SEWER DESIGN PRACTICES

Currently Prevailing in the United States

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THIS paper does not purport to advance any new theory of design nor to advocate any special method now in use, but proposes simply to show trends that designers in the municipal field are making or that state or municipal authorities are requiring in the field of sewer design.

In order to obtain first-hand knowledge of present points of view it was necessary to obtain definite replies to certain questions, on which it was thought there might be difference of opinion. A questionnaire was sent to a large number of consulting engineers, civic authorities, and state officials. The questionnaire was quite inadequate to cover the entire design field, but in these busy times it was considered expedient to keep it short in order to secure a larger number of replies.

The number of persons written to and the number of answers received are shown in Table 1.

The Author

TABLE I

Questionnaires

	No. Sent	States Represented	No. Replies	States Represented	% Replies	% States
Consulting Engineers	47	18	27	11	57	61
Civic Authorities	185	44	86	38	46	86
State Offices	48	48	31	31	65	65
Total	280	..	144	..	51.5	..

In these times when personnel is depleted this result is considered excellent. Since the replies were very widespread it is believed that the answers will be truly representative of nation-wide practice.

Background

What are commonly called today "sewerage systems" should in reality be called water carriage systems since the fouled water from domestic and manufacturing use is used as the transportation vehicle to carry away the solids as well as the liquids.

These water carriage systems are two in number: (1) The separate system, (2) The combined system. In the former the domestic sewage, so called, is carried in one net-work of pipes called the sanitary or domestic sewers, while the storm water is carried in another called storm sewers. In the combined system the domestic sewage and the storm water are carried in the same pipes.

In this paper no attempt is made to set forth the advantages and disadvantages of either of these systems. The prevailing practice at the moment is that of providing separate systems. This practice is followed primarily because of the sewage treatment problem and partly because the costs to treat all the rainfall as well as the domestic sewage are not bearable by municipalities. It must be noted however that cities already with combined sewers will have to continue with the system.

Inasmuch as the domestic sewage has at its maximum a volume very much less (some authorities give 2 per cent) than that of the storm drainage, it has been customary in the design of combined sewers to design them for the storm water only. No information is available to show that there is any trend away from this custom and consequently the assumption will here be made that this is the continued practice.

The problem thus reduces itself to two phases:

A. The design of domestic or sanitary sewers.

B. The design of sewers to carry storm water.

A. On the Design of Domestic Sewers

The design must naturally be made so that the sewer is large enough to carry all the liquids and solids that reach it at such velocity, as will prevent the solid particles from depositing or stranding.

Volume of Domestic Sewage

The volume of water that reaches the sewer is, in part at least, a direct result of the utilization of the domestic water supply. In sewer design, however, interest is not in total flow, but in rates. It used to be more or less the rule that a fair estimate of the maximum rate of water consumption of municipalities would be about three times the average yearly rate.[1] Then since there was retardation in the use of water in households, manufacturing, etc., the discharge into the sewers would be a little less than this high rate. The figure commonly quoted for sewage flow was twice the average yearly rate of water consumption.[2] It is understood that water for manufacturing purposes, obtained from private supplies, would add to this quantity and would have to be computed wherever it occurred.

Ground Water

The amount of ground water that finds its way into sewers should also be given consideration. Designers have used "so many gallons per mile of sewer" or "gallons per acre."

Velocity

Domestic sewers should be laid on sufficient slope to prevent deposits, particularly of organic matter. The velocity necessary has always been an essential problem.

Since most domestic sewers are comparatively small, they are usually made of circular pipe.

Circular sewers have the same hydraulic radius regardless of whether flowing full or half full, therefore the velocity is the same at these depths. The maximum dis-

Ed. Note: Most of the material appearing in this paper was also presented by the author before the Canadian Institute on Sewage and Sanitation in a review of sewer design practices.

charge occurs when the sewer is flowing about eight-tenths full. For many years it was claimed that domestic sewers should only flow half full in order that proper ventilation might be maintained at all times.[2]

With these ideas in mind it was thought that the questionnaire should request answers to four questions.

(1) What is the minimum velocity to be used?

(2) What percentage, if any, should be used in calculating the maximum rate at which municipal water was returned to the sewers?

(3) Should domestic sewers be designed to flow full or half full?

(4) Should provision be made for ground water.

Results of Questionnaires

The results are tabulated in Tables II to VI inclusive.

Conclusions on Domestic Sewer Design

From the foregoing tabulations the following conclusions appear logical.

(1) If the average water consumption can be obtained the maximum flow of domestic sewage may be obtained by using a factor between 1.0 and 2.0 of the water supply. Apparently the authorities agree that a considerable amount of judgment is necessary in the individual cases.

