Detroit Water and Sewerage Department

Wastewater Master Plan

DWSD Project No. CS-1314

Evaluation of Collection System Design Standards

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Evaluation of Collection System Design Standards

1. Introduction

Various design standards are used in the design of sewer systems and related wastewater facilities. This memo reviews the design standards as used by City of Detroit and the surrounding suburban communities in southeast Michigan. These standards are compared to standards and approaches as recommended by the Ten States Standards and by the American Society of Civil Engineers.

2. Southeast Michigan Practice

2.1 Historical System Design Standards

In 1958, the Supervisors Inter-County Committee, a committee that represented the Six-County Metropolitan Area of Southeastern Michigan, requested the National Sanitation Foundation (NSF) to conduct a study dealing with sewerage and drainage problems in the area. The study resulted in two reports that were released in 1964. These reports reviewed the regional system as it existed at that time and provided standards to guide future design.

The report titled "Sewerage and Drainage Problems and Administrative Affairs" provides a partial history of the design criteria used in the various systems within the City of Detroit and by the suburban communities served by the Detroit Water and Sewerage Department (DWSD) collection system. For instance, the Detroit River Interceptor (DRI) was sized to provide 0.5 cfs / 1000 people or a maximum per capita flow of 324 gpcd. The DRI was placed in operation in 1938, and it was designed to serve a combined sewer system.

Information regarding the various existing sewer collection systems is summarized in Table 1. This table reflects conditions and projected flows as understood in 1964 and is provided to help understand the historical basis of the systems that exists today.

After review of the various existing systems tributary to the DWSD treatment plant (in 1964), the report summarizes that in general, the existing systems provide 0.4 cfs / 1000 people (259 gpcd) for separate sewer systems and 0.5 cfs / 1000 people (324 gpcd) for combined systems. The rate of 0.4 cfs / 1000 people for suburban communities with separate systems has been institutionalized in many of the Wastewater Service Agreements made between the communities and DWSD. The major exceptions to this generalization are the communities along Lake St. Clair. As indicated in the table, these communities have a much higher design capacity, on the order of 10 times as high (4.0 cfs, for example).

These higher design capacities were set in part to minimize storm / combined flow into Lake St. Clair and to avoid adversely affecting the raw water intake by Detroit at Belle Isle in the Detroit River. The extra precaution in protecting Lake St. Clair is reflected in the Basis of Design, which is discussed next**.**

Table 1. Design Criteria for Existing Systems in 1964

City, Community or District	Sewer System Type	Design Criteria	Population	Design Capacity	
				cfs	gpcd
Wayne County:					
Rouge Valley	Combined/Sanitary	0.45 cfs/1000	720,350	324	291
Northeast Wayne District	Combined/Sanitary	0.50 cfs/1000	255,000	127.5	323
Grosse Pointe Shores	Combined	4.0 cfs/1000	5,000	20	2585
Oakland County:					
Evergreen-Farmington	Combined/Sanitary	0.44 cfs/1000	398,693	176	285
Southeast Oakland	Combined/Sanitary	0.41 cfs/1000	681,300	278	264
Clinton-Oakland	Sanitary	No Information			
Grosse Pointe Farms	Combined/Sanitary	4.0 cfs/1000	20,000	80	2585
Grosse Pointe Park	Combined/Sanitary	4.65 cfs/1000	180,000	84	3016
Detroit	Combined	0.50 cfs/1000	4,000,000	2000	324

*****Source: 1964 National Sanitation Foundation Report

In consideration of the existing system and present and future area requirements, the report committee developed a Basis of Design for the six-county area, summarized below as follows:

A. All new systems should be designed as separate systems. A chart depicting minimum sewer size and slope is provided for populations less than 20, 000 (see Figure 5-1 in report; a partial reconstruction of this figure is provided in Figure 1 below). For populations of 20,000 and larger the sewers and interceptors should provide a minimum of 0.4 cfs / 1000 people.

B. Existing combined systems should be intercepted at rates not less than 0.5 cfs / 1000 people, unless operating records indicate lesser amounts would be satisfactory. Future interceptors for combined areas discharging to Lake St. Clair should provide intercepting rates of not less than 1.0 cfs / 1000 people.

C. Stormwater overflow from combined sewers should be held to a minimum through the use of storage. In general, storage facilities should be designed to contain the runoff from a one-year frequency storm, with consideration given to studies of existing systems to determine the practicability of providing such storage.

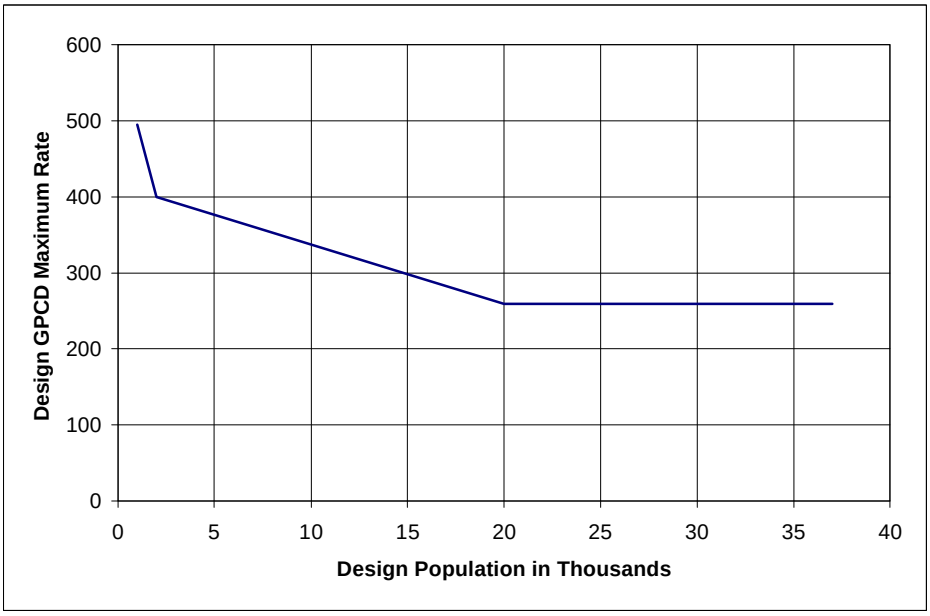


Figure 1. Separate Sanitary Sewer Design Chart (from NSF report)

As can be seen from Figure 1, the design capacity on a unit basis decreases as the population increases. This approach reflects that as the size of the tributary area and the related collection system increases (assumed with increase in population), the difference in peak flow to average flow will decrease due to attenuation of the peak flow within the collection system.

2.2 Recent System Improvements Design Standards

In 1972, the U.S. government passed the Clean Water Act in response to increasing environmental concerns. In the 1970s and 1980s, the emphasis of complying with the act was on construction grant programs that built additional interceptors and upgraded wastewater treatment plants.

The 1990s saw the enactment of additional initiatives to address sanitary sewer overflows, storm water quality, and combined sewer overflows. These initiatives are addressed by the state of Michigan through the NPDES permitting program.

In planning and designing of various system improvements and facilities required to comply with various regulations or to meet additional capacity needs, extensive evaluations of the various local and regional sewer systems were conducted. These evaluations often included development of models and the use of design storm events for predicting peak flows. Typically a design event on the order of a 10-year, 1-hour event was used in these evaluations, likely due to that return interval being commonly used in design of storm sewers.
The size of the peak flows calculated from this size design event will vary relative to the 0.4 cfs / 1000 people standard; however, for some communities, it is thought that the peak flows will be about double the rate calculated using 0.4 cfs / 1000 people criteria.

The next two sections review other design standards used in design of sewer systems. As will be seen, these design standards also reflect a reduction of the design capacity on a unit basis with increases in population.

3. Ten States Standards

The Recommended Ten States Standards for Wastewater Facilities is a guide for the design and preparation of plans and specifications for wastewater collection systems and treatment facilities. This guide was prepared by a group now known as the Great Lakes-Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers (1997 edition). The committee originally consisted of representatives from ten midwestern states (including Michigan); hence the guide is commonly referred to as the Ten State Standards. Currently the board also includes the Province of Ontario. The manual is intended to establish as far as practical, uniformity of practice among these states and the province.

The manual states that the sewer capacity should be designed for the estimated ultimate tributary population, unless considering parts of the system that can be readily increased in capacity. Consideration should be given to the maximum anticipated capacity of institutions, industrial parks, etc. as well. In determining the required capacities of sanitary sewers the following factors should be considered:

A. Maximum hourly domestic sewage flow;
B. Additional maximum sewage or waste flow from industrial plants;
C. Inflow and groundwater infiltration;
D. Topography of the area;
E. Location of sewage treatment plant;
F. Depth of excavation; and
G. Pumping requirements.

In determining the required hydraulic capacity of sewers, the following flows are defined for use in these recommended design standards:

A. Design Average Flow: the design average flow is the average of the daily volumes to be received for a continuous 12-month period. However, the design average flow for the facilities having critical seasonal high hydraulic loading periods shall be based on the daily average flow during the seasonal period.

B. Design Maximum Day Flow: The design maximum day flow is the largest volume of flow to be received during a continuous 24-hour period.

C. Design Peak Hourly Flow: the design peak hourly flow is the largest volume of flow to be received during a one-hour period.

D. Design Peak Instantaneous Flow: The design peak instantaneous flow is the instantaneous maximum flow rate to be received.

For existing collection systems, the design standards recommends making projections of anticipated flows from actual flow data to the extent possible. The results are to include the probable degree of accuracy of the data used. In addition, consideration is to be given to flow reduction anticipated due to infiltration / inflow reduction or flow increases due to elimination of sewer bypasses and backups.

For new systems, a design flow is recommended to be based on an average daily flow of 100 gallons per capita plus wastewater flow from industrial plants and major institutional and commercial facilities unless other justification on which to better estimate flow is provided. The rate of 100 gallons per capita per day (gpcd) is to be used with a peaking factor to determine a peak hourly flow rate to be used for design. The peaking factor varies according to population according to the following formula (Equation 1) and as illustrated in Figure 2. The peak factor is intended to include infiltration for systems built with modern construction techniques; however, an additional allowance is recommended where conditions are unfavorable.

$$\frac{\textit{Peak Hourly Flow}}{\textit{Design Average Flow}} = \frac{18+\sqrt{P}}{4+\sqrt{P}} \quad \cdots \quad (P = \textit{population in thousands}) \qquad (1)$$

As can be seen, the peaking factor decreases with increasing population. This reflects that as the size of the tributary area and the related collection system increases, the difference in peak flow to average flow will decrease due to attenuation of the peak flow.

4. ASCE Engineering Practice

A joint committee of the American Society of Civil Engineers (ASCE) and the Water Pollution Control Federation (WPCF) prepared a book titled *Design and Construction of Sanitary and Storm Sewers*. This book is jointly published by ASCE as Manual and Reports on Engineering Practice No. 37 and by WPCF as Manual of Practice No. 9. The book is intended to be a compilation of current practices in this field and to be used as an aid, but it is not intended to be a standard for design.

