Chapter-five
Water Quality In Urban Area

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Introduction

- Wastewater, or sewage, is one of the two major urban water-based flows that form the basis of concern for the drainage engineer & hydrologists .
- Wastewater is the main liquid waste of the community.
- Safe and efficient drainage of wastewater is particularly important to maintain public health (b/c of the high levels of potentially disease forming micro-organisms in wastewater) and to protect the receiving water environment (due to large amounts of oxygen consuming organic material and other pollutants in wastewater).

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- The basic sources of wastewater are summarized in Fig. 5.1 and consist of:
  1) Domestic
  2) Non-domestic(commercial and industrial)
  3) infiltration/inflow.

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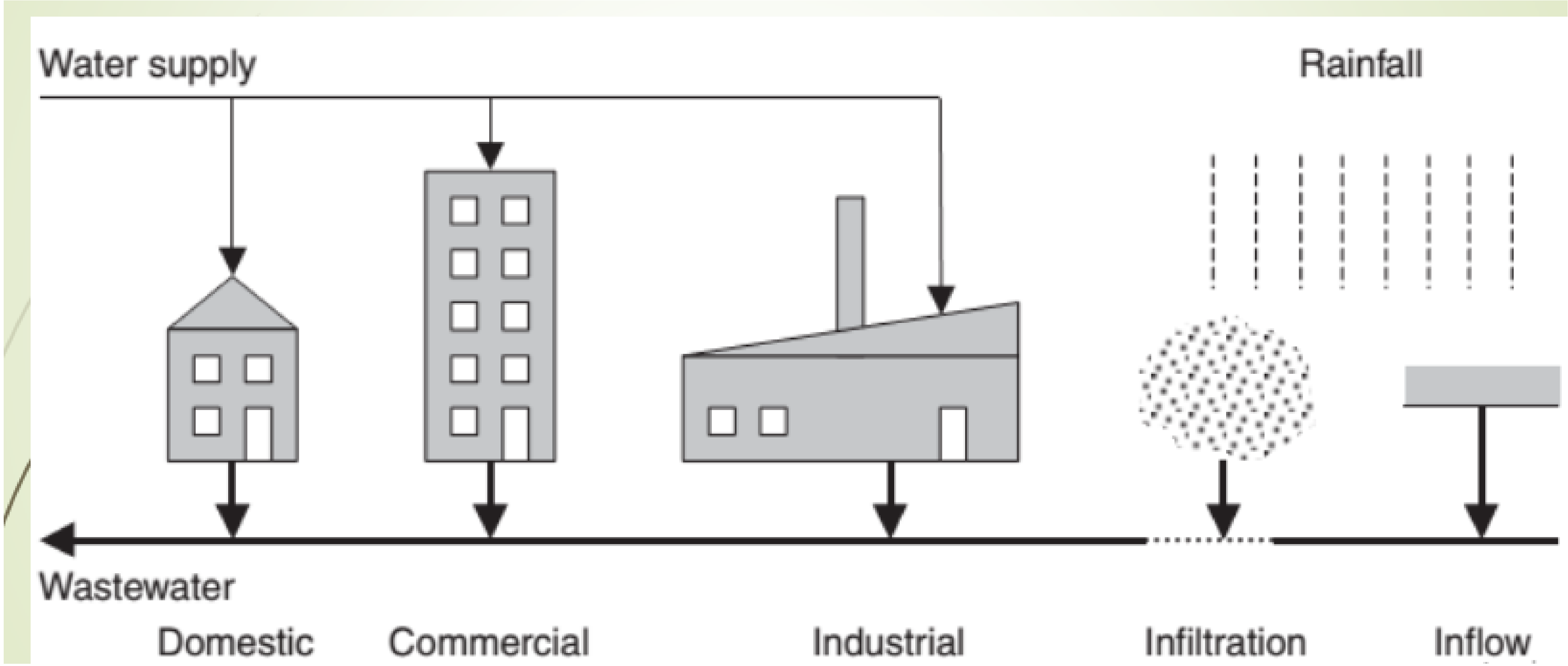

Fig. 5.1 Sources of wastewater

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- In many networks, the domestic component of wastewater is the most important. Domestic wastewater is generated primarily from residential properties but also includes contributions from institutions (**for example, schools, hospitals**) and recreational facilities (such as **leisure centers**). In terms of flow quantity, the defining variable is domestic water consumption, which is linked to **human behavior and habits**. In fact, very little water is actually consumed, or lost from the system.

