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GOVERNMENT OF DUBAI

بـلـديـة دبـي
Dubai Municipality

SEWERAGE DESIGN GUIDELINES

Sewerage and Recycled Water Projects Department

Waste and Sewerage Agency

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LIST OF ABBREVIATIONS

ANSI-HI	American National Standards Institute - Hydraulic Institute
ASCE	American Society of Civil Engineers
CAPEX	Capital Expenditure
DEWA	Dubai Electricity and Water Authority
DI	Ductile Iron
DM	Dubai Municipality
DUSUP	Dubai Supply Authority
DXB	Dubai International Airport
FRC	Fibre-Reinforced Concrete
GPT	Gross Pollutant Trap
GRP	Glass-Reinforced Plastic
HDPE	High Density Poly-Ethylene
HGL	Hydraulic Grade Line
HSE	Health and Safety Executive of the UK
MWL	Mean Water Level
NPSH	Net Positive Suction Head
O&M	Operation and Maintenance
OL	Obvert Level

OPEX	Operational Expenditure
PE	Polyethylene
QA/QC	Quality Assurance and Quality Control
RCP	Reinforced Concrete Pipe
RoW	Right-of-Way
RTA	Roads and Transport Authority of Dubai
SRPD	Sewerage and Recycled Water Projects Department
SS	Suspended Sediment
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
UPS	Uninterruptible Power Supply
uPVC	Unplasticised Poly-Vinyl Chloride
ACPH	Air changes per hour
ADF	Average daily flow
BOD	Biological oxygen demand
CAW	Combined air and water wash
COD	Chemical oxygen demand
DS	Dry solids

DWF	Dry weather flow
FOG	Fats, oil & grease
FST	Final settling tank
l/sec	Litres per second
Lpcd	Litres per capita per day
mg/L	Milligrams per litre
MLR A	Mixed liquor ratio, Available
MLR R	Mixed liquor ratio, Required
MLSS	Mixed liquor suspended solids
MLSS	Mixed liquor suspended solids
MPN	Most probable number
NTU	Nephelometric Turbidity Units
PDF	Peak daily flow
PHF	Peak hourly flow
PMF	Peak monthly flow
PST	Primary settling tank
RAS	Return activate sludge
TKN	Total Kjeldahl Nitrogen
TSS	Total suspended solids

VOC	Volatile organic carbon
WSA	Waste and Sewerage Agency

1. OBJECTIVES

1.1 Introduction

This guide is for use by design consultants, contractors, and developers when planning, designing, and constructing the conventional foul water gravity sewers, property connections, pumping stations, rising/pressure mains, and sewerage treatments in Dubai Emirate intended to be part of Dubai Municipality sewerage system. There shall be no deviation from these guidelines except where formally confirmed by Dubai Municipality (DM) in writing; such deviation from guidelines being technically justified or representing advances in knowledge or technology.

DM is committed for using new and innovative technologies where they, in DM's opinion, represent the best technical solution, provide low life cycle costs and value for money. All technologies will be considered for use by DM providing they have been proven in terms of performance, quality, and cost.

All design shall be based on the guidelines. DM reserves the right not to approve the connection to DM network or adopt any system that fails to meet the minimum standards of these guidelines.

Engineers and other disciplines using this Design Guidelines must be experienced and appropriately qualified professionals who are familiar with the planning, design, construction, operation, and maintenance of drainage networks. The Design Guidelines is to be utilised as guide to good practice and compliance. The Design Guidelines does not absolve users of their professional and contractual responsibilities. The Design Guidelines is not exhaustive in its coverage and is not intended to replace the proven theory listed elsewhere.

Note: The design basis of special works including vacuum sewerage, low pressure sewer networks, sewerage rehabilitation, and special structures such as inverted siphons, vortex drop manholes, energy dissipaters and flow control structures are to be treated on a case-by-case basis and discussed and agreed upon with DM.

1.2 Approvals Process

The Consultant shall submit the design document to DM for review and approval. The design stage wise requirements will be collected from DM before submission of the documents.

1.3 Permanent Works

This guideline applies only to the design of the 'permanent works.' This includes the design of any interim solutions, which may be required until a long-term solution is available. The design of all temporary works required for the construction of the permanent and interim works shall be the responsibility of the Consultant who shall ensure that any such works do not adversely impact the permanent works.

1.4 Innovation

The Consultants and Developers shall encourage the parties involved in the planning, design and construction of a sewerage system to devise innovative solutions and challenge conventional thinking where this could be beneficial to the project and of course to the Emirate of Dubai. Required documentation and sufficient detail must be submitted to DM to allow the proposal to be appraised.

1.5 Copyright

Copyright of the Design Guidelines is the property of DM.

1.6 Updates

This guideline will be revised by DM from time to time to keep up to date with technical developments and improved practices. It is the responsibility of the users to ensure that they are working to the latest issue. DM can be contacted for information on revisions. Any errors that are found or recommendations for improvement shall be notified to DM.

1.7 Inquiries

All inquiries regarding the DM Sewerage Guidelines shall be sent to DM's official incoming email (dm@dm.gov.ae) and copying the SRPD Director and the Head of Projects Planning and Development Section.

2. DESIGN CONSIDERATIONS

2.1 General Planning

A sewerage system shall be designed in four main steps consisting of:

- Preliminary Investigations and Optioneering
- Detailed Survey
- Preliminary Design
- Final Design

The designer shall collect all relevant information relating to the design. This includes digital mapping with all topographical features and contours, future development plans for the area, details of existing sewerage assets both within and adjacent to the design area, details of other utility assets, hydrological information, current and projected populations, and per capita consumption information.

A detailed on-site survey may be required to validate the critical design information before the initial desktop design is undertaken. During the project optioneering phase, the "life cycle cost" of each alternative or option shall be estimated for comparison purposes. The best overall design for the area will then be selected, leading to the production of final construction drawings.

2.2 Design Life

The minimum periods of time for new assets to last before replacement are shown in

Table 2-1.

Table 2-1— Design Life for DM Assets (ADM 1998, ADSSC, 2011)

Sr. No.	Asset type	Minimum Design Life (Years)
1	Pipelines	60
2	Structures	30 50-60 select which one is more suitable
3	Mechanical and Electrical Equipment	15
4	Instrumentation, Computer Hardware, and Sensors.	5

The maintenance of all civil, mechanical, electrical, and instrumentational equipment will be required during the above periods. A plan maintenance schedule and spare parts list shall be submitted as part of the design submission. During NPV analysis, the cost for maintenance and replacement of equipment shall be considered.

2.3 Basic Design Consideration

2.3.1 Sewer Network

The sewer network design shall take account of the following:

- Demarcation of sewer catchment based on topography, maximum acceptable sewer depth, pump station location and minimum life cycle cost of sewerage system
- Pipe corridor allocation
- Shortest pipe route alignment to ensure economy of design
- Sewer depths (shall be sufficient to accommodate all existing and future properties likely to be built within the catchment area)
- Method of construction based on depth and other factors such as socio-economic impact, geotechnical information, groundwater and the proximity of foundations, services, etc.
- Provision of adequate sewer pipe slope to prevent deposition of solid matter in the pipe by ensuring self-cleansing velocities
- Design consideration to achieve self-cleansing velocities at times of peak flow each day for the likely flows in early years
- Adequate access provision for maintenance
- Septicity development shall be avoided as far as possible or else include the mitigation plan as part of the design proposal

2.3.2 Investigations

The Consultants require site investigation and may require additional investigations include but not limited to below mentioned list, during the design process.

- Geotechnical and groundwater investigations
- Geotechnical investigations

- Topography survey
- Bathymetric survey
- Salinity monitoring
- Flow monitoring
- Environmental studies, e.g. hydrodynamic modelling

2.3.3 Environmental Legislation

The Consultant's proposals shall comply with all relevant local, regional, and international legislation. The Consultant shall comply with the requirements of Dubai Municipality, Environment Department, and other authority in UAE, if required. In case of any conflict between the legislation and standards, DM have all the rights to take decision.

2.3.4 Health and Safety Considerations

The designer of a project is in a unique position to be able to reduce the potential health and safety risk involved during both the construction stage and the operations stage. The earliest decisions of the designer can affect health and safety issues thereby influencing later design choices. Addressing these issues early in a project's development may save a considerable amount of time and money in redesigning unsafe facilities.

The designer has a responsibility to consider those people who will inevitably operate, maintain, repair, clean or even eventually demolish the structure. Failure to address these issues, by eliminating, reducing, or adequately warning users of the risks, may make it difficult to provide safe systems within the working environment.

Considerations in design to mitigate risks shall include but not be limited to:

- Hazardous Area Zoning classification for design consideration
- Local regulatory requirement (Dubai civil defence, DM Environment, JAFZA, DEWA, etc.)
- Design shall minimise the need to enter into confined spaces
- Safe access for all plant requiring maintenance
- Sewerage system facilities shall be secured and be inaccessible to the general public

- Adequate lifting facilities for all heavy equipment
- All hazards shall be identified and signposted
- Adequate lighting for regular operation and maintenance
- Welfare facilities for O&M staff
- Flow isolation and overflow facilities

2.4 Value Management and Value Engineering

Value engineering is mandatory to enhance the value of a project by structurally examining the decisions about benefits, risks and costs. The value engineering workshops with DM shall be arrange throughout the project duration from concept to detail design stages or even afterwards. Each individual project has different value engineering requirements which shall be confirmed with DM.

Consultant is obliged to prepare a report for each individual value engineering workshop, covering, and DM requirements and submit for review and approval.

2.5 Options Appraisal

For selection of best possible option, consultant is to provide more than one option for the design with layouts. The consultant shall also check the following before reaching to the conclusion:

- Capital Cost (CAPEX)
- Operational and Maintenance Cost (OPEX)
- Economic Appraisal of Option
- Evaluation of each option

2.5.1 Capital Cost (CAPEX)

The project estimate shall be based on the latest market rates, preferably obtained from DM Tender/Contract documents. The accuracy of estimates will vary with the stage of the project. The unit rates can be used for master plan and strategic studies, but for detail design the estimate shall be based on the detailed bill of quantities. The format and method for estimation shall be provided by DM on the request before commencing the design stage.

2.5.2 Operational and Maintenance Cost (OPEX)

The Operation and Maintenance Cost (OPEX) for all the options shall include but not limited to the following:

- Cost for labour (per hour/day/month/year)
- Vehicle and equipment cost (per hour/day/month/year)
- Power (DEWA latest tariff)
- Parts and consumables
- Chemicals (if any)
- Operation and Maintenance

The Consultant shall provide the OPEX for each individual option and submit to DM for review and used further to recommend the best possible options.

2.5.3 Economic Evaluation for Each Option

The proposed competing options shall be evaluated economically by comparing the associated life cycle cost. The life cycle cost includes the CAPEX and OPEX (calculated from start of construction) where the costs are to be set at the current base price. Consultant will communicate with DM to finalize the discount rate and period to be used for life cycle cost.

2.5.4 Evaluation of Each Option

For selecting the best possible option for the individual project that proposed within jurisdiction of Emirates of Dubai, consultant shall critically analyse the proposed options. The analysis shall cover but not limited to the following:

- Sustainability
- Adaptability and Resilience
- Feasibility
- Operability
- Constructability
- Financial
- Environment

3. SEWERAGE SYSTEM

3.1 Population and Flows

3.1.1 Population Forecast

All proposed new works shall be assessed based on both current and ultimate populations within the project area. All future developments shall be considered when designing new works. During planning and design phase, the development related information will be received from below:

- DM Planning Department
- Individual developers as applicable

Sewage flow calculations shall be derived based on best available planning information with respect to the population within a given community or project area.

The population study shall be based on three main sources of information that are listed below:

1. Current Population Data by Dubai Statistical Centre
2. Dubai Structure Plan Population by Dubai Municipality Planning Department
3. Ultimate Holding Capacity by Dubai Municipality Planning Department

The designer shall confirm all data prior to design of any system with respective departments for revisions. Design data related to private developments within the project area shall be collected from the developer and joined with Dubai Municipality Planning department data. Population projections until the design horizon shall be developed for the planning area considering current population, latest structure plans, and population and ultimate holding capacity for the planning area of the project. Consideration shall also be given to the expected rate of development.

3.1.2 Sewage Flow

Sewage flows shall be projected based on per capita consumption combined with current and forecasted population. In addition to the population data, the designer shall collect the latest Land Use and Zoning Plan of the project area from the Dubai Municipality Planning Department. The Land Use and Zoning Plan shall be used to identify the types of development located in the project area.

To estimate the per capita sewage generation rates, the following methods will be used:

a. Review the potable water consumption
b. Calibrate the estimated sewage flow parameter with actual flow measured at main pumping stations and STPs or even at the installed flow meters (if any)
c. Review Middle East practices

For ease of transition to the use of international standards DM has retained the tables below for reference only. The estimated sewage generation shall be approximately 80% of potable water demand that is already established by Dubai Electricity and Water Authority (DEWA).

3.1.2.1 Sewage Flows from Residential Area

Sewage flow for the design of sewerage facility is based on population and the average rate of flow per capita per day. For new development sewage flows shall be estimated based on the dwellings multiplied by the anticipated occupancy rate. The per capita sewage generation rates for different type of developments are presented in the **Table 3-1**.

Table 3-1— Per Capita Sewage Generation Rate

Development Type	DEWA Water Demand Range	Water Demand Typical	Average Daily Sewage Flow
	(Litre)	(Litre)	(Litre)
Low cost residential	250 - 400	250	200/day/capita
Medium cost residential	250 - 400	280	225/day/capita
High cost residential	250 - 400	350	280/day/capita
Villas	250 - 400	400	320/day/capita
High Rise	250 - 400	350	280/day/capita
Labour Accommodation	80 - 150	150	120/day/capita

In general, an equivalent sewage generation rate of 280 liter / capita / day shall be used to calculate the sewage flows from the developments. However, the strategies that have been announced by the Dubai

Supreme Council of Energy related to reduce the water consumption should be considered during this estimation.

3.1.2.2 Institutional Area Flows

The recommended sewage generation rates from institutional areas are as given in **Table 3-2**.

Table 3-2— Per Capita sewage generation rates for Institutional sources

Source	Unit	Flow (Litres/Unit-day)	
		Range	Typical
Hospital medical	Bed	500-900	600
	Employee	19-56	38
Hospital mental	Bed	280-530	380
	Employee	19-56	38
Prison	Inmate	280-570	450
	Employee	19-56	38
Rest home	Resident	190-450	320
Schools			
With cafeteria, gym and sowers	Student	56-115	95
With Cafeteria only	Student	38-75	56
Without cafeteria and gym	Student	19-65	42
School, boarding	Student	190-380	280

Note: Number of persons taken as twice the number of beds.

3.1.2.3 Industrial and Commercial Areas Flows

Sewage flows from industrial users or trade effluent shall be considered. These shall be obtained on a case-by-case basis. Specific industrial and commercial connections will have varied inputs to the sewerage network. The Design Consultant shall capture all projected demands for such connections when designing the sewerage network. Typical sewage generation rates from commercial sources are given in

Table 3-3.

Table 3-3— Per Capita sewage generation rates for Commercial sources

Source	Unit	Flow (Litres/Unit-day)	
		Range	Typical
Airport	Passenger	7-11	11
Automobile Service Station	Vehicle Served	26-50	38
	Employee	34-56	45
Bar	Customer	4-19	11
	Employee	38-60	50
Department Store	Toilet room	1500-2300	1900
	Employee	30-45	38
Hotel	Guest	150-230	180
	Employee	26 - 50	38
Industrial Building			
(Sanitary waste only)	Employee	26-60	50
Laundry (self-Service)	Machine	1500-250	2100
	Wash	170-120	190
Office	Employee	26-60	49
Restaurant	Meal	8-15	11
Shopping Centre	Employee	26 - 49	38
	Parking Space	4-8	8
Dry Industry	Employee	50 at 8 per m^2	

DM emphasize that all sewerage design shall be done in accordance with accepted international standards. Where deviations from standard are required, it must be fully justified on a case-by-case basis.

3.1.3 Sewerage Catchment Flow Projections

The year wise sewage generated in the project area needs to be estimated based on the population forecast, the sewage generation rate as per the type of development, land use map and zoning map of the project area. The sewerage network in the project area to be designed based on the ultimate sewage load. Other utilities such as pumping station treatment plant etc. can be designed in phases based on estimated sewage loads.

3.2 Gravity Sewer Network

The sewer network will consist primarily of a combination of gravity sewers including Header sewers, Lateral sewers, Trunk sewers and Main Collector sewers. The design engineer shall ensure that best use is made of the topography of the design area to minimize the amount of pumping required whilst keeping construction costs at an economic level.

The sewer capacity shall be designed for the estimated ultimate contributing population. A similar consideration shall also be given to the maximum anticipated capacity of institutions, industrial and commercial areas, etc.

All sewer designs are to be modelled using numerical software such as Sewer GEM, Info-SEWER, InfoSWMM or equivalent.

3.2.1 Peaking Factor

Sewage flow generally follows a diurnal pattern. Peak times are in the morning and evening. The sewerage network has to be able to convey the peak flow of sewage at all locations in the network. A peaking factor shall be applied to all sewage flows. The recommended empirical formula to calculate the peaking factor for populations greater than 500 people is shown below.

$$\text{Peak Factor} = 4.25 \times (\text{Population}/1000)^{-1/6}$$

For population up to 500, a peaking factor of 5.0 shall be considered.

For populations less than 500 where the flows are insufficient to give self-cleansing velocities a sewer is considered to be self-cleansing if a 150mm nominal internal diameter gravity pipe having a gradient not less than 1 in 133 is provided and at least 10 dwelling units are connected.

3.2.2 Hydraulic Calculations

The Colebrook White equation shall be used for sewer design in Dubai. The general form of the Colebrook White equation is:

$$V = -2\sqrt{2gDS}\ \log\left[\frac{Ks}{3.7D} + \frac{2.51\gamma}{D\sqrt{(2gDS)}}\right]$$

Where:

V = velocity (m/s)

g = gravitational acceleration (m/s^2)

D = internal pipe diameter (mm)

S = hydraulic gradient; (invert slope for full pipes, water surface slopes for open channels (1m/1000m)

Ks = a linear measure of effective roughness (mm)

γ = kinematic viscosity of fluid (m^2/s)

The recommended Ks value based on pipe material condition as poor is 1.5 mm.

The Manning Equation can also be used to design sewers running full or partially full. The Manning Equation can be expressed in the following forms.

$$v = \frac{1}{n} R^{2/3} S^{1/2}$$

Where:

V = pipe velocity, (m/s)

N = coefficient of roughness, (dimensionless)

R = hydraulic radius, (m)

S = slope of energy grade line, (m/m)

D = internal diameter of pipe, (m)

Q = flow rate, (m^3/s)

A = cross-sectional area of flow, (m^2)

The recommended vale for the coefficient of roughness (n) is 0.013.

Consideration shall be given to dynamic modelling in designing systems for more than 10,000 inhabitants.

3.2.3 Minimum and Maximum Sewage Flow Velocities

The lowest sewage flows are found at night. The minimum flow velocities have to be high enough to provide self-cleansing thus avoiding sedimentation. Maximum velocities are set to prevent asset corrosion and the build-up of Hydrogen Sulfide gas.

Sanitary sewers must be designed so that sediment does not accumulate during period of low flow without providing some period with enough flow to clean out the pipes. To assure the suspended sediment carrying capacity of the sewer, two approaches shall be used:

4. Self-Cleansing Velocity
5. Minimum Tractive force

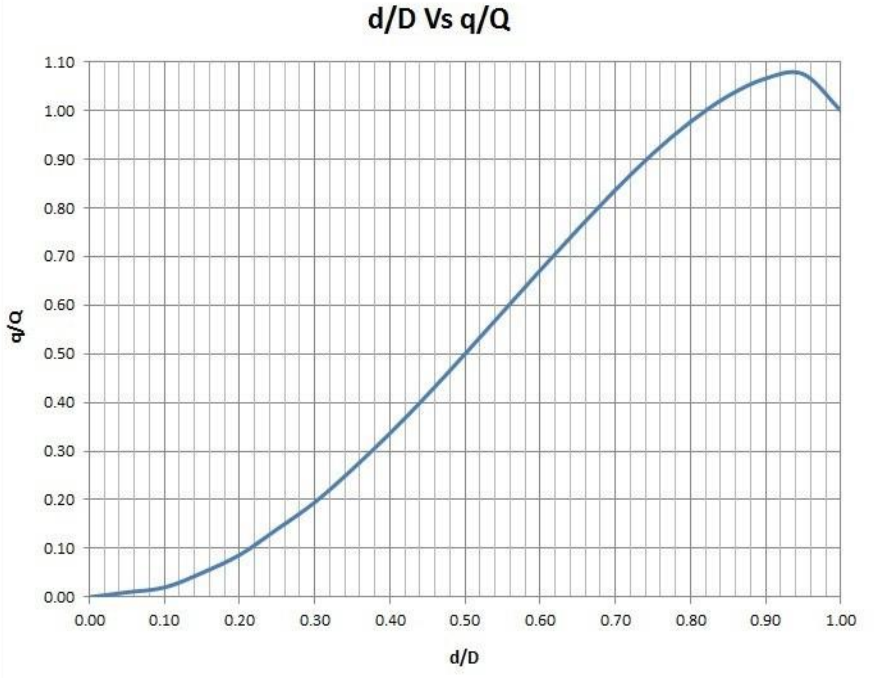
To provide a self-cleansing regime within gravity sewers, the minimum velocity shall be above 0.75 m/s at peak flow.

Additionally minimum pipe gradient for the sewer shall be calculated based on the hydraulic design approach of minimum tractive force, discussed later in **Section 3.2.5.2**.

To reduce pipe erosion, manhole nuisance and safety issues, in general the maximum velocity shall not exceed 2.5 m/s at the design depth of flow.

3.2.4 Depth of Flow

The relationship between d/D and q/Q where q is the flow when the depth of flow is equal to d and Q is the flow when the pipe is full is presented in **Figure 3-1** at d/D = 0.75, the pipe is at 91 percent of its full flow capacity and has a high potential to be surcharged.



d/D	q/Q
0.00	0.00
0.05	0.01
0.10	0.02
0.15	0.05
0.20	0.09
0.25	0.14
0.30	0.20
0.35	0.26
0.40	0.34
0.45	0.42
0.50	0.50
0.55	0.59
0.60	0.67
0.65	0.76
0.70	0.84
0.75	0.91
0.80	0.98
0.85	1.03
0.90	1.07
0.95	1.08
1.00	1.00

Figure 3-1— Relationship between d/D vs q/Q

The recommended design criteria for percentage of pipe full in gravity sewer pipes at peak flow condition are shown in **Table 3-4**.

Table 3-4— Per Capita sewage generation rates for Commercial sources

Sewer Line	d/D	
	Minimum	Maximum
Pipe Diameter up to 500 mm	0.50	0.70
Pipe Diameter : 500 - 800 mm	0.50	0.65 - 0.70
Pipe Diameter: Greater than 800 mm	0.50	0.65

Note d/D is the ratio of flow depth to nominal diameter of pipe.

3.2.5 Pipe Gradients

3.2.5.1 Based on Self Cleansing Velocity

The gravity sewer pipe gradients shall be sufficient to maintain the design minimum velocity 0.75 m/s to ensure sewer cleansing. Sewers shall not be oversized to facilitate flatter slopes. Uniform slopes must be maintained between successive manholes. The slope shall ensure that sewage flow stays below the maximum design velocity to prevent the accumulation of sewer gases.

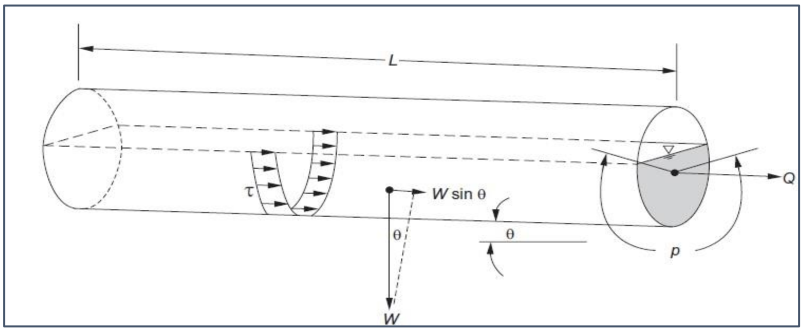
The minimum sewer line gradient based on the Colebrook-White equation and acceptable self-cleansing velocity of 0.75 m/s is given in **Table 3-5**.

Table 3-5— Minimum Sewer Line Gradient

Sewer Nominal Diameter (mm)	Minimum Gradient (mm/m)
150 mm	7.50
200 mm	5.00
250 mm	3.75
315 mm	2.70
400 mm	2.05
500 mm	1.55
600 mm	1.25
700 mm	1.00
800 mm	0.85
900 mm	0.75
1000 mm	0.65
1200 mm	0.50
1400 mm	0.45
1600 mm	0.35
1800 mm	0.30
2000 mm and above	0.25

3.2.5.2 Based on Minimum Tractive Force

The methodology of minimum tractive force is based on the theory that during steady state flow, gravitational force of the fluid must equal to the friction force along the pipe wall. The tangential force exerted by the sewage per unit of wetted boundary area is known as Tractive force. The forces acting on a fluid element is presented below:



$$\text{Tractive Tension}, \tau = \frac{W\text{Sin}\theta}{pL}$$

Where:

τ = Tractive Tension, (Pascal)

W = Weight of Fluid (N)

p = Wetted perimeter (m)

L = Length of Pipe (m)

The weight of fluid is given by

$$W = \rho\, g\, A\, L$$

Where:

ρ = Fluid Density, (Kg/m^3)

g = Gravitational Acceleration, (m/sec^2)

A = Area of Fluid section, (m^2)

L = Length of Pipe, (m)

$$S_{min} = K\, \tau^{1.23}\, Q^{-0.461}$$

Where:

S_{min} = Minimum slope to move particles

K = 2.33×10^{-4} (SI) – if Q is in (m^3/s)

K = 5.5×10^{-3} (Imperial) – if Q is in (L/s)

τ = Tractive Tension, (Pascal)

Q = Flow, (m^3/s)

Steeper gradient calculated based on self-cleansing velocity and minimum tractive force methodology shall be adopted as minimum pipe gradient. At the head of the sewerage systems the flow velocity based on the minimum self-cleansing approach may not be attainable. In these circumstances the minimum pipe gradient for the sewer shall be calculated based on the hydraulic design approach of minimum tractive force.

Table 3-6 gives the nominal gradients for the housing units on the assumption that there are 6 persons per unit and average tractive tension of 1.5 Pascal. Pipe diameter of 200 mm will be used.

Table 3-6— Minimum Slope based on Tractive Tension

Units	Population	Average Flow (L/s)	Peak Factor	Peak Flow (l/s)	Minimum Slope (ST)	
					mm/m	IV:XH
5	30	0.10	5	0.49	12.6	80
10	60	0.19	5	0.97	9.2	110
15	90	0.29	5	1.46	7.6	130
20	120	0.39	5	1.94	6.7	150
25	150	0.49	5	2.43	6.0	165
30	180	0.58	5	2.92	5.5	180
35	210	0.68	5	3.40	5.1	200

3.2.6 Pipe Materials

Pipe material for sewer pipes shall be selected based on the following factors:

A. Suitability for intended use and characteristics of foul water
B. Availability of material locally
C. Capital cost of selected material offset against reduction or elimination of maintenance costs
D. Capital cost of installation by Non-disruptive methods offset by reduction in disruption to traffic and cutting of new roads
E. Ground conditions such as soil and ground water characteristics
F. Environmental conditions such as high temperature, poor ventilation, high level of corrosive products and sand accumulation

G. Handling, transporting and installing the materials

H. External loading and abrasion conditions

Recommended pipe material to be used in Dubai for sewer pipes are given in **Table 3-7**. Use of alternate materials must be justified and approved from DM.

Table 3-7— Recommended Sewage Pipe Materials

Category of Use	Size Range	Construction Method	Preferred Materials
House Connections	Up to 200mm O.D.	Open Trench,	uPVC, MDPE or HDPE
		Non-Disruptive (Trenchless)	GRP, HDPE Either encased in Concrete or slip lined through sleeve pipe and grouted
Sewer Mains	200mm to 300mm	Open Trench,	uPVC, HDPE
		Non-Disruptive (Trenchless)	GRP, HDPE Either encased in Concrete or slip lined through sleeve pipe and grouted
Sewer Mains	350mm & Greater	Open Trench	GRP, HDPE, GRP/PVC lined Reinforced Cement Concrete (RCC) pipes,
		Non-Disruptive (Trenchless)	GRP , HDPE Either encased in Concrete or slip lined through sleeve pipe and grouted GRP/HDPE standalone pipe with suitable stiffness

3.2.7 Pipe Depths

The minimum depth for sewer pipes shall be 1.2 m to the crown of the pipe. This is required to provide pipe protection from external loads and to avoid interference with other utilities. If circumstances require installation of a pipe with depth less than 1.2 m above the crown, then concrete protection is required. The minimum cover from finished ground level to the top of pipe shall be as given in **Table 3-8**:

Table 3-8— Minimum Cover and Vertical Clearance for Pipes

Type of crossing	Minimum cover/Vertical clearance (m)
Without protection	1.2
With protection	0.5
Road crossing by non-destructive methods	2.5
Under exiting utilities (Vertical clearance)	
Water Pipeline	0.5 (for open cut)
Electricity, Telecommunication etc.	0.3
Oil and Gas	As per Dubai Supply Authority (DUSUP) requirements

A proper design check is required for the pipe at shallow depth beneath the major roads or highways. Minimum horizontal clearance of 3 m is required. If utilities are in the same trench, the other utility shall be placed on a separate bench on un-disturbed soil.

These are minimum requirements. However, the exact required clearance shall be discussed in detail and confirmed with all utility providers.

The recommended maximum cover for sewer pipes is approximately 10 - 12m. Depths with cover greater than this shall be investigated with pipe manufacturers to identify any special requirements that may be necessary. Where the cost of excavation becomes prohibitive the Engineer shall incorporate pumping stations into the design.

3.2.8 Pipe Sizes

The minimum size of gravity sewer main shall be 200 mm nominal internal diameter.

3.2.9 Location and Utility Crossings

Roads and Transport Authority (RTA) approved Right of Way (ROW) shall be considered when selecting the route for the sewers. The locations of other utility assets have also to be considered when selecting the route for the sewers. The basic criteria such as vertical and horizontal clearance when a sewer line crosses or runs near to another utility shall be as per requirements of relevant utility authority. A potable water main shall always be above the sewer main to protect public health.

3.2.10 Sewer Manholes

Manholes are required on sewer lines to allow access to the system and to ensure controlled transitions in hydraulic flow. Manholes shall be provided at the following locations:

- Change in pipe gradient
- Change in pipe diameter
- Junction of two or more pipes
- At regular spacing on straight pipeline based on maintenance equipment
- End of each lateral sewer

Manhole shall be of sufficient size to permit access for maintenance activities. In addition, their design and material selection shall be such that to guarantee maximum performance for an extended service life.

Drops are sometimes required at manholes when a branch sewer adjoins a truck sewer. Connections under these conditions require the use of a backdrop when the difference in invert elevations exceeds 600mm. Backdrops shall be constructed external to the manhole. Internal backdrops, while permissