a means of determining approximate depth from ground level to the sandstones of the Douglas and Pedee Groups. The top of the Douglas Group was judged to be the best datum upon which to draw structure contours for this purpose, and its depth below the surface can be determined in any given locality simply by algebraically subtracting the elevation of this datum from ground elevation. Approximate depth of the Douglas Group increases to 1,400 feet in the southwest corner of the area west of the outcrop belt. Within the structural trough east of the Nemaha Anticline the depth to the Douglas Group ranges from an average of rerhaps 1,100 feet in the north to about 1,300 feet in Morris County.

Origin

Much has been written about the origin of Pennsylvanian sandstones in Kansas and neighboring states. The basal member of the ideal cyclothem in this region is composed of subaerially deposited sandstone, which lies disconformably upon older strata (Weller, 1930, p. 102; Moore, 1950, p. 6). Evidence presented by the cyclic repetition of lithologic types over wide areas in central United States indicates that the land surface during time of deposition was flat enough that slight relative changes in sea level could cause extremely widespread submergence or emergence (Moore, 1950, p. 16). It was during these periods of emergence that most of the Pennsylvanian sandstones were deposited on eroded, though low-lying, land surfaces. Not all Pennsylvanian sandstones are continental, of course, but marine sandstones are relatively few and probably represent near-shore deposits that "accumulated contemporaneously with aggradation of the alluvial plain" (Weller, 1931, p. 172).

With the possible exception of the local sandy phase of the Vinland Shale, all sandstone in the Douglas and Pedee Groups is almost certainly of continental origin. The plant remains that are found in outcrops suggest this, and shape of the sand bodies in long, branching, and relatively narrow trends as shown on Plates 1 and 2, the crossbedding, and the disconformable relation to older strata seen in surface exposures all indicate deposition by stream channel filling. In most places the massive, crossbedded sandstone occurs in areas where the underlying disconformity cuts most deeply into older rocks, or, in other words, in areas of main channel deposition. The thin-bedded, fine-grained sandstone presumably was deposited along channel margins in calm water. Possibly the cause of deposition was lessening of velocity of the streams near the mouth because of a steadily rising base level during enroachment by Pennsylvanian seas.

Recent work by Winchell (1957) in the subsurface of southern Kansas has disclosed, in the Sedgwick Basin, marine sandstone (Stalnaker) equivalent to the Tonganoxie. Extending southward into this basin from the area included in the present report are several small channels filled with Tonganoxie Sandstone. These channels are interpreted as the southward continuation of the Tonganoxie Valley, and probably represent a distributary system developed by basinward drainage.

Present uses of Water from Douglas Sandstones

Water obtained from sandstones of the Douglas Group is used extensively in northeastern Kansas for both municipal and domestic supplies. In the outcrop area and for a considerable distance down dip (west), the Ireland and Tonganoxie sandstones are important aquifers. Water from both of these sources is generally of good quality near the outcrop, but commonly becomes harder and brackish farther west with increasing depth to a point where it is unsuitable for drinking (H. G. O'Connor, personal communication).

Several small municipalities in Leavenworth, Douglas, Franklin, Osage, and Coffey counties obtain all, or nearly all, of their water supplies from these sandstones. The water systems of Wellsville, Baldwin, and Waverly are supplied entirely from Ireland Sandstone, and Quenemo gets water partly from Ireland Sandstone and partly from Pleistocene gravels. Tonganoxie Sandstone provides water for the towns of

Overbrook and Tonganoxie. Pomona, in northwestern Franklin County where Ireland and Tonganoxie sandstones are in contact, may obtain water from both sources.

Summary and Conclusions

Sandstones of the Douglas and Pedee Groups occur in definite channel-like trends, which are interpreted as alluvium-filled river valleys. Mapped as two aggregate units according to their stratigraphic position above or below the Haskell Limestone, the distribution of these deposits shows at least two distinct drainage patterns controlled chiefly by the streams that deposited the Ireland and Tonganoxie Sandstones.

Above the Haskell Limestone, where the Ireland member of the Lawrence Shale is the dominant sand body, the sandstones occur in two major trends. The most important of these, an ancient river valley probably more than 100 feet deep, follows an irregular westward course across the central part of the area. Tributary to this is a second channel, in places as much as 90 feet deep, which extends southward from Nemaha and Brown counties to merge with the main channel in Wabaunsee County. Other deposits, locally attaining considerable thickness, are present in the southwestern part of the area.

Two major trends are evident also in the deposition of sandstone below the Haskell Limestone. Here the Tonganoxie Sandstone is dominant, having been deposited in a southwest-trending valley that in places is more than 140 feet deep. This valley is prominent in the eastern part of the area, roughly parallel to the outcrop of Douglas-Pedee strata, and seemingly is continuous with the "Tonganoxie Valley" mapped by Lins (1950). The other major trend of sandstone deposition joins this Tonganoxie Valley in southeastern Lyon County and has been traced southward from Nemaha County.

All sandstones of the Douglas and Pedee Groups have similar physical characteristics, but a few laboratory analyses indicate that there may be some minor differences between the Ireland and Tonganoxie Sandstones. All samples from the Tonganoxie are better sorted than samples from the Ireland, and all are predominantly fine sand. The Ireland samples studied, on the other hand, have diverse predominant size grades ranging from medium sand to coarse silt. Two Ireland sample localities are outside of major channel trends, however, whereas all samples of Tonganoxie Sandstone were collected from main channel deposits.

Composition of all sandstones studied is essentially the same. Subangular to angular quartz grains make up about 90 to 95 percent of the volume of all samples analyzed, the remainder being composed mostly of thin flakes of muscovite, some tourmaline, and rare chlorite grains. Relative quantity of muscovite seems to be greater in silty, thin-bedded sandstone from channel borders than in massive, crossbedded sandstone from main channels.

Although the coefficient of permeability of Douglas-Pedee sandstones is low, main channel deposits averaging between 100 and 200 meinzers, these sandstones are the principal aquifers in parts of northeastern Kansas for both domestic and municipal water supply. Knowledge of where they have considerable thickness in the subsurface should aid in locating additional supplies of ground water and possibly in selecting reservoirs for underground storage of surplus water during periods of ample surface supply.

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