3.1 Sewerage System

3.1.1 Role of Sewerage System

The objective of sewerage systems and services is to ensure sustainable urban development, hygienic sanitary conditions, and clean water environment. In other words, the roles of the sewerage system are to collect and treat sanitary wastewater from domestic and industrial sources, and drain storm water so that the livable environment is safeguarded. In recent years, extreme rainfall events have been increasingly observed in Japan, as shown in Figure 3.1.

In addition to these basic functions, the recycling of resources from sewerage systems has emerged as a new role in recent years. Water, sludge, biogas, and heat are recyclable. By tapping into these sources, the creation of energy-independent treatment plants and the reduction of greenhouse gasses (GHGs) are being achieved. Sludge recycling rate is increasing as shown in Figure 3.2.

3.1.2 Components of a Sewerage System

A sewerage system is defined as all the facilities to collect and treat municipal and industrial sanitary wastewater and drain storm water, and then to return the treated wastewater and storm water to the receiving water bodies [1].

3.1.2.1 Collection of Domestic Sanitary Wastewater

Sanitary wastewater from the kitchen, toilet, and bath is collected through the house sewer and a cleanout, which are located inside the private property. The house sewer and cleanout belong to the property owner, whose maintenance is the responsibility of the property owner (see Figure 3.3).

The wastewater then flows down to another cleanout located at the boundary with public roads. This cleanout and subsequent sewer belong to the municipality. Wastewater comes into the main sewer by
FIGURE 3.1  Increase of recent rainfall extremes in nationwide events, with 50 mm/h or more in Japan.

FIGURE 3.2  Trend of sludge recycling in Japan.
way of lateral flow. The diameter of the sewer pipe increases as the volume of wastewater increases down the line. Because wastewater is basically collected by gravity, the sewer pipe may have to be kept at a greater burial depth as it travels toward its destination. Deep sewer pipes are costly to install and difficult to maintain. Therefore, wastewater may be periodically pumped close to ground level at lift stations to prevent excessive depth. Ultimately, the wastewater reaches a treatment plant and, after treatment, the treated water is discharged into rivers and seas.

### 3.1.2.2 Separate and Combined Sewer System

Wastewater includes sanitary wastewater and storm water. Two systems exist for their collection. One is a separate system where sanitary wastewater and storm water run into separate sewer lines. The other is a combined system where sanitary wastewater and storm water run into the same sewer. Generally, the installation cost of a separate system is higher than that of a combined system. Combined systems were used in older cities. Later, combined sewer systems were considered an affordable solution to improve sanitation and urban flood. However, because sanitary wastewater and storm water run into
the same sewer lines in wet weather, a part of the combined sewage overflows due to gravity from the sewer outfalls or is discharged from pump stations into the receiving water body. Normally, around three times as much as planned dry weather flow is accommodated in a combined sewer line and sent to a wastewater treatment plant (WWTP) by way of interceptors. Although combined sewer overflows (CSOs) are diluted by storm water, sanitation and pollution problems occur as long as sanitary wastewater is in the overflows. Especially in the beginning of rainfall events, pollutants deposited on road surfaces and sewer lines are flushed into the wet weather flow and can be a threat to health and environment. Therefore, a separate system is mandatory for cities starting a new sewer project today. To reduce the CSO problems, many cities are working on control measures such as storing the first flush of wet weather flow and sending it to a WWTP in dry weather for treatment.

3.1.2.3 Sewer Service Operator

Local governments, for example prefectures and municipalities in Japan, are sewer service operators. They build, own, and operate the sewerage system. Private companies undertake the tasks from local governments on a contract basis.

1. Municipal sewerage: Two types of municipal sewerage systems are in place. In one, municipal governments collect and treat wastewater. In the other, municipal governments collect wastewater with their sewer network that connects the manholes to the prefecture’s trunk sewer.

2. Prefecture sewerage: Prefecture sewerage receives wastewater from two or more municipalities and transports it to WWTPs for treatment.

3.1.3 Hydrological Cycle and Sewerage

The hydrological cycle begins with rainwater flowing on the ground surface and partially infiltrating into the soil while the remaining flows into rivers and lakes. Surface and groundwater is used for human consumption and then flows down to rivers and seas. Water evaporates continuously by solar energy from the surface water, soil, and sea. It turns into clouds and returns to the ground in the form of precipitation. This is the complete natural hydrological cycle.

Industrialization and urbanization have made it impossible for the natural purification capacity to treat wastewater. Sewerage is man-made, but it plays an important role in the hydrological cycle for the management of sanitary wastewater and storm water, as shown in Figure 3.4.
3.2 Planning of Sewerage

3.2.1 Principle

The fundamental roles of sewerage are treatment of sanitary wastewater and drainage of storm water. Biosolids, grit, screenings, and scum are generated as by-products of sanitary wastewater treatment. Without treating and disposing of those by-products safely and Surely, sustainable wastewater treatment is not possible. In the planning of sewerage, both sanitary wastewater and storm water need to be considered and not only liquid but solid by-products also have to be considered.

In recent years, due to changes in economic conditions and water conservation, reduction of wastewater generation per capita has occurred, so that many municipalities have faced shrinking revenue and deficit. In order to sustain sewer services, a reduction of operation and investment costs, setting a reasonable fee, and increasing the ratio of house connections to public sewers are absolute requirements.

Wastewater collection and treatment consume a lot of energy in pumping, aeration, sludge transport, and treatment. The more advanced the treatment used, the more energy is needed. Sewerage planning focuses on minimizing the life cycle cost for the total capital investment, operation, and maintenance by using energy-efficient equipment and automation systems [2].

3.2.2 Type and Nature of Sewerage Plans

Sewerage plans include a master plan and an implementation plan. A master plan forms the outline of a sewerage system based on natural and social conditions. The master plan should be consistent with other sectors’ master plans such as those for environment, economic development, water resource development, water supply, and so on. An implementation plan must be consistent with the master plan. In many cases, it takes a phased approach.

Sewerage is made up of a sewer network, pumping stations, and WWTPs. They are connected and related to each other to form a system. The master plan is the backbone of the system.

During or after a project start, it is preferable not to change any part of the implementation plan. A change of one facility or component is likely to influence many other facilities of the system. While making a master plan, however, the freedom to make changes exists but is more difficult and costly afterwards. Therefore, an appropriate master plan is very important for successful project implementation. Figure 3.5 shows a series of steps in a master plan from operation to management of a sewerage plant.
3.2.3 Process of Sewerage Planning

The process of creating a master plan includes formulation of a basic policy, necessary data collection, prediction, analysis, evaluation, and decision [3] (see Figure 3.6).

1. **Formulation of basic policy:** Based on local and national requirements for sewerage services, a basic policy should be decided taking the following points into account:
   a. Setting a clear goal is necessary. An example is to meet the environmental quality standard of receiving water bodies.
   b. Priority should be given to several goals such as sanitation improvement of individual properties, pollution control of public water, urban flood control, and so on.
   c. Feasibility of meeting the goals needs to be studied to identify what obstacles exist or will appear in the future.

2. **Data collection:** A master plan normally has a 20-year planning horizon. Necessary basic information includes social data such as population, economic data such as industry sales output, and natural data like weather and geography. These sets of data are used to determine the flow and quality of wastewater coming into a sewerage system.

3. **Prediction:** The planned flow for sanitary wastewater and storm water (wastewater flow) and the planned pollutant load are predicted using a variety of base data. These data include sanitary wastewater generation per person per day, population, industry sales output, precipitation, and runoff rate. The base data also need to be predicted 20 years ahead based on the past trend.

4. **Analysis:** Several alternatives are proposed for the trunk sewer route, location of WWTPs, and layout of WWTP facilities. Then, they are compared with each other based on planning assessment criteria for analysis (see Table 3.1).

![FIGURE 3.6 Process of planning.](image)

<table>
<thead>
<tr>
<th>Basic policy</th>
<th>Data collection</th>
<th>Prediction</th>
<th>Facility planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>* Target year</td>
<td>* Natural condition</td>
<td>* Planned wastewater flow</td>
<td>* Sewer</td>
</tr>
<tr>
<td>* Planning area</td>
<td>* Related plans</td>
<td>* Planned pollutant loads</td>
<td>* Pumping stations</td>
</tr>
<tr>
<td>* Sewer type</td>
<td>* Pollutant loads</td>
<td>* Existing facilities</td>
<td>* WWTPs</td>
</tr>
</tbody>
</table>

### TABLE 3.1 Requirement of Sewerage Plan

- The plan shall collect and treat sanitary wastewater and recycle the by-products
- It shall drain storm water and discharge it to the public waters
- It shall be made on long-term perspective
- It shall absorb changes in economic and social situations
- It shall enable economical and easy maintenance
- It shall comply with laws and regulations
- It shall conform to the master plan
5. **Evaluation**: Alternative plans are evaluated to see if they meet the objectives of sewerage according to local and national requirements.

6. **Decision**: Based on the process mentioned earlier, a sewerage plan is formalized after authorization of the central or prefectural government.

### 3.2.4 Basic Items in Planning

The target year, area, sewer type, outfall, and high water level of receiving water are the basis of a sewerage plan.

#### 3.2.4.1 Target Year

The capacity of a sewerage system needs to be decided based on the long-term prediction of its usefulness. Useful sewerage facilities have a long life and therefore their construction also takes longer. In the case of sewers, phased construction or installation is technically difficult. However, the future is uncertain. As a compromise for deciding a foreseeable future period, the target of 20 years ahead of the base year is often employed.

#### 3.2.4.2 Area and Sewer Type

The planning area should be the area, which will be urbanized by the target year. Relevant urban plans need to be referred as they designate the urbanization area and greenbelt area.

The sewer type includes a combined system and a separate system. A separate system is desirable but a combined system is an option if the receiving water is not sensitive and appropriate measures are taken. Features and precautions for both systems are described as follows with a comparison summary (see Table 3.2).

1. **Separate system**: A separate system accommodates sanitary wastewater and storm water in separate sewer lines. This is the standard for new projects. The feature and cautions are as follows.
   a. **Inflow and infiltration**: As sanitary and storm sewer lines are installed in parallel, wrong connections may occur. Poor cleanout cover allows storm water to enter the sanitary line and groundwater infiltrates, wearing out the sanitary line. If a sanitary sewer alone is installed as a priority, the property owner may connect the house storm water line to the public sanitary line. These situations lead to sanitary sewer overflow and pollution problems in rainfall events. In a separate system, supervision and training of plumbing work are very important to avoid wrong connections and poor workmanship.
   b. **Pollution by way of storm sewer line**: A separate sewer system is desirable because it is designed to treat sanitary wastewater all the time. However, runoff contains pollutants from urban surfaces or farmland. The pollutants directly enter public waters and cause pollution in some cases.
   c. **Depth of sanitary sewer**: A sanitary sewer line tends to be deep because a steep slope is necessary to secure a minimum flow rate due to reduced flow upstream of a network. Consequently, lateral lines connecting to the main sewer should be deep as well.
   d. **Congestion of underground utility line**: In a separate system, two sewer lines are normally installed under the roads for sanitary wastewater and storm water. However, where trunk lines are installed under the roads, another line for collectors is needed. Not only sewers but also other utility lines such as gas, water supply, electricity, and communication are in place. Congestion of utility lines is likely to lead to high installation cost of sewers due to temporary relocation work. Therefore, trunk sewers need to be planned under big roads.
TABLE 3.2  Comparison of Sewer Types

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Combined</th>
<th>Separate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction</td>
<td>Ease of work: Single sewer installation reduces chances of conflicting with other utility lines. Combined sewer diameter is larger than separate sanitary sewer with the same dry weather flow.</td>
<td>Installation of two separate lines in narrow roads is difficult. A sanitary sewer with small diameter needs a steep slope leading to deep installation.</td>
</tr>
<tr>
<td>Cost</td>
<td>Single installation reduces the cost.</td>
<td>Two-line installation is costly, but only sanitary line installation is less costly compared with combined system.</td>
</tr>
<tr>
<td>Operation and maintenance</td>
<td>Deposition in sewer: Big diameter and mild slope cause deposition of solids. The deposited solids are flushed by wet weather flow.</td>
<td>Deposition in a sanitary line is less likely. A storm line situation is the same as a combined line.</td>
</tr>
<tr>
<td></td>
<td>Grit from surface: Grit inflow occurs, leading to wear of machinery and deposition.</td>
<td>There is little grit inflow for a sanitary sewer. A storm sewer has the same situation as a combined one.</td>
</tr>
<tr>
<td></td>
<td>Ease of inspection and cleaning: Big diameter is easy for inspection but difficult to clean.</td>
<td>Small diameter of a sanitary line is likely to clog, but easy to clean. A gutter for drainage tends to have much sedimentation.</td>
</tr>
<tr>
<td></td>
<td>Wrong connection: Not applicable.</td>
<td>Supervision of plumbing is necessary. Inflow and infiltration problems are likely.</td>
</tr>
<tr>
<td>Pollution control</td>
<td>CSO: CSO causes pollution. CSO control is necessary.</td>
<td>Sanitary sewer overflow can happen in wet weather.</td>
</tr>
<tr>
<td></td>
<td>Pollution by runoff: Initial runoff is accommodated in the sewer and sent to a WWTP by an interceptor. Additional runoff is discharged as part of CSO.</td>
<td>Storm water is discharged without treatment to waters.</td>
</tr>
<tr>
<td>Land use</td>
<td>The gutter is removed after sewer installation, leading to widening of roads.</td>
<td>The gutter is likely to remain for the collection of storm water.</td>
</tr>
</tbody>
</table>

2. **Combined system**: A combined system accommodates sanitary wastewater and storm water in a single sewer line. It has been used in the center of older cities where urban flood control was a big problem. Its features and caution are described as follows.

   a. **Combined sewer overflows**: At the beginning of rainfall events, a combined sewage system contains high concentration of pollutants as the deposits are flushed and are removed from the inner surface of the sewer line. If it overflows directly to public waters, it causes pollution. When a combined sewer system is used, CSO control is necessary.

   b. **Ease of installation**: A combined sewer system uses a single sewer line for sanitary wastewater and storm water. Therefore, compared with a separate system, installation is easy and less costly. It has been used in the downtown of old cities where urban flood control was imminent. It runs at a relatively shallow depth and has significant advantages in flat areas.

3.2.4.3 **Outfall**

The outfalls to receiving waters are for effluent from WWTPs, CSO from pumping stations, or overflow structures of gravity network. The necessary considerations for outfalls are as follows:

- The location needs to be decided taking into account the planned high water level, use, and water quality standards of receiving waters.
• The location and direction of the outfalls should be decided so that effluent flows away quickly given the current of receiving waters.
• Outfalls need to have a gate if a surge of receiving water level is expected or special measures are necessary to allow continual discharge from the outfall. CSO outfalls should have screens to reduce floatables entering the receiving waters.

3.2.4.4 Planned High Water Level
Planned high water level for sewerage should correspond to the planned high water level of the receiving waters or the highest water level on record. Based on the planned high water level, the hydraulic head and gradient are checked so that gravity drainage and pump drainage areas are discerned. Storm water and treated effluent need to be discharged smoothly in the event of planned high water level.

3.2.5 Data Collection
3.2.5.1 Natural Data
The important point of sewerage planning is to maximize the natural and existing capacities that help reduce the cost of new sewerage systems. Gravity flow is the principle of a sewer network as it reduces the installation and operational costs. Setting the trunk sewer route and locating pumping stations and WWTPs need to observe this principle as much as possible. For storm sewer planning, existing drainage channels should be utilized. These examples show why data collection and additional surveys on current natural and man-made conditions are important. Necessary data are shown by the following:

1. Geography and geology
   a. Geographical map
   b. Geological map, soil condition data, groundwater, and ground subsidence data
2. Hydrology
   a. Flow and water level of rivers, creeks, and channels in the planned area
   b. Longitudinal and cross sections of these areas
   c. Current of sea and lake
3. Weather
   a. Precipitation and flooding
   b. Temperature and wind direction at expected site for pumping stations and WWTPs

3.2.5.2 Relevant Plans
Relevant plans include a water supply plan for domestic and industrial uses, a development plan for industry and residence, and upper development plans. These plans need to be obtained and reviewed to decide the capacity and the location of a sewerage system. The specifics are shown as follows:

1. Long-term plans relating to sewerage planning
2. Urban plan
   a. Urbanization and greenbelt
   b. Zoning plan
   c. Plan for urban streets and highways
   d. Residential development and industrial development plans
3. River plan
   a. Planned longitudinal and cross sections
   b. Planned high water level and flow
   c. Planned low water level and flow
   d. Other river improvement plans
3.2.5.3 Generated and Allowable Pollutant Loads

In planning, the amount of current and future pollutant loads needs to be estimated together with allowable loads to the receiving waters. To do this, the following information is necessary:

1. Generated pollutant loads
   a. Current and future amounts of drinking water supply in its plan
   b. Current and future amounts of industrial water supply in its plan
   c. Population, industry sales output, manufacture, agriculture, and livestock
   d. Wastewater quantity and quality from major factories and commercial facilities

2. Allowable pollutant loads to receiving waters
   a. Current water quality and flow
   b. Environmental water quality standard, location of measurement, and low water flow
   c. Effluent permit

3. Use of water body
   a. Current and future water abstraction for tap
   b. Current and future fishery

4. Current and future plan for water use

3.2.5.4 Existing Relevant Infrastructures

The following facilities need to be surveyed as long as they are relevant:

1. Other underground utility lines
2. Existing sewerage facilities
3. Current situation of human waste disposal
4. Current highways and streets

3.2.5.5 Recycling and Use of Sewerage Asset

In the planning, recycling of energy, water, and sludge as well as open spaces for sewerage facilities needs to be studied. Other wastewater operators and solid waste disposal operators should be referred. The following are recyclable or usable assets:

1. Water reclamation
2. Sludge recycling
3. Footprint of WWTPs and pumping stations
4. Open space of sewer cross section
5. Heat of sanitary wastewater

3.2.5.6 Others

If necessary, the following should be surveyed:

1. Cultural heritage and historic ruins
2. Earthquake, tsunami, seiche, storm surge, and tropical cyclone

3.2.6 Treatment and Reclamation of Sanitary Wastewater

3.2.6.1 Planned Population

Planned population is the base for planned sanitary wastewater flow. Predictions are made for the total population and its distribution in the planned area in the target year.

1. Planned total population: At first, based on the past trend, prediction is made for the planned total population in the target year. Then, the figure is adjusted so that it fits the predictions made by
higher relevant authority predictions. Careful consideration is needed to avoid overestimation, especially in the area where major development for a housing complex is planned.

2. Distribution of population: Planned total population is distributed in the planned area corresponding to the land use plan and population density.

3. Daytime population: Planned population is the nighttime population or the number of registered residents. However, in big business and commercial districts, population inflow during the daytime is considerable. This influence is also considered in the planned sanitary wastewater flow. Therefore, planned daytime population needs to be estimated. Tourist places receive many seasonal and/or weekend visitors, and this population needs to be estimated in addition to residents.

3.2.6.2 Planned Sanitary Wastewater Flow

Planned sanitary wastewater includes domestic wastewater, commercial wastewater, industrial wastewater, tourism wastewater, groundwater, and other wastewater. By totaling the flow of each, planned daily average sanitary wastewater flow, planned daily maximum sanitary wastewater flow, and planned hourly maximum flow are estimated.

1. Domestic sanitary wastewater: Domestic wastewater is generated from ordinary households. Planned domestic sanitary wastewater is sanitary wastewater generated per person per day multiplied by planned registered population.

2. Commercial wastewater: Planned commercial wastewater flow should refer to planned commercial water supply flow if it is clear. If not, planned commercial wastewater flow is calculated either from daytime population or from setting an incremental parameter for domestic wastewater by land use in zoning.

3. Industrial wastewater: Wastewater flow from existing major factories needs to be measured as this can influence the planning of WWTPs. Wastewater flow from minor planned factories is estimated by using industrial database or by multiplying the average flow per production output with actual production output by industry type.

4. Tourism wastewater: Tourism wastewater comes from tourist usage. Tourism wastewater flow should be calculated for daytrip and overnight tourists separately by multiplying the number of tourists with wastewater flow per tourist.

5. Other wastewater: Many touristic places often have hot springs. In general, it is necessary to study whether or not hot spring water should be treated as sanitary wastewater. The ways hot spring water is used need to be inspected for its acceptance. If used hot springs are accommodated into sanitary sewer lines, this needs to be added to the planned sanitary wastewater flow.

6. Groundwater: It is difficult to assess how much infiltration of groundwater into sanitary sewers occurs in dry weather when sewer lines are newly installed. When part of the sewer network is already in place, groundwater infiltration is estimated by subtracting metered water consumption flow from dry weather sanitary wastewater flow. Another way to estimate groundwater infiltration is by reference to similar sewer networks already in place like those of neighboring municipalities with similar sewer materials. If these methods are not feasible, 10%–20% of the total domestic and commercial sanitary wastewater is regarded as groundwater infiltration.

7. Planned daily maximum flow of sanitary wastewater: Planned daily maximum flow of sanitary wastewater is maximum daily flow out of 365 days in the target year. This flow is used to design WWTPs. Planned daily maximum flow of sanitary wastewater is daily maximum flow per person multiplied by planned population, plus industrial wastewater flow, groundwater flow, and other flows.

8. Planned daily average flow of sanitary wastewater in dry weather: Planned daily average flow of sanitary wastewater is the total amount of sanitary wastewater generated in the target year divided by 365 days. It is used for the prediction of tariff revenue. Planned daily average flow of sanitary wastewater is normally 70%–80% of planned daily maximum flow of sanitary wastewater.
9. **Planned hourly maximum flow of sanitary wastewater**: Planned hourly maximum flow of sanitary wastewater is a peak hour flow on the day when planned daily maximum flow of sanitary wastewater is expected. It is used to design sewers, pumping stations, and the pumps and channels in WWTPs. Planned hourly maximum flow is around 1.3–1.8 times as much as planned daily maximum flow for medium to large sewer systems. The figure may reach more than twice the quantity in some small systems and systems receiving a lot of tourism wastewater.

10. **Planned wet weather hourly maximum flow of sanitary wastewater in wet weather**: For a combined sewer system, to reduce CSO pollution, planned wet weather hourly maximum flow of sanitary wastewater will be three times as much as that of dry weather and will be accommodated in interceptor sewers.

11. **Wet weather inflow and infiltration**: For a separate sewer system, wet weather inflow and infiltration to sanitary sewers may arise due to poor house sanitary sewers, keyhole of manhole cover, wrong connection of house storm drain, and raised groundwater level on rainfall events with a poor public sewer system. It is observed nationwide, but difficult to predict the flow in the planning stage. Therefore, there is no need to take it into consideration in the plan.

### 3.2.6.3 Planned Pollutant Load

1. **Pollutant load of domestic sanitary wastewater**: Pollutant load of domestic sanitary wastewater is from human waste and gray water. The results of a survey on pollutant load per person per day are shown in Table 3.3.

2. **Pollutant load of commercial sanitary wastewater**: Pollutant load of commercial sanitary wastewater differs with types of commerce and whether or not they have water reclamation within their property. Locally specific prediction is necessary. If it is difficult to make local predictions, the quality of commercial sanitary wastewater could be assumed to be the same as that of domestic sanitary wastewater.

3. **Pollutant load of industrial sanitary wastewater**: Basically, pollutant load of major industrial sanitary wastewater should be surveyed. Pollutant load from minor factories and planned factories can be predicted by multiplying the average quality by factory type by the average discharge by factory type. The quality of discharge from factories with high concentration of pollutants should be assumed to be within a permit level by the use of pretreatment facilities.

4. **Pollutant load of livestock sanitary wastewater**: Cattle and pig barns generate much higher pollutant load compared with human-produced wastewater. This needs to be reflected in the plan appropriately.

5. **Other pollutant loads**: Other pollutant loads include those from human WWTPs, hospitals, laundry, solid waste incineration plants, and tourism facilities. These loads need to be reflected into the sewerage plan adequately.

### 3.2.6.4 Planned Influent Quality and Effluent Quality

Planned influent quality is planned daily influent pollutant load divided by planned daily average flow. Planned effluent quality needs to be set for biochemical oxygen demand (BOD), total nitrogen (TN), and total phosphorus (TP). The following table presents the study results on pollutant load (g/Person/Day):

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Breakdown</th>
<th>Average</th>
<th>Human Waste</th>
<th>Gray Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biochemical oxygen demand</td>
<td></td>
<td>58</td>
<td>18</td>
<td>40</td>
</tr>
<tr>
<td>Chemical oxygen demand</td>
<td></td>
<td>27</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Suspended solids</td>
<td></td>
<td>45</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Total nitrogen</td>
<td></td>
<td>11</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>Total phosphorus</td>
<td></td>
<td>1.3</td>
<td>0.9</td>
<td>0.4</td>
</tr>
</tbody>
</table>
total phosphorus (TP) by referring to the environmental quality standard of receiving water, which is technically achievable by treatment method, permit by law, and consistency with the upper plan.

### 3.2.6.5 Sewer Planning

Sewer planning must consider the following requirements:

- Gravity flow is the basis of a sewer network. In some geographies, pipe flow with either vacuum or pressure system may be feasible. The size of a separate sanitary sewer shall be decided to accommodate the planned hourly maximum flow of sanitary wastewater. The size of a separate storm sewer shall be decided to accommodate the planned storm water flow.
- The interceptor of sanitary wastewater in a combined system shall be decided to accommodate the planned wet weather flow of sanitary wastewater.
- The position of the sewer shall be decided considering the geography, geology, width of roads, and the positions of other utility lines.
- The shape and slope at the cross section of the sewer shall have the velocity to avoid deposition and wear.
- The sewer shall have a structure with no exfiltration and infiltration.
- The sewer shall be underground except for the open channel of the separate storm sewer and the open channel to the outfall from WWTPs.
- The sewer shall not be excessively deep while securing minimum allowable depth by the road authority.
- Inverted siphon shall be avoided except in inevitable cases.
- Main roads accommodate other utility lines such as water and gas. Consultation with other utility companies and the road authority shall be done while making cross section maps.

### 3.2.6.6 Pump Station Planning

Sanitary wastewater pumps include lift stations and final pumping at the WWTP. Lift stations are used to prevent the sewer from being too deep. Final pumps are placed in WWTPs to feed wastewater for the liquid treatment process. When storm water does not drain by gravity, storm water pumps should be planned. Storm water pumps should be able to drain planned storm water flow at planned high water level of the receiving water.

In a combined sewer system, sanitary wastewater pumping stations and storm water pumping stations are located neighboring each other. The following items need to be kept in mind for planning:

- Pumping stations shall be located considering the factors of economy, ease of construction, ease of operation and maintenance, and impact to the surrounding environment.
- Sanitary wastewater pumps of a separate sewer system shall pump the planned hourly maximum flow.
- Sanitary wastewater pumps of a combined sewer system shall pump the planned wet weather sanitary wastewater flow.
- The electrical system shall be housed within a watertight chamber, with as much equipment and controls at maximum elevation as possible.
- The layout of pumping stations shall match the surrounding environment.
- In case of a small capacity, when there is no need of grit removal, grinder pumps are used and housed in the manholes.

### 3.2.6.7 Planning of a WWTP

Planning of a WWTP shall consider the following:

- Effluent permit
- Location
• Site area
• Planned sanitary wastewater flow
• Ground level
• Selection of treatment method
• Harmonization with neighborhood

The liquid treatment method for the removal of organics is conventionally used for medium to large capacities with a population of over 10,000 and oxidation ditch for small capacities.

### 3.2.6.8 Water Reclamation

In case water reclamation is planned, its use and supply situations in target areas shall first be surveyed and then the necessary add-on treatment planned. If regulatory authorities set the permit for reclaimed water, it shall be met.

### 3.2.6.9 Advanced Treatment

In case biological secondary treatment cannot meet the target effluent quality, advanced treatment shall be undertaken. Advanced treatment includes the internal mixed-liquor recycling process for nitrogen removal, the anaerobic–oxic (A/O) activated sludge process and the coagulant adding process for phosphorus removal, and the A^2/O process for the removal of both nitrogen and phosphorus.

### 3.2.7 Sludge Treatment and Recycling

The sludge shall be treated and recycled as follows:

1. **Planned sludge generation**: Planned sludge generation shall be estimated from planned daily maximum sanitary wastewater flow, concentration of suspended solids, removal rate, and water content of sludge.

2. **Treatment process**: The sludge treatment process shall match a liquid treatment process, using recycling and a disposal method. An example of commonly taken pathways is shown in Figure 3.7.

3. **Recycle use**: Sludge is generated as long as wastewater treatment continues. The amount continues to increase with network expansion and continuation of liquid treatment. It is necessary to seek sustainable recycling methods.

### 3.2.8 Storm Water Drainage Planning

#### 3.2.8.1 Planned Storm Water Flow

Planned storm water flow is calculated by the following formula:

![Flowchart of sludge](image-url)
where

\[ Q = \frac{1}{360} \cdot C \cdot I \cdot A \] (3.1)

\[ I = \frac{a}{(t^n + b)^n} \]

where

- \( t \) is the travel time (s)
- \( a, b, m, n \) are the statistically derived coefficients

### 3.2.8.2 Reduction of Runoff

The method to reduce runoff includes storage and infiltration as shown in Figure 3.8.

### 3.2.8.3 Storage Tank and Sewer for Flood and CSO Control

These structures are constructed to control urban flood and to regulate the amount of storm water entering the river channels through storm sewers or combined sewers so that river floods are prevented.

To reduce the CSO pollution, the first overflows from a gravity sewer line and the first discharges from the storm water pumps in a combined system are stored in a tank. After rainfall events, the stored combined wastewater is sent to WWTPs.

**FIGURE 3.8** Runoff reduction.
3.2.9 Implementation Plan

3.2.9.1 Efficient Planning

Construction of the main components in a sewerage system such as the trunk sewer line, pumping stations, and WWTPs shall follow a phased implementation plan to meet the actual inflow of wastewater while avoiding overcapacity. Equipment shall be selected not only by initial cost but also running cost. In the beginning of operation, special consideration should be given to little inflow of wastewater. Examples of considering factors for each component are shown in the following sections.

1. Sewer: A sewer cannot help being oversized in the initial stage when the network and the house connections are incomplete. The following actions might be feasible in some cases locally:
   a. By dividing the planned flow into early flow and future expected flow, early flow is accommodated in the first installed sewer, and the future flow will be accommodated in a second different sewer that will be installed at the time of construction of the new road. Installation of another sewer with the new road construction can lower the initial cost.
   b. By connecting two neighboring treatment areas with an interceptor, one WWTP with a single trunk line can handle the wastewater generated from two planned treatment areas. After the increase of wastewater by the expanding network and collectors, another interceptor line and WWTP are constructed. The extra interceptor will be used for disaster management and a drying operational WWTP for rehabilitation work.

2. Pumping stations: Civil engineering structures should be constructed fully from the beginning even if the initially entering wastewater is relatively small. However, pumps can match the actual flow. The initial measures are as follows:
   a. Use of submersible pumps may be economical.
   b. Manhole grinder pumps may be enough to delay the construction of pumping stations.

3. WWTPs: In the planning, the layout, the structures, and the required performance are set to meet the planned wastewater flow in 20 years. On the other hand, projects are implemented phase by phase. In each phase or intermediate years, effective and efficient performance is required. In municipalities with declining population, a reduction of the initial investment may be needed. Some measures that could be taken are described as follows:
   a. Prefabricated treatment system may be enough at the initial stage.
   b. Grit chamber, pump well, and first clarifier may be substituted with manhole grinder pump. When the wastewater inflow increases, these facilities are constructed as planned.
   c. Pipe gallery can be delayed by ground or aerial installation.
   d. In the beginning, few operators are stationed. Operation building can be delayed.
   e. Chlorination tank can be delayed by the use of an outfall channel.

4. Types and Combinations of Pump Equipment: The types and combination of pump equipments are as follows:
   a. The types and combinations of capacities shall match the rising trend of the inflow.
   b. The initially installed pumps are expected to reach their full capacities within a few years.

3.2.10 Use of Sewerage Resource and Space

3.2.10.1 Water Reclamation

Treated wastewater is a valuable water resource and this amount continues to grow as a sewerage system expands. Current use of treated wastewater in Japan is shown in Figure 3.9. For the use of treated wastewater, the quality permit is stipulated by application, and it is necessary to meet the requirement.
3.2.10.2 Sludge Recycling

Sludge generation continues to increase with sewerage expansion and the introduction of advanced treatment. The current recycling use of sludge in Japan is shown in Figure 3.10. In recycling, the following need to be considered:

- Effective and efficient use of material and energy in sludge
- Matching supply and demand by securing customers
- Education and advertisement on the recycled products for stakeholders

![FIGURE 3.10 Sludge recycling in Japan (2010).](image-url)
3.2.10.3 Use of Sewerage Facility Space

1. Use of sewer cross section: A sewer network is connected to office buildings and individual houses. As wastewater runs by gravity, there is an open space inside the sewer. By installing a fiber-optic cable in the sewer, a reliable information network is made possible at relatively low cost. There are three uses of fiber-optic cables:
   a. The sewer operator’s use for effective and efficient operation and maintenance of pumping stations and WWTPs by connecting one to the other
   b. The local government’s use
   c. The ordinary citizen’s use

2. Use of open space of WWTPs and pumping stations: WWTPs and pumping stations are important public assets in an urban area. The open space should be used wisely, for parks, sport fields, community centers, and office buildings. When WWTPs and pumping stations are rehabilitated, the use of open space should be planned to enrich these facilities.

References