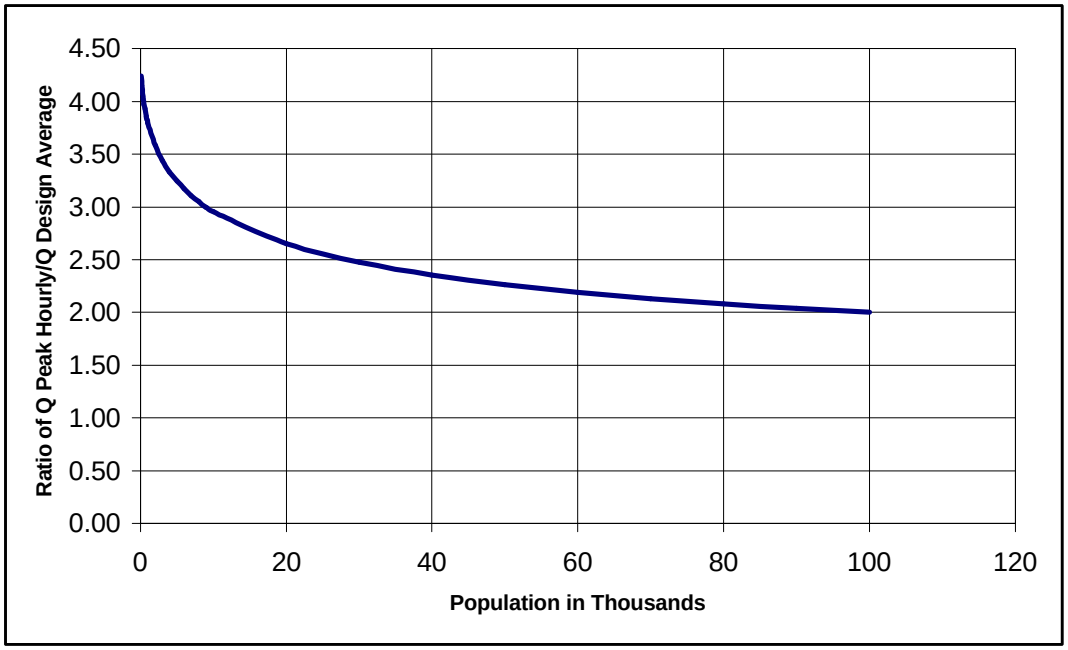


Figure 2. Ratio of Peak Hourly Flow to Design Average Flow

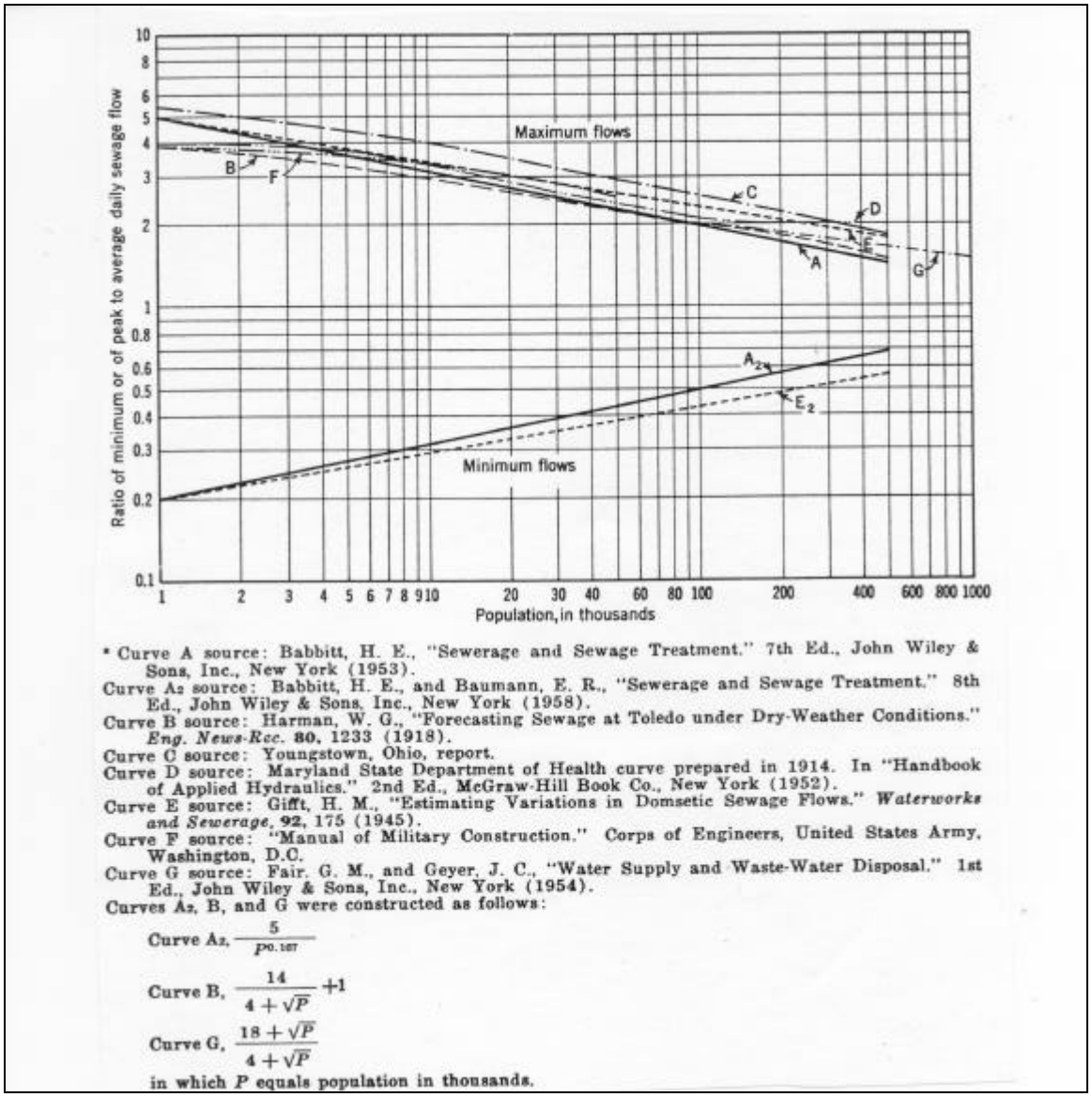
In determining the quantity of sanitary sewage to use in the design of the collection system, the manual recommends the following:

- Determine the design period for which the system is to be built;
- Estimate population for design period;
- Project tributary area and land usage;
- Determine the average daily per capita sewage flow;
- Determine the daily minimum and maximum and average flow and the peak 15-minute flow for any 12-month period.

The manual does not specify an average daily per capita flow rate to use; rather, a table of average flows at a number of locations is provided. These flows range from a low of 50 to a high of 209 gallons per capita per day (gpcd), with a median of 100.

As a sewer needs to be designed for peak flows versus average flow, three charts are included that give the ratio of extreme flows to average daily flows compiled from various sources. These charts show that the ratio decreases with an increase in population or in the average flow. One of these charts (Figure 4 in the manual) is given in Figure 3 below. This chart shows ratios compiled from various sources. Curve G, in fact, is the same as used in the Ten States Standards described in the previous section. The ratios in this chart define the peaking factor in terms of population. The other two charts define the peaking ratio relative to average daily flow.

These average flows and ratios for determining maximum and minimum flows assume that extraneous flows are nominal. If that is not the case, then a judgment allowance must be made.



* Curve A source: Babbitt, H. E., "Sewerage and Sewage Treatment." 7th Ed., John Wiley & Sons, Inc., New York (1953).
Curve A_2 source: Babbitt, H. E., and Baumann, E. R., "Sewerage and Sewage Treatment." 8th Ed., John Wiley & Sons, Inc., New York (1958).
Curve B source: Harman, W. G., "Forecasting Sewage at Toledo under Dry-Weather Conditions." *Eng. News-Rec.* **80**, 1233 (1918).
Curve C source: Youngstown, Ohio, report.
Curve D source: Maryland State Department of Health curve prepared in 1914. In "Handbook of Applied Hydraulics." 2nd Ed., McGraw-Hill Book Co., New York (1952).
Curve E source: Gifft, H. M., "Estimating Variations in Domsetic Sewage Flows." *Waterworks and Sewerage*, **92**, 175 (1945).
Curve F source: "Manual of Military Construction." Corps of Engineers, United States Army, Washington, D.C.
Curve G source: Fair, G. M., and Geyer, J. C., "Water Supply and Waste-Water Disposal." 1st Ed., John Wiley & Sons, Inc., New York (1954).
Curves A_2, B, and G were constructed as follows:

Curve A_2, $\frac{5}{P^{0.167}}$

Curve B, $\frac{14}{4+\sqrt{P}}+1$

Curve G, $\frac{18+\sqrt{P}}{4+\sqrt{P}}$

in which P equals population in thousands.

Figure 3. Various ratios of extreme flows to average daily flow (From Figure 4 in Engineering Practice report No. 37)

The manual notes “many state regulatory agencies (14 out of 38 state boards of health) have set 400 gpcd for laterals and 250 gpcd for trunk sanitary sewers as the minimum acceptable design flow rates where no actual measurements or other pertinent data are available. These minimum values assume the presence of a normal quantity of infiltration, but make no allowance for flows from foundation drains, roofs, yard drains, or of unpolluted cooling water. Additional design quantities should be added

where conditions favoring excessive infiltration or other extraneous flows are present. Also, provision must be made for industrial wastes which are to be transported by the sewers."

If one assumes that the average per capita flow per day is 100 gallons, then the flow of 250 gpcd for the trunk sewers reflects a factor of 2.5. A review of the curves in Figure 3 indicates that a factor of 2.5 would correspond to a population of 30,000 to 150,000, depending on which method is used.

Consideration must also be made for dry weather groundwater infiltration. A table giving the allowances used at a number of cities ranged from 50 to 1,500 gallons per day per inch-diameter per mile (gpd / in-mi) of sewer. The majority of stipulated allowances fell in the range of 375 to 625 gpd / in.-mi. For small sewers (24 inch and smaller), the manual states that it is common to allow 30,000 gpd / mile for the total length of sewers, laterals, and house connections.

