

CASE STUDY NUMBER 11

ERICSON, NEBRASKA
FLAT GRADE SEWERS

WWBLC11

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History

Ericson, Nebraska is a community of about 75 homes and 130 people. In the early 1960's, the failure of septic tank and leaching field systems because of a high ground water table led to the flow of sewage in roadside ditches. Engineering reports were made in 1963 and 1968. A conventional gravity sewer system including a lift station was designed to correct this problem, but bids were rejected because of the high cost of dewatering. A flat grade sewer system without either dewatering or a lift station was designed in 1973 and constructed in 1974. The system saved both capital and operating and maintenance costs compared to the conventional gravity sewer design. Since initial installation, five new homes have been connected to the system. The sewer system also serves several commercial establishments and a school.

Flat Grade Sewers

In flat terrain, sewers designed by conventional standards lead to deep excavations and the frequent use of lift stations, because minimum required sewer slopes are greater than the ground surface slope. Both effects incur excessive costs. Many small communities in Nebraska have sewer systems with flatter slopes than conventional standards would allow, and also use 6 inch laterals rather than the conventional minimum of 8 inches. These systems are therefore significantly less costly than they would have been if designed by conventional standards. In the 70 to 80 years of experience with flat grade sewers in Nebraska, they have been observed to perform well and have not required noticeably more maintenance (flushing or rodding) than conventional sewers. They have also avoided the operation and maintenance of many lift stations. This reduces O&M costs significantly.

A brief examination of sewer hydraulics will give some theoretical corroboration to the observed success of flat grade sewers in Nebraska. Conventional gravity sewers are designed to have a velocity greater than 2 fps when full (or half full). This velocity is thought to be necessary to prevent the accumulation of sewage solids. Given the diameter of the pipe, a minimum slope to achieve 2 fps can be calculated using various formulas, one of the more popular of which is Manning's formula. For example, 8 inch pipes are customarily required to have a minimum slope of 0.4%. At this slope, assuming a roughness coefficient $n = 0.013$, the 8 inch pipe carries 0.77 cfs when full. Assuming a sewage flow of 50 gallons per person per day, 3 persons per dwelling unit, and a peaking factor of 4, the 8 inch pipe can serve up to 825 dwelling units, neglecting infiltration. In conventional gravity sewer systems, 8 inches is the minimum diameter in order to avoid clogging, and so many of the 8 inch laterals are far from full at peak flow. Therefore, for sewers serving small numbers of houses, the minimum slope requirement does not result in a velocity of 2 fps. For small service areas, then, the use of smaller pipes at flatter slopes ought to be considered. Table 1 illustrates the consequences. Notice that for fifty dwelling units, 6 inch pipe produces slightly higher actual velocity than 8 inch pipe at every slope shown even though the nominal (full) velocity is always greater in the 8 inch pipe. Therefore, for small service areas, 6 inch pipe should perform as well as or better than 8 inch pipe. Since most house connections are 6 inches in diameter or less, objects that pass through the house connections will also pass through the 6 inch laterals, and so clogging should not be a problem in 6 inch laterals. Secondly, for a given diameter, a decrease in slope produces a smaller decrease in actual velocity than in nominal (full) velocity. Therefore the real consequences of decreasing the

slope of a partially full sewer are not as severe as would be predicted by changes in full velocity.

State Regulations

The regulations of the Nebraska Department of Environmental Control formally recognize the propriety of using flat grade sewers in small communities of flat terrain. Small communities are allowed to use 6 inch pipes in the upper reaches of the system if they have stable or declining populations. Larger or growing communities must use a minimum size of 8 inches. Conventional minimum slopes, for which full velocity would be not less than 2 fps, are ordinarily imposed. But the regulations explicitly allow flatter slopes if two conditions are met. First, the property owner or municipality must supply a letter to the Department stating that he has been informed that flat grades are being used and that this may lead to increased maintenance. Secondly, the design engineer must explain why flat grade sewers were selected and describe and evaluate other alternatives. The engineers who have much experience with flat grade sewers have found that they do not in fact require increased maintenance, although conventional wisdom on sewer design says that they should.

