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TABLE OF CONTENTS

STORAGE BASIN AND PUMPING PLANT DESIGN (G 500)

LIST OF FIGURES

G 500 STORAGE BASIN AND PUMPING PLANT DESIGN

G 510 BASIC DESIGN DATA

The selection of a drainage system and the need for storing and pumping water are discussed in Sections G 130 to G 135. Only the design of storage basins and pumping plants will be covered in this chapter.

There is no standard method of design which is applicable to all possible combinations of storage and/or pumping systems. The specific requirements of each application must be thoroughly analyzed so that the design may take advantage of any existing conditions favorable to the economical disposal of water. Design examples of simple storage systems are presented to show what the design involves and what final data are required.

G 511 TYPES OF STORAGE AND PUMPING SYSTEMS

The four types of drainage systems utilizing storage and/or pumping are as follows:

l. storage only-A reservoir of adequate capacity to store the entire runoff of the design storm with disposal of the water after the peak of the storm. This solution is usually neither practical nor desirable.

2. Pumping only-Pumping facilities of adequate capacity to dispose of the design storm runoff without storage. This method is too expensive.

3. Storage and pumping-A reservoir and pumping plant of combined capacity equal to the design storm runoff.

4. Storage and gravity outflow-A reservoir and gravity outflow conduit of combined capacity equal to the design storm runoff.

Of these four systems, the last two are the most commonly used. They may be combined in many different ways. A simple design example of each of the last two systems is presented in Sections G 520 and G 530. The basic design principles shown in these examples also apply to other combinations of these two systems.

G 512 EXTENT OF DESIGN

All drainage facilities are generally designed by the Storm Drain Design Division or District office except the pumping plant. This facility is designed and detailed by the Pumping Plant Design Section of the Sewer Design Division. However, the storm drain designer must furnish basic design data to the Sewer Design Division.

After a pumping system has been found to be necessary, the storm drain designer must determine its outlet, choose a site for the storage basin (or storage chamber) and pumping plant, provide an economical balance between storage and pumping capacity, and study the probable flood or inundation damage which might result from a malfunction of the pumping plant. With this information, the Sewer Design Division makes the final pumping plant layout and design, coordinates the design with the Bridge and Structural Design Division, prepares the final construction plans, selects and controls tests on equipment for the plant, and supervises the construction of the pumping plant and the installation of equipment.

After completion of construction, the Storm Drain design office shall transmit one set of plans to the Sewer Maintenance Division of the Bureau of Sanitation, thereby notifying them of completion of construction and the need for maintenance scheduling.

G 513 DESIGN CRITERIA

The following equation shall be used to determine the required outflow and storage capacity of a storage basin:

Volume of inflow = Volume of storage + Volume of outflow.

The design of storage basins and/or pumping plants shall meet the following criteria:

1. Storage only: The basin capacity must equal the inflow volume of a 50-year storm. Means must be provided to restore a ten-year storm capacity in the basin within ten days after a major storm, and to restore total basin capacity within 14 days after a major storm.

2. Pumping only: The total pumping capacity must equal the peak inflow runoff rate of a 50-year storm. Standby pumping facilities and an

auxiliary power supply should be provided to ensure immediate operation under all circumstances.

3. Storage and pumping: The combined storage basin and pumping capacity must be adequate to handle the inflow volume of a 50-year storm without basin overflow. An auxiliary power supply and standby pumping facilities must be provided if deemed necessary to prevent injury or property damage from basin overflow.

4. Storage and gravity outflow: The combined capacities of the retarding basin and gravity outflow must be adequate to handle the inflow volume of a 50-year storm without basin overflow. The gravity outflow conduit must be sized to handle the retarding basin outflow plus a ten-year storm runoff of contributing areas downstream from the basin. Also, the outflow capacity must be such as to restore 40% of a 50-year storm volume of inflow in the basin within a 24-hour period (Section G 221).

The gravity conduit which collects the runoff into a storage basin or pumping plant shall be designed to the storm frequencies indicated in Section G 222. Provisions shall be made to drain excess flow between a l0-year and a 50-year storm into the basin.

G 514 DESIGN STANDARDS

A storage basin and/or pumping plant acceptable to the City for storm drain purposes must meet the following minimum requirements.

G 514.1 Storage Basins: A storage (or retarding) basin shall consist of the following requirements:

1. A permanent drainage easement for the entire basin site enclosed with a chain link fence (or equivalent) with access gates;
2. Stable cut and fill slopes;
3. A roadway and ramp providing access to the storage basin floor (as per Section G 648);
4. A slope on the basin floor from point of inflow to point of outflow;
5. Protection from erosion within the basin at conduit inlets and outlets;
6. An appearance made acceptable by landscaping.

If the basin is located adjacent to a sanitary disposal site through which seepage of underground water from the basin would contaminate the existing water table, the basin must be lined or otherwise made impermeable to prevent such seepage. Extra borings of the basin site must be taken to locate the limits of the disposal area.

If the basin is located in an area where underground water is a known source of water supply, measures shall be taken to ensure that the basin does not intercept, interrupt, or diminish the flow of underground water.

A permanent storage basin to be used for recreation purposes cannot conform to all the above standards. Since this condition occurs infrequently, special standards of design are beyond the scope of this manual. However, the general use as a storage basin still applies.

G 514.2 Pumping Plants: Although the design is detailed by the Sewer Design Division, the general requirements for the pumping plant are determined by the storm drain designer, as stated in Extent of Design (Section G 512). These general requirements consist of the following items:

1. A permanent drainage easement where required for the pumping plant site enclosed with a chain link fence (or equivalent) with access gates. The site must be of sufficient size to accommodate ultimate pumping plant facilities.
2. A gravity outflow conduit where required, or other adequate pumping plant outlet.
3. The standby equipment and auxiliary power required to protect the public from damage.

G 520 DESIGN OF STORAGE PLUS GRAVITY OUTFLOW

A storage plus gravity outflow drainage system consists of a gravity flow collector drain, a retarding basin, and a gravity outflow drain. The design of this system involves complex trial and error calculations to determine a hydraulic balance between outflow and storage capacities.

The use of a retarding basin on a drainage system (as expressed by the equation: Volume of inflow = volume of outflow + volume of storage) is to reduce the outflow rate by storing the excessive inflow. This means that as the inflow into the basin site increases beyond the capacity of the outflow conduit, part of the inflow is temporarily stored. The outflow rate increases with the rise in head from increased storage but cannot exceed a maximum value at maximum storage. When the rate of inflow decreases until it becomes equal to or less than that of the outflow, the rise in level of the stored water ceases and the rate of outflow thereafter either remains constant or begins to diminish, continuing, however, to be greater than that of the coincident inflow rate. The net effect of this series of events is a decrease in the required size and construction cost of the entire outfall conduit downstream from the basin, and decreases the amount of debris and silt carried in the outfall conduit. The outlet of a temporary basin can be controlled, but the outlet must be sized for ultimate capacity without the basin.

G 521 DESIGN PROCEDURE

The general sequence of design functions for a storage plus gravity outflow drainage system is summarized as follows:

1. Review of entire project (Section G 321)
2. Location of retarding basin (Section G 522)
3. Collector drain alignment and hydrology (Section G 330)
4. Outflow drain alignment and hydrology (Section G 523)
5. Inflow volume calculations (Section G 524)
6. Outflow capacity limitations (Section G 525)
7. Hydraulic calculations for outflow conduit size and head loss (Section G 526)
8. Determination of storage capacity (Section G 527)
9. Calculations of outflow and storage (Section G 528)
10. Design of basin, and collector and outflow drains (Sections G 340 to G 360 and G 529)

G 522 BASIN LOCATION

In selecting the retarding basin site, the following factors must be considered:

1. The site must be low enough in elevation to allow a gravity flow collector drain to the basin, yet high enough in elevation to allow a gravity flow outlet drain from the basin.
2. The site must be of sufficient size for the construction of the ultimate improvement of the basin.
3. Right of way for the entire site must be acquired, including vehicular access for maintenance.
4. The site should be located close to the outlet selected. Streets, existing drains, or open channels should be investigated as possible outlets.

G 523 HYDROLOGY

After the basin site has been located and the outlet has been selected, the drainage area contributing to the basin is tabled by the Peak Rate Method (Section G 240). This Q and t_c provide the data required for the basin Mass Inflow Hydrograph calculations.

The outflow conduit capacity from the basin must equal the sum of the design peak flow from the basin and the design storm from the downstream drainage area contributing to the outflow conduit. This area is tabled by the Peak Rate Method in the same manner as any other area, starting with the initial time of its local area. The peak basin outflow Q is added directly to the tabled Q at each point of concentration without any adjustment for time of concentration. It is estimated that the peak of the basin outflow hydrograph is broad enough timewise to add directly to the peak of the local area hydrograph.

G 524 INFLOW VOLUME

The collector drain hydrologic tabling provides Q, t_c and BPRR for the peak inflow into the storage basin. From these values, the volume of water is calculated (as shown on Figure G 524) and plotted as a Mass Inflow Hydrograph.

The volume is the product of the rate (Q) and the time. Q is the product of MF and the Runoff Rate. MF is the multiplying factor that converts the runoff rate per acre to the inflow rate at clock time:

$$MF = A(F_{RO}) = Q/BPRR$$

On Figure G 524, column 1 covers the period of intense runoff of a 24-hour storm, and column 2 is the runoff rate at clock time, both taken from Figure G 252F. Column 3 is the rate (Q) at clock time (MF x ROR). Columns 4 and 5 are increments of rate and time between clock times. Column 6 is the volume for the increment of time, and Column 7 is the summation of increment volumes.

G 525 OUTFLOW CAPACITY

The outflow capacity of a storage basin is limited by its outlet, whether existing or to be constructed. If an existing facility is used, the outflow from the basin plus the runoff from the local area downstream must not exceed the capacity of the outlet. If a new conduit outlet is constructed, its size is determined by the type of basin used. For a permanent basin, full use of available storage is made and the basin outflow conduit is sized to carry the basin outflow plus runoff from the local area downstream of the basin. For a temporary basin, its outflow conduit must be sized for the ultimate drain capacity without use of storage basin. However, the discharge to the existing system must be limited to the calculated quantity from the storage equation until the downstream system is improved. For tract developments, the outflow from a basin must not exceed the runoff from the tract area prior to improvement. No design factor is more important than the proper determination of the basin outflow capacity, since it usually sets the storage capacity of the basin.

G 526 OUTFLOW HYDRAULICS

The relative location of the storage basin to the outlet is plotted in plan and profile to provide a worksheet (Figure G 526) for the outflow conduit hydraulic calculations. These determine the outflow conduit size and grade and the storage basin depth. From these data, the storage basin Discharge-Head Curve and the Volume-Depth Curve (Figure G 526C) can be calculated and plotted.

The known data on the plan portion of Figure G 526 are the location and capacity of the outlet, the location of the storage basin, and the alignment of the outflow conduit. The local area Q's, the maximum basin outflow Q (60 cfs), and the conduit structures are added on the plan. The lengths of conduits are scaled. The outlet and basin are next plotted at their proper location and elevation on the profile, and the ground line over centerline of conduit is plotted. The difference in water surface elevations between the storage basin and the outlet is the total head available for the outflow conduit. The hydraulic calculations required to determine the outflow conduit sizes and the procedure to set the conduit grades are given in Figure G 526A.

The storage basin is generally set as deep as economy allows. For shallow ground slopes, the basin depth is usually limited by the minimum construction grade of the outflow conduit. For steep ground slopes, the basin depth may be increased by flattening the construction grade of the outflow conduit for a short distance just below the basin. The increased depth decreases the surface area required for the basin site.

After the outflow conduit size and grade have been set, the outflow is determined for various depths of water in the basin. For pressure flow, four basin outflow Q's are selected up to the maximum allowable capacity (60 cfs) and the required head (H~) for each Q is calculated. (See Figure G 526a.) For open channel flow, the Q is calculated for various depths of flow in the conduit, and the corresponding basin headwater (H') is determined. The results of these two flows are plotted as a Discharge-Head Curve (Figure G 526C). This curve is the outflow portion of the equation:

Inflow = outflow + storage.

G 527 STORAGE CAPACITY

After the outflow is determined, the storage capacity must be estimated. For a set maximum outflow rate, the storage capacity required can be approximated by the use of the mass hydrograph. The mass inflow hydrograph curve (Figure G 534) is plotted from the inflow calculations (Figure G 524). The mass outflow hydrograph is then plotted for an estimated constant outflow rate equal to half the set maximum gravity outflow rate (30 cfs). The required storage capacity then is the maximum volume scaled vertically between the two hydrographs (approximately 500,000 cu. ft.).

With a set basin depth of 10.5 feet and capacity of about 500,000 cu. ft., the basin dimensions must be determined to fit the physical characteristics of the site selected. In this example, the basin dimensions shown on Figure G 526C were chosen. The volume of the basin was calculated by the average end area method at one-foot depth intervals. The result was plotted as a *volume-depth* curve, as shown on Figure G 526C. This curve is the storage portion of the equation:

Inflow = outflow + storage.

56.0 + 56.2

G 528 OUTFLOW-STORAGE CALCULATIONS

The computation of outflow and storage for a retarding basin consists in achieving a hydraulic balance of all variables by trial and error for each increment of time (ΔT). These variables are as follows:

a) The inflow volume,

b) The storage volume,

c) The depth in the basin for the volume stored,

d) The total head (H_T) or headwater (H') affecting outflow,

e) The outflow volume.

When all these variables are in agreement, the inflow volume equals the outflow volume plus the storage volume.

The data required to make this computation are as follows:

a) The inflow hydrograph calculations as shown on Figure G 524,

b) The retarding basin *Volume-Depth* Curve as shown on Figure G 526C.

c) The outflow conduit *Discharge-Head* Curve also shown on Figure G 526C The sudden increase in head (Figure G 526C), caused by a change from inlet control for open channel flow to outlet control for pressure flow, is averaged to simplify the curve.

An example of the computation *Inflow = Outflow + Storage* is shown on Figure G 528. The sum of outflow and storage volumes must be made equal to the inflow volume for each increment of time (ΔT) as follows:

1. For the increment of time from 80 to 90 minutes (ΔT = 600 seconds), assume 36,000 cu. ft. (column 4) will be stored out of an inflow of 72,540 cu. ft. (column 3). The sum (S) of the storage (at 80 minutes, column 5) is 259,240 + 36,000 = 295,240 cu. ft. at 90 minutes.

2. Find elevation of water in the basin (Figure G 526C) for S Storage Volume of 259,240 (204.5 at 80 min.) and of 295,240 (205.1 at 90 min.) and the corresponding basin outflow rates for the 80-minute and 90-minute times. Average the 80 and 90-minute Q's and multiply by ΔT for the outflow volume for ΔT:

$$\frac{56.0+56.2}{2}\times 600 = 33{,}660\,\text{cu.ft.}$$

3. Then apply the equation:
Storage volume for ΔT = 36,000 cu. ft.
Outflow volume for ΔT = 33.660 cu ft.

69,660 cu. ft.
Inflow volume for ΔT = 72,540>69,660

This is hydraulically unbalanced, and must therefore be adjusted.

4. A small increase in storage hardly increases the outflow; therefore, the storage is increased to 38,880 cu. ft., which provides the balance desired. The storage (38,880) plus the outflow (33,660) is equal to the inflow (72,540). Two or three quick passes should suffice to balance each AT increment to the end of the computation. Only the final, balanced values are listed on the computation sheet (Figure G 528).

It should be noted (column 6 of Figure G 528) that the elevation of water in the basin (207.6 feet) matches the allowable design elevation of 207.5 feet. Usually the basin capacity is inadequate and must be increased in width or depth. The basin capacity must then be recalculated and the Volume-Depth Curve must be replotted. If the basin depth is increased, the Discharge – Head Curve must be adjusted accordingly. Finally, the Outflow-Storage calculations (Figure G 528) must be recalculated to determine the resulting maximum elevation of water in the basin.

For most small reservoirs, the storage-outflow calculations using only the fourth day of the storm (see Section G 221) is adequate. But for major reservoirs (such as Bixby Slough, Chatsworth, or Santa Ynez) which have large surface areas, the outflow-storage calculations must be made for all four days of the storm because the accumulated storage from day to day is significant. To coordinate clock time and accumulated storage from day to day, the S Storage Volume remaining at the end of one day (378 minutes) is carried over to the beginning of the following day (-1062 minutes) to continue the inflow-outflow-storage calculations.

There are no shortcuts to this type of computation. Many trial computations similar to that shown on Figure G 528 may be required to arrive at an optimum solution. A change in any of the variables listed in the first paragraph of Section G 528 requires recalculation as shown on Figure

G 528. To save design time, it is recommended that the computer Reservoir Analysis program be used whenever possible for such solutions (see Section G 930).

G 529 DESIGN OF BASIN AND CONDUITS

To complete the design of a storage plus gravity outflow system, the retarding basin and its inflow and outflow conduits must be detailed. The collector drain must be hydraulically balanced with the storage basin water surface at peak inflow as indicated on Figure G 528. The retarding basin must be detailed to the standards given in Subsection G 514.1. A typical retarding basin is detailed on plan D-19405, sheet 3 of 7. The collector drain and outflow drain conduits are designed as shown on the Flow Chart (Figure G 314).

G 530 DESIGN OF STORAGE PLUS PUMPING

A storage plus pumping drainage system involves the designing of many parts a closed conduit (or open channel) collector drain, a storage basin, a pumping plant, and a gravity outflow (or a force main) conduit. The various parts of the design must be closely coordinated, and effective communication must be maintained between the many design offices involved. This section covers that portion of the drainage system which is designed and coordinated by the storm drain designer.

G 531 DESIGN PROCEDURE

The general sequence of design functions for a storage plus pumping drainage system is summarized as follows:

1. Review of entire project (Section G 321).

2. Location of storage basin and pumping plant (Section G 532).

3. Collector drain alignment and hydrology (Section G 330).

4. Mass inflow hydrograph (Section G 533).

5. Mass outflow hydrograph and storage capacity (Section G 534).

6. Collector drain hydraulics (Section G 340).

7. Design of pumping plant (Section G 535).

8. Design of basin and conduits (Sections G 529 and G 350 to G 370).

G 532 PLANT LOCATION

A pumping plant is normally located adjacent to the storage basin. The storage basin location is discussed in Section G 522.

The pumping plant site should conform to the design standards given in Subsection G 514.2. However, most pumping plants do not require a site with fenced-in right of way. A local street sump with light runoff is usually pumped by a small underground plant in the street, using the street sump for storage. The site should be selected to prevent flood hazard in the pumping plant proper. Also, the site should be located as close to the outlet as practicable.

G 533 MASS INFLOW HYDROGRAPH

The Mass Inflow Hydrograph is a curve representing the cumulative inflow volume of runoff at clock times based on the peak runoff rate. The inflow volume of runoff is calculated as shown on Figure G 524, and the results are plotted as shown on Figure G 534.

The Mass Inflow Hydrograph curve should be plotted for the full 24-hour period (1440 minutes). This is required to determine the point of tangency between the inflow and outflow hydrographs. A 50-year storm and hydrograph of runoff is explained in Section and Figure G 221.

G 534 STORAGE AND PUMPING CAPACITIES

Before the storage capacity can be determined, the optimum pumping capacity must be established. The pumping rate is generally selected as small as existing conditions allow. This is usually economical. However, where the acquisition of land is costly, it may be economical to increase the pumping rate and to decrease the area required for the storage basin. Under no circumstances can the pumping capacity exceed the capacity of the outlet during storm conditions.

The storage capacity required for a selected pumping capacity is determined as follows:

1. The pumping rate selected is plotted as a slope line (Mass Outflow Hydrograph) representing the accumulated volume pumped vs. time. This line (Figure G 534) is placed tangent to the Mass Inflow Hydrograph line. The point of tangency is the starting point of constant pumping used to establish the storage capacity. This eliminates the short ON and OFF pump cycling.

2. The storage capacity required to accommodate the chosen pumping rate is the maximum volume (measured along the ordinate) between the Mass Inflow and Mass Outflow Hydrographs as indicated on Figure G 534.

The storage capacity thus determined is acceptable for design without the storage-outflow calculations shown on Figure G 528. If more than one pump is used, the rate of outflow may change, thereby changing the slope of the Mass Outflow Hydrograph. The designer is urged to coordinate his storage basin design closely with the Pumping Plant Design Section of the Sewer Design Division.

G 535 PUMPING PLANT DESIGN REQUEST

The Pumping Plant Design Section of the Sewer Design Division designs the pumping plant and appurtenances (as stated in Section G 512) when requested by the Storm Drain Design Division or District Office. The basic design data submitted with the request are the following:

1. Plant Site: A plan (and profile if available) similar to Figure G 526, showing the location of the pumping plant, the storage basin (if any), the outlet, and the alignment of the force main conduit.

2. Plant Capacity: The quantity (Q) to be pumped, the Mass Hydrograph (Figure G 534), and the storage basin capacity (if any).

3. Standby Equipment: A recommendation on the need for standby pumps, auxiliary power, or other auxiliary equipment.

Generally, standby equipment and auxiliary power are required. However, consideration should be given to:

a) the extent and frequency of flood damage, and

b) the length and frequency of loss of power.

If flood damage occurs only with a storm of 50-year frequency, no life is endangered, and the cost of property damage is about equivalent to the cost of standby equipment, no standby equipment should be recommended. If loss of power seldom occurs, and then only for two hours or so, possibly the 2-hour pumping capacity can be added to the storage capacity more economically than the auxiliary power supply can be installed and maintained. Based on his investigations, the designer will submit his recommendations on standby equipment and auxiliary power requirements with his submittal of design data.

G 536 DESIGN OF CONDUIT

Most storm drain systems utilizing pumping which are designed and constructed by the City are small local sumps with minimum storage capacity other than the street itself. All runoff that can be drained by gravity should be intercepted before the runoff enters the sump. Of all the parts of a storage plus pumping drainage system itemized in Section G 530, only the collector drain conduit is completely designed by the storm drain designer for most pumping systems. The procedure outlined in Section G 531 should be followed in the design.