5.1.2 Non-domestic

Commercial

- This category includes businesses such as shops, offices and light industrial units, and commercial establishments such as; restaurants, laundries, public houses and hotels.
- Demand is generated by drinking, washing and sanitary facilities, but patterns of use are inevitably different to those generated by domestic usage.

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- Industrial
  The component of wastewater generated by industrial processes can be important in specific situations, but is more difficult to characterize in general because of the large variety of industries.
- In most cases, effluents result from the following water uses:
  - sanitary (e.g. washing, drinking, personal hygiene)
  - processing (e.g. manufacture, waste and by-product removal, transportation)
  - cleaning
  - cooling.

5.2 Water Quality

- Hydrology is a science that is concerned with, not only the quantity but also the quality of water.
- In the past, there has been a tendency amongst civil engineers not to concern themselves in any detail with the quality aspects of wastewater and storm water which is conveyed in the systems they design and operate.

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- This is a mistake for several reasons:

1) Significant quality changes can occur in the drainage system.

2) Decisions made in the sewer system have significant effects on the WTP performance.

3) Direct discharges from drainage systems (e.g. combined sewer overflows, storm water outfalls) can have a serious pollution impact on receiving waters.

Therefore, **this chapter** looks at the **basic approaches** to **characterizing wastewater** and **storm water** including outlines of the main water quality tests used in practice.

5.2.1 Basics

1.Strength

- Water has been called the ‘universal solvent’ because of it sability to dissolve numerous substances.
- The term ‘water quality’ relates to all the constituents of water, including both dissolved substances and any other substances carried by the water.
- The strength of polluted liquid containing a constituent of mass **M** in water of volume **V** is its concentration given by **(c =M/V)**, usually expressed in **mg/l**.
- This is numerically equivalent to parts per million (ppm) assuming the density of the mixture is equal to the density of water (**1000 kg/m3**).
- The plot of concentration c as a function of time t is known as a **pollutograph**