The relatively flexible position on sewer design taken by the Nebraska Department of Environmental Control was developed by Mr Ted Filipi, who was director of the Department from 1937-1972. His philosophy was that engineering judgement should control the design of sewers rather than strict adherence to conventional standards. While current regulations tend towards conventional standards, they still allow flat grade sewers, and flat grade sewer systems continue to be built in Nebraska, since the largest unsewered communities in the state have populations of about 400 people or less.

System Design

The flat grade sewer system in Ericson, Nebraska serves about 80 homes, 130 people, and several commercial establishments and a school. Both 6 and 8 inch pipes were used at slopes varying from 0.11 to 0.2 ft/100 ft (%). The 8 inch PVC outfall was laid at a slope of 0.15%. No lift station was required. Test borings were made throughout the village to establish the level of the groundwater table. The sewers were designed at water table level; some lines required fill to prevent freezing. The system layout is shown in Figure 1.

Sewage Treatment

The sewage treatment plant is a two-cell total retention lagoon. One cell has an area of 0.69 acres and the other 1.39 acres; their depth is 4.5 feet. The lagoon is designed for an average flow of 9,400 gpd and a maximum flow of 11,000 gpd. In 1983, a wet year, discharge from the lagoon was required; this was accomplished by spray irrigation on small plots.

Operation and Maintenance

The system has not required any unusual maintenance and has performed well.

Construction Cost and Funding

The system was constructed in 1974 for about \$107,000, including engineering and legal fees and land acquisition. Table 2 shows a breakdown of the costs. Table 3 shows the sources and amounts of funding for the project. The loan must be paid back over a period of 40 years, and the Village of Ericson was also required to obtain public liability and property damage insurance. A minimum monthly user rate of \$3.50 was set.

Principals

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2. City Council Chairman

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3. Construction Contractor

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4. EPA Construction Grant Officer

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5. Nebraska Department of Environmental Control

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References

Design and Construction of Sanitary and Storm Sewers, WPCF Manual Practice No. 9, Water Pollution Control Federal, Washington, DC, 1970.

Design Guidelines: Sanitary Sewers, State of Nebraska, Department of Environmental Control, Engineering Division, 1974.

Table 1. Comparison of 6 and 8 inch Pipe at Various Slopes

Basis: Dwelling Units (DU)	50
Average Flow	50 gpcd
Average Occupancy	3 persons/DU
Peaking Factor	4
Infiltration/Inflow	0
Resulting Peak Flow	0.0464 cfs
Manning's n	0.013

Slope (ft/100 ft)	Capacity of Sewer (cfs)		Velocity When Full (fps)		Actual Velocity* (fps)		% Change in Full Vel. +		% Change in Actual Vel. +	
	6 in	8 in	6 in	8 in	6 in	8 in	6 in	8 in	6 in	8 in
	0.1	0.18	0.38	0.91	1.10	0.64	0.63	-55	-50	-44
0.2	0.25	0.54	1.28	1.55	0.81	0.79	-37	-30	-30	-23
0.3	0.31	0.66	1.57	1.90	0.96	0.93	-23	-14	-17	-10
0.4	0.36	0.77	1.81	2.20	1.05	1.03	-11	0	-9	0
0.5	0.40	0.86	2.03	2.45	1.15	1.13	0	11	0	10

* At peak flow, assuming that n varies with depth.

+ from standard minimum slope: 6 inch 0.5%
 8 inch 0.4%

Table 2: Construction Costs (1974)

ITEM	TOTAL COST
Construction	\$92,389.02
Engineering	10,026.95
Surveying	199.10
Land	758.00
Legal Fees	525.00
Bond Counsel	150.00
Bond Election	186.92
Advertising	119.78
Initial Funding of O&M Account	300.00
Interest during Construction	2,600.23
TOTAL	\$107,255.00

Table 3: Funding

SOURCE	AMOUNT
USEPA Grant	\$24,261
State of Nebraska Grant	4,044
Farmers Home Administration Grant	12,500
Farmers Home Administration Loan	50,000
Village Contribution	16,450
TOTAL	\$107,255

[**Note:** the text refers to Figure 1 but no figure appears in the original report.]