(2) For minimum flow requirements some state officials apparently prefer to set down certain minimum requirements based on gallons per capita per day. Viz., New York, 400 gpcpd. for laterals, and 250 gpcpd. for mains. Minnesota has the same rule; New Jersey requires 20 gals. per lin. ft. of sewer per day. Alabama, Illinois, North Dakota, Oklahoma, Oregon have somewhat similar provisos. Seven of the states replying have no requirement at all. It would appear that there is perhaps a very slight trend toward state requirements of this nature.

(3) As regards infiltration, each engineer or official evidently bases his reply on his experience. It is noted that thirty-five municipalities require provision for infiltration; twenty-five do not; fifteen provide it where necessary.

Three engineers provide for infiltration; one depends on joint tightness, and nineteen provide it when necessary. This is logical as the consulting designer has a wider field to view than the municipal official.

The state authorities hold similar views to those expressed by the consulting engineers.

(4) Concerning minimum velocities, from Table IV it is quite evident that two feet per second is the minimum velocity at which the majority of designers aim.

This is in conformity with the report of a committee of the Boston Society of Civil Engineers—to study limiting "velocity of flow in sewers."[3]

(5) Regarding design depth of flow, it appears that forty-two state that sewers should be designed to flow half full, eleven at or about the depth for maximum discharge (8/10ths full), and sixty-seven design to flow full. It would appear that the present trend is to design for full depth of pipe.

It is apparent, of course, that after sewers fill to capacity air must be drawn into the sewer when this flow passes. Thus each day there must be inflow and outflow of air in addition to the normal flow. This should be ample to provide for ventilation.

B. On the Design of Storm Sewers

As noted previously this discussion will cover the design of combined sewers as well as purely storm water conduits. No attempt will be made herein to consider the shape of the sewers or their hydraulic properties. Further, the areas are small compared with those of large watersheds, and hence the flows will vary much more rapidly.

Finally it is usual to consider that the rainfall is uniform over the entire area.

Background:

Early in storm sewer design it was often customary to design for specific intensities, those intensities continuing for a specific time. With the advent of more scientific measur-

TABLE II
Design Requirements for "Q"
Factors for Use of Water Records to Obtain Sewage Flow

	Below 2	2	2.5	3	Above 3	No Requirement
Consulting Engineers	2	3	5	1	0	..
Civic Authorities	21	9	0	3	2	..
State Authorities	8	3	1	1	1	7
Total	31	15	6	5	3	7

TABLE III
Design Requirements for "Q"
Gals. Per Capita Per Day

	Below 100	100	200	250	300	400	Varied
Consulting Engineers	..	..	1	..	..	1	3#
Civic Authorities	4	14	2	..	7	2	6
State Authorities	..	1	1	2*	..	2*	..
Total	4	15	4	2*	7	5	9

*New York requires 400 for laterals 250 for mains.
#One uses M = 500/P/½.

TABLE IV
Infiltration Provided For

	Yes	No	If Local Situation Requires
Consulting Engineers	3	1	19
Civic Authorities	35*	25	15
State Authorities	3	2	15
Total	41	28	49

*15 give quantitative requirements from 10,000 gals. to 40,000 gals per mile; from 1,000 to 1,500 cu. ft. per acre; from .001 to .015 cu. ft. per acre per day.

TABLE V
Minimum Velocities in Domestic Sewers

	Velocities in Feet Per Second			
	Below 2.0	2.0	2.5	Above 2.5
Consulting Engineers	2	20	3	1
Civic Authorities	3	40	16	1
State Authorities	1	21	3	2
Total	6	81	22	4

TABLE VI
Flow Depths in Diameters

	½	¾	1.0	No Requirement	Vary
Consulting Engineers	7	3	12	..	1
Civic Authorities	21	7	47	..	6
State Authorities	14	1	8	7	..
Total	42	11	67	7	7

ing devices this was found to be inadequate. Certain municipalities by measuring the rainfall in detail and the corresponding run-off obtained equations connecting these parameters. Thus there arose the era of empirical formulae.

Kuichling in 1889[4] advocated a reasoned approach to the problem. This has come to be called the Rational Method of Storm Water Sewer Design. Briefly it may be put in algebraic form:

$$Q = CiA$$

Where Q = rate usually in cu. ft. per sec.
C = run off coefficient.
i = intensity of rainfall—continuing for a time period equal to the time for the water after falling at the most distant point to reach the point under consideration.
A = acres of the contributary watershed.

Variations or modifications of the Rational Method have been advanced and advocated from time to time. Among these has been Ogden's suggestion[5] that Kuichling's Rochester data showed a straight line relationship between the population per acre and the coefficient "c."

Then Grunsky suggested[6] that attention should be given to storage on the ground and in the sewers. A fuller discussion of these varied methods is given in a paper by the author.[7] For a more exhaustive discussion the reader is referred to American Sewerage Practice, Vol. I by Metcalf and Eddy.[8] The problem of storage underlies the basis of design in the present U. S. Army airport requirements for runways.[9] Provision by this method obviously is not made for the sewers to be large enough to take all the rainfall *immediately* it reaches the inlets.

Questionnaire

The matters that have appeared somewhat controversial have been:

(1) The use of empirical formulae.

(2) The use of the "rational method" in any of its variations.

If the rational method was employed there arose the question of rainfall data, i.e., durations and intensities and the relationship between them. If the data could not be obtained locally, what was done about it? Should different rainfall curves be used in designing laterals and main sewers? Was there any relation between classes of areas and run off?

Again the question of the size of the questionnaire had to be considered. It was therefore cut to the few questions shown in the questionnaire in Appendix I hereto.

Answers to Questionnaire

Table VII shows the number who state whether they use the empirical or rational method of approach.

Of those who stated that they used the rational method, one consulting engineer says "sometimes"; and one says "partly"; two municipalities state "partly"; two use rational method as a check.

To the question of run off factors, Table VIII shows the answers.

TABLE VII
Number Using Empirical Formulae vs. Rational Method

	Using Emp. Form.	Using Rat. Meth.	Using Freq. Curves	No Freq.	Vary
Consulting Engineers	2	20	18	3	5
Municipalities	15	61	44	6	6
Total	17	81	62	9	11

TABLE VIII
Number Using Run-off Factors "C" in Rational Method

Areas*	1	2	3	4	5	6
Consulting Engineers	14	14	15	15	15	15
Municipalities	70	70	70	70	70	70
Total	84	84	85	85	85	85

*AREAS—Legend in Table VIII.
1—Rural, 2—Partly Built, no Paving, 3—Good Residential, 4—Crowded Residential, 5—Commercial, 6—Business.

Conclusions on Storm Sewer Design

The answers indicate clearly certain trends.

(1) It is evident from Table VIII that the profession is using the "Rational Method of Sewer Design" more and more.

(2) To the question as to how the rainfall curves were deduced mathematically the replies were disappointing. A few stated that the curves were set by eye. A very few advised the curves were worked out by the probability method. But the great majority did not even suggest how the curves were deduced. No conclusion can therefore be reached thereon.

(3) To the question where data could be obtained on rainfall if none were available locally, the following answers were received: seven would refer to Yarnell[10], nine would refer to the nearest weather bureau or city with data, one to Metcalf and Eddy[8], one to Davis.[11]

(4) Most consulting engineers and municipalities state they use frequency curves, but select a frequency curve of five, ten, or fifteen years as an over all curve for use throughout the entire area. As noted in Table VII only a very few use different frequencies for laterals, submains, and trunks. Most replies indicated that the frequency selected in any case should be determined by a study of the economics. A balance between the cost of the complete removal of the storm water (i.e., public convenience) and the cost of construction should be made. Table IX shows the answers of a very few who gave arithmetical data. This shows opinion to be divided, but the tendency is to use an over all rainfall curve frequency of five to ten years.

(5) The greatest difference of opinion lies in the evaluation of the "run off" ("imperviousness") factor.

From the answers given, the following data has been collected.

Area	"C"
Rural Areas	0.05 to 0.5
Partly Built-Up Unpaved Areas	0.2 to 0.75
Good Residential Areas	0.35 to 0.85
Crowded Residential	0.35 to 0.80
Commercial	0.5 to 1.00
Business	0.5 to 1.00

There does not seem to be any unanimity of opinion or does there seem to be any trend. It might be suggested that a study of Ogden's "population-run off coefficient" curve based on Kuickling's data might help reconcile the very varied opinions expressed.[4]

TABLE IX
Rainfall Frequencies

	Over All			
	5-Year	10-Year	15-Year	15 or More
Consulting Engineers	2	2	..	..
Municipalities	8	6	2	..
Total	10	8	2	..

Practically no state makes provision in its State Health Department requirements for storm sewer design. Consequently in the data, tables, or discussion given no mention is made of state requirements.

APPENDIX I

Sewer Design Questionnaire

Storm Sewer Design

1. Have you an empirical rule for the design of sewers in your locality? If so, please give.
2. Do you employ the rational method of storm sewer design?

Rainfall Curves

3. After collecting data what mathematical method do you use for determination of rainfall curve?
4. If rainfall data for any particular area is not available, what information would you use?
5. Do you use frequency curves for rainfall?
   Wherein do you use frequency curves rather than an overall maximum one?
6. Are different frequency curves used in designing laterals, submain, trunk and intercepting sewers?
7. Do you use run off factors? If so, what factors do you use for rural areas?
   Partly built up—no paving.
   Partly built up—but paved—good residential.
   Crowded residential.
   Commercial.
   Business.

Sanitary Sewer Design

8. What velocity do you regard as the minimum for "self cleansing?"
9. What factor do you use to obtain maximum "domestic sewage flow" from the average per capita per day water consumption?
10. In designing domestic sewers—do you design for maximum flow filling (i) half the pipe?
    (ii) the whole pipe?
11. Do you make allowance in every case for infiltration or do you determine ground water table and make allowance when it rises above the sewer?

Location Date Signature

REFERENCES

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8. Metcalf and Eddy—American Sewerage Practice. Vol. I.
9. U. S. Aviation Engineers—Technical Manual—T.M.—5-255.
10. Yarnell—U. S. Department Agriculture—Bulletin 204.
11. Davis — Handbook of Applied Hydraulics. (McGraw-Hill, 1943).

How to Avoid Galvanic Corrosion

Galvanic corrosion is caused by two dissimilar metals in contact with a liquid capable of conducting an electric current. One of the metals or alloys is more soluble in the liquid than the other. Through its tendency to pass into solution an electric current is produced and takes away with it the more soluble (less noble) metal which passes into the solution as ions. In truth this phenomena is that of the wet-cell of old which was employed to produce direct electric current. The greater the difference in solubility of the two metals exposed to the liquid (electrolyte) the greater the current flow and the more rapid the galvanic action and corrosion of the weaker metal. The direct connection of dissimilar metals or their connection by a conductor, such as the wall of a steel tank, is known as a galvanic couple and unless one or the other of the two metals is effectively insulated galvanic corrosion to various degrees ensues.

Metals are classified in a galvanic series such as the accompanying table represents.

The most soluble and easily corroded metals are at the top of the list and the least corrodible are at the bottom. The farthest apart the metals are in the list the greater will be the galvanic action and corrosion rate to the weaker metal. The closer together the two metals in the series are the least the galvanic action between the two. Therefore a connection between zinc or aluminum and copper or red-brass would result in marked galvanic corrosion attack, whereas copper to lead or nickel would produce far milder galvanic corosion.

Position of Metals in the Galvanic Series

Corroded End (anodic, or least noble)

Magnesium
Magnesium alloys
—
Zinc
—
Aluminum 2S
—
Cadmium
—
Aluminum 17ST
—
Steel or Iron
Cast Iron
—
Chromium-iron (active)
—
Ni-Resist
—
18-8 Stainless (active)
18-8-3 Stainless (active)
—
Lead-tin solders
Lead
Tin
—
Nickel (active)
Inconel (active)
—
Brasses
Copper
Bronzes
Copper-nickel alloys
Monel
—
Silver solder
—
Nickel (passive)
Inconel (passive)
—
Chromium-iron (passive)
18-8 Stainless (passive)
18-8-3 Stainless (passive)
—
Silver
Graphite
Gold
Platinum

Protected End (cathodic, or most noble)

The following precautions are in order if galvanic corrosion is to be held to a minimum.

1. Select combinations of metals as close together as possible in the galvanic series.

2. Avoid combinations where the area of the less noble material is relatively small.

3. Insulate dissimilar metals wherever practical. If complete insulation cannot be achieved, anything such as paint or plastic coatings at joints will help.

4. Apply coatings with caution. For example, when painting—do not paint the less noble material without also coating the more noble, otherwise greatly accelerated attack may be concentrated at imperfections in coatings on the less noble metal. Keep such coatings in good repair.

5. Prevent or limit aeration of the corrosive liquid as much as possible to sustain the polariziing effect of the hydrogen film which forms on bare cathode surfaces.

6. If practical, add an appropriate chemical inhibitor to the corrosive solution.

7. Avoid using threaded connections to join metals well apart in the series, as the threads will probably deteriorate excessively. Brazed or welded joints are preferred.

8. Whenever possible, install relatively small replaceable sections of the less noble material at joints and increase the thickness of the less noble material in such regions.

9. Install pieces of bare zinc or steel to provide a counteracting effect to suppress the unwanted galvanic corrosion.

86 Firms to Exhibit at Milwaukee

At the A.W.W.A. Wartime Conference being held this month in Milwaukee 86 member firms of the Water and Sewage Works Mfrs.'s Assn. will be represented in the Exhibit Hall. So marked was the demand for exhibit space that the allocations had to be restricted to one exhibit space per applicant, so the number of firms to be represented was restricted to the 86 available spaces on the basis of first come first served.

This fact, together with the recorded hotel reservations, points to a new record in attendance for A. W. W.A.'s annual meetings.