Commercial, industrial, institutional contributions are also to be considered. The manual also discusses the use of fixture unit method of design, in which estimate of peak sewage flows are based on the number of fixtures in a home or, more commonly in the use of this method, in an institution such as a hospital, hotel, school office building or apartment building. This method is recommended for small populations only.

5. Comparison of Design Standards

The various approaches to determining design flows are shown in Figure 4. The approach to determining design flows by DWSD and the other standards are similar in that they all recognize the need to account for variation in average daily flows. The DWSD practice as recommended in the NSF report is conservative in that it does not reduce the design flows for populations above 20,000, but holds it constant at the 0.4 cfs (259 gpcd) rate.

Another difference in the approach is that the design chart as given by NSF gives the actual flow to use for a given population versus a ratio of minimum or peak to average daily flow. In order to compare the NSF approach directly with the other standards as was done in Figure 4, the flows were converted to a ratio by assuming an average gpcd flow rate of 100 gpcd.

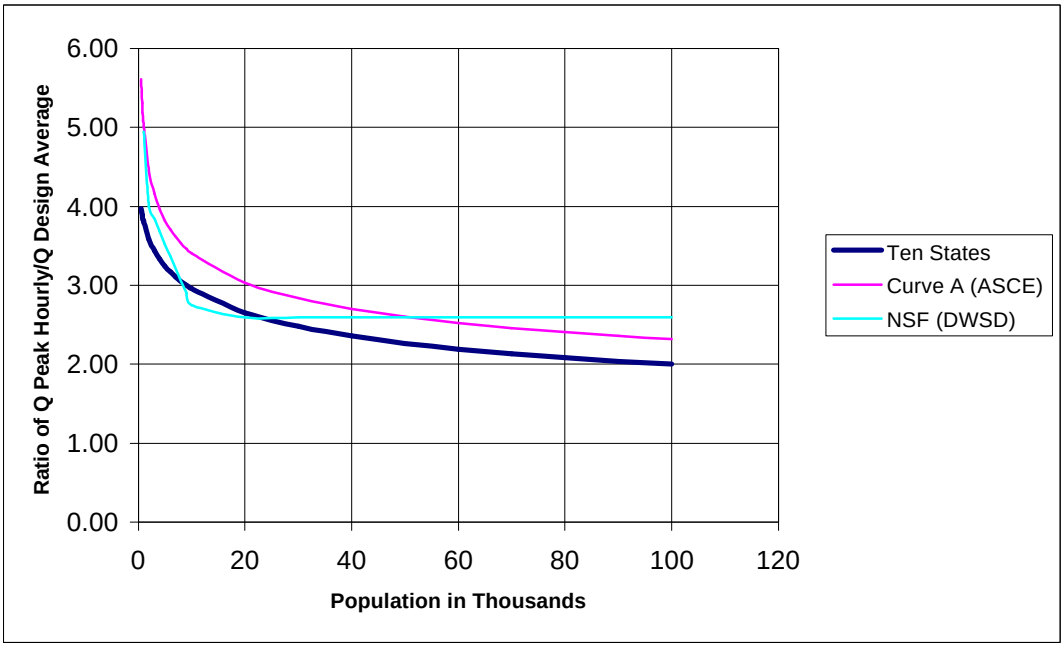


Figure 4. Comparison of various design standards ratios

6. Summary/Conclusion

The historical basis for the DWSD regional collection system has been reviewed and compared to other standards commonly used by engineers. The basis of design for new sanitary sewers in southeast Michigan has been the use of a design rate of 0.4 cfs / 1000 people for tributary populations of 20,000 and larger. This rate is comparable to the other standards reviewed for tributary populations of up to 150,000 people (depending on what "curve" is used in Figure 3). For higher tributary populations, the design rate tends to be conservative.

The 0.4 cfs / 1000 people rate is intended to account for diurnal variations in dry weather flows and to account for normal quantity of infiltration. It assumes that the system is well designed, constructed, and maintained and has minimal extraneous inflows and infiltration. In addition, the 0.4 cfs / 1000 people rate was intended to be used as a design standard and not as a basis for contracts.