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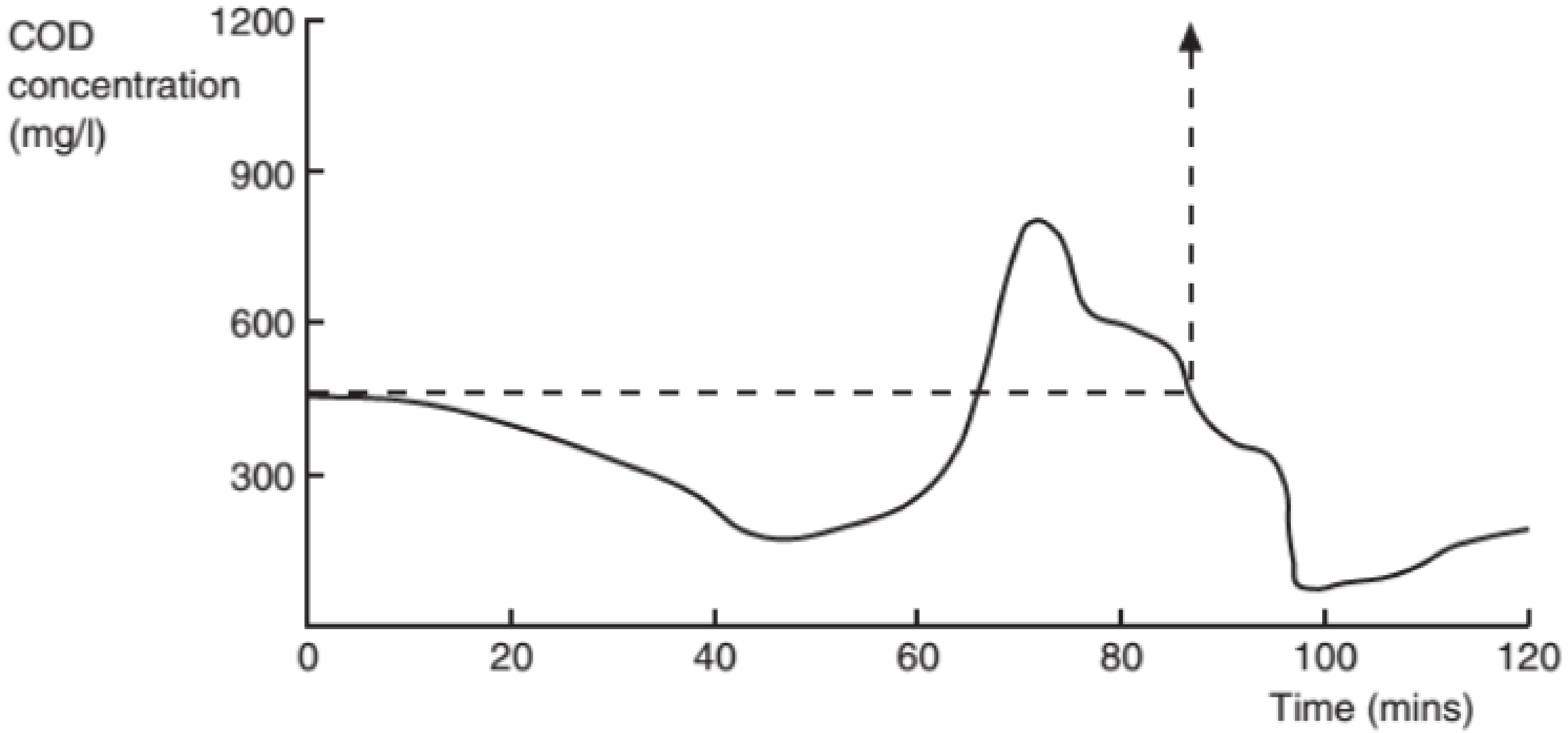

Fig.5.2 Storage: interpreting simulated pollutograph

Example 5.1

- A laboratory test has determined the mass of constituent in a 2 litre wastewater sample to be 0.75 g. What is its concentration(c) in mg/l and ppm? If the wastewater discharges at a rate of 600 l/s, what is the pollutant loadrate (L)?

$$c = \frac{M}{V} = \frac{750}{2} = 375 \text{ mg/l} = 375 \text{ ppm}$$

$$L = cQ = 0.375 \times 600 = 225 \text{ g/s}$$

2.Equivalent concentrations

- It is common practice when dealing with a pollutant (X) that is a compound to express its concentration in relation to the parent element (Y).
- This can be done as follows:
- Concentration of compound X as element Y=

$$\text{concentration of compound } X \times \frac{\text{atomic weight of element } Y}{\text{molecular weight of compound } X}$$

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- The conversion of concentrations is based on the gram molecular weight of the compound and the gram atomic weight of the element.
- Expressing substances in this way allows easier comparison between different compounds of the same element, and more straightforward calculation of totals.

Example 5.2

A laboratory test has determined the mass of orthophosphate,(PO4-3) in a 1 L stormwater sample to be 56 mg. Express this in terms of phosphorus (P).

Gram atomic weight of P is 31.0 g

Gram atomic weight of O is 16.0 g

Gram molecular weight of orthophosphate is $31 + (4 \times 16) = 95$ g

Hence from equation

$$56 \text{ mg } PO_4^{3-}/l = 56 \times \frac{31 \text{ g}P}{95 \text{ g } PO_4^{3-}} = 18.3\ PO_4^{3-}-P/l$$

5.2.2 Parameters

- There is a wide range of quality parameters used to characterize wastewater and these are :

i. Sample sizing & analysis

ii. Solids

iii. Oxygen

i. Sampling and analysis

There are three main methods of sampling:

1) Grab,

2) Composite and

3) Continuous

- Grab samples;- are simply discrete samples of fixed volume taken to represent local conditions in the flow. They may be taken manually or extracted by an automatic sampler.
- Composite sample;- consists of a mixture of a number of grab samples taken over a period of time or at specific locations, taken to more fully represent the composition of the flow.

Continuous sampling; consists of diverting a small fraction of the flow over a period of time.

This is useful for instruments that give almost instantaneous measurements, e.g. pH, temperature.

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- In sewers, where flow may be stratified, samples need to be taken throughout the depth of flow if a true representation is required.

Mean concentrations can then be calculated by weighting withrespect to the local velocity and area of flow.

ii. Solids

- Solid types of concern in wastewater and storm water can broadly be categorized into four classes:

a) Gross ,

b) Grit ,

c) Suspended &

d) Dissolved (as shown in the table 5.1, below).

- Gross and suspended solids may be further sub-divided according to their origin as wastewater and storm water.

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Solid type	*Size (μm)*	*SG (–)*
Gross	>6000	0.9–1.2
Grit	>150	2.6
Suspended	≥0.45	1.4–2.0
Dissolved	<0.45	–

Table 5.1 Basic classification of solids

A. Gross solids

- There is no standard test for the gross solids found in wastewater and storm water, but they are usually defined as solids (specific gravity (SG)0.9–1.2) captured by a 6 mm mesh screen (i.e. solids >6 mm in two dimensions).
- Gross storm water solids consist of debris such as bricks, wood, cans, paper, etc.
- These can cause maintenance problems by deposition and blockage, and can cause blinding of screens at WTPs, particularly during storm flows.

B. Grit

- Again, there is no standard test for determination of grit, but it may be defined as the inert, granular material (SG≈2.6)retained on a 150µm sieve.
- Grit forms the bulk of what is termed sewer sediment.

C. Suspended solids

- Suspended solids (SS) content: is the solid matter (both organic and inorganic) maintained in suspension, and retained when a sample is filtered (0.45µm pore size).
- In the SS test, the residue is washed, dried and weighed under standard conditions and expressed as a concentration.
- The accuracy of the SS test is approximately 15%.

D. Volatile solids

- The **solids retained during the SS test can be ignited at 550 °C** in a muffle furnace.
- The **residue** is known as **non-volatile** or **fixed material**.
- The volatilized fraction (the **volatile solids**) gives an indication of the organic content of the SS.

iii. Oxygen

- A key to understanding the reactions occurring anywhere within the urban drainage system is measurement and prediction of the oxygen levels in the aqueous phase.
- Dissolved oxygen (DO) levels depend on **physical**, **chemical** and **biochemical activities** in the system.

Dissolved oxygen

- Dissolved oxygen (DO) can be measured analytically using the Winkler titration method.
- Titration is a laboratory technique where measured volumes of a reagent (the titrant) are incrementally added to a sample up to the equivalent amount of the constituent being analyzed.
- Membrane electrodes are now more commonly and conveniently used both in the laboratory and for in situ measurements.
- The concentration of DO is an excellent indicator of the 'health' of a receiving water.
- All the higher forms of river life require oxygen. Coarse fish, for example, require in excess of 3 mg/l (see Table5.3).
- In the absence of toxic impurities, there is a close correlation between DO and biodiversity.

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Table **5.2** Dissolved oxygen concentration (under standard conditions) in water as function of temperature

Temperature (°C)	*DO (mg/l)*
0	14.62
5	12.80
10	11.33
15	10.15
20	9.17
25	8.38
30	7.63

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Table 3.3 Oxygen requirements of fish species (adapted from Gray, 1999)

Characteristic species	*Minimum DO concentration (mg/l)*	*Minimum saturation (%)*	*Comment*
Trout, bullhead	7–8	100	Fish require much oxygen
Perch, minnow	6–7	<100	Need more oxygen for active life
Roach, pike, chub	3	60–80	Can live for long periods at this level
Carp, tench, bream	<1	30–40	Can live for short periods at this level

Example 5.3

- In a standard laboratory test, a crucible and filter pad are dried and their combined mass measured at 64.592 g. A 250 ml wastewater sample is drawn through the filter under vacuum. The filter and residue are then placed on the crucible in an oven at 104 °C for drying. The new combined mass is 64.673 g. The crucible and its contents are next placed in a muffle furnace at 550 °C. After cooling,the combined mass is measured as 64.631 g.

Determine;

- (a) The suspended solids concentration of the sample,
- (b) The volatile fraction of the suspended solids.

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Solution

Mass of suspended solids removed:	
Crucible + filter + solids	= 64.673 g
Crucible + filter	= 64.592 g
Mass of suspended solids	= 0.081 g
Concentration of SS:	
81 (mg)/0.250 (l)	= 324 mg/l
Mass of volatile suspended solids removed:	
Initial crucible + filter + solids	= 64.673 g
Final crucible + filter + solids	= 64.631 g
Mass of volatile solids	= 0.042 g
Volatile fraction of suspended solids:	
42 (mg)/81 (mg)	= 0.52

5.3 Wastewater quality

- Wastewater contains a complex mixture of natural organic and inorganic material present in various forms, from coarse grits, through fine suspended solids to colloidal and soluble matter.
- Much is in the form of highly putrescible compounds. In addition, a small proportion of manmade substances, derived from commercial and industrial practices, will be present.
- In fact, wastewater is **99.9%** water although the remaining **0.1%** is very significant, particularly if it is allowed to enter the environment.

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- Fresh domestic wastewater is cloudy-grey in color with some recognizable solids and has a musty/soapy odor.
- With time (2–6 hours depending on ambient conditions), the waste ‘ages’ and gradually changes in character as a result of physical and biochemical processes.
- Stale wastewater; is dark grey/black with smaller and fewer recognizable solids, and ‘older’ flows can have a pungent ‘rotten eggs’ odor due to the presence of hydrogen sulfide.

Pollutant sources

- Wastewater quality is influenced by the contaminants discharged into it derived mainly from human, household and industrial activities.
- The quality of the carriage water (the original drinking water) or infiltrating groundwater can also be influential.

Human excreta

- Human excreta are responsible for a large proportion of the pollutants in wastewater. Adults produce 200–300 g of faeces and 1–3 kg of urine per day.
- Faeces account for 25–30 g/hd.d of BOD and urine 10 g BOD/hd.d,
- which is 60% of the organic compounds found in wastewater

Toilet

- **Toilet paper** is used in large quantities. Although this disintegrates quickly in the turbulent flow in sewers, it is only slowly biodegradable due to the presence of the cellulose fibres.

- Approximately 7 g/hd.d is disposed of, most of which will become suspended solids (Friedler et al., 1996).

Industry

The characteristics of industrial wastewaters, or trade effluents as they are often called, are similar to those of domestic wastewater in that they are likely to contain a very high proportion of water, and the impurities may be present as suspended, colloidal or dissolved matter.

5.4 Sewer Systems in Urban area

5.4.1 Separate sewer system and combined sewer systems

- Based on the principle of collection, sewers can be separate or combined drains
- Separate sewers: Consists separate collection of municipal wastewaters (black water from toilets, grey water and industrial wastewater) and surface run-off (storm water).
- The separate collection prevent the overflow of sewer systems and treatment stations during rainy periods and the mixing of the relatively little polluted surface run-off.

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- *Combined sewers:*
  - Combined sewer systems are sewers that are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe.
  - Most of the time, combined sewer systems transport all of their wastewater to a sewage treatment plant, where it is treated and then discharged to a water body.
  - Overflow during heavy storms
  - Combined sewer systems are designed to overflow occasionally
  - Occasionally discharge excess wastewater directly to nearby streams, rivers, or other water bodies.

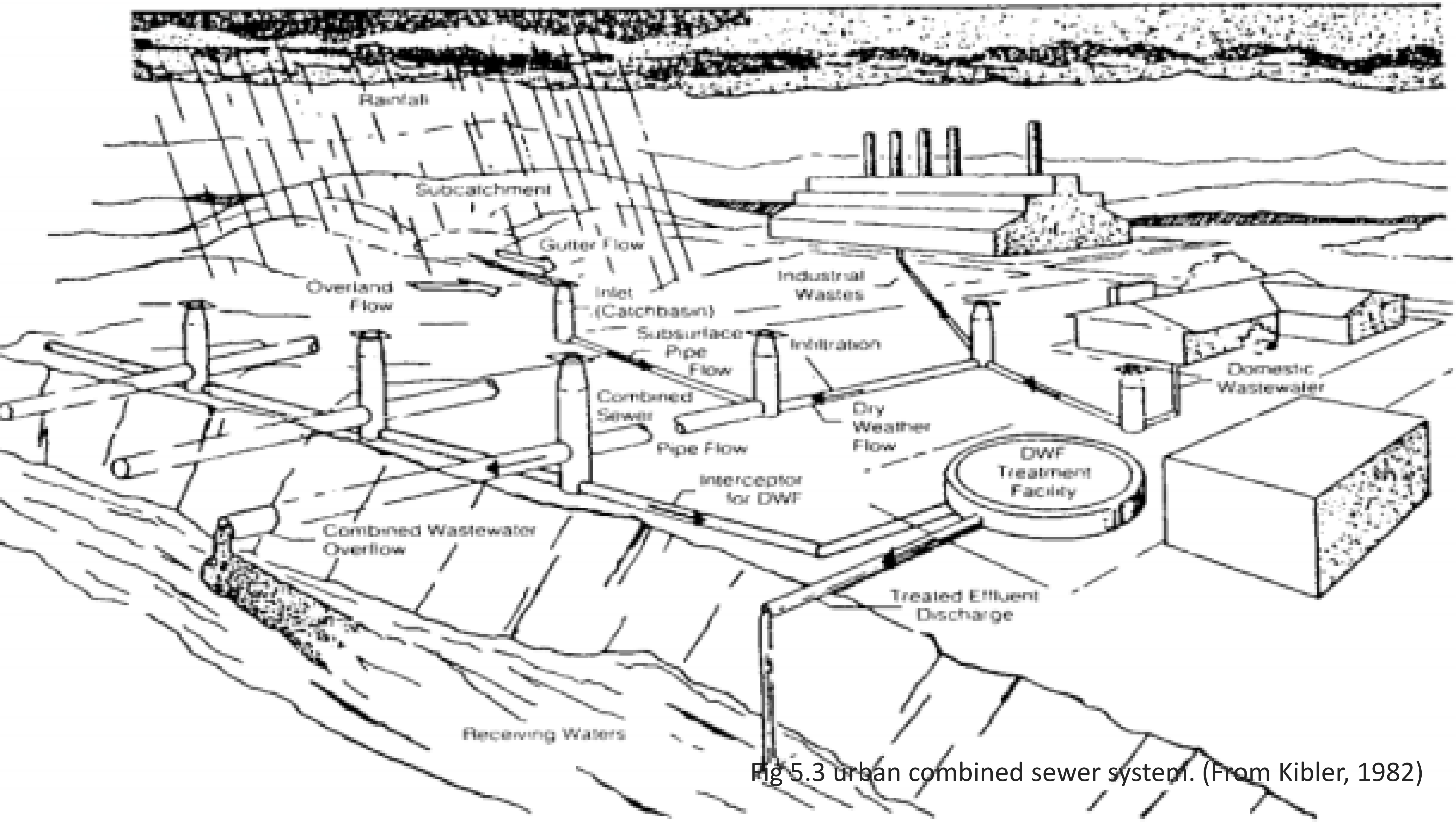

Fig 5.3 urban combined sewer system. (From Kibler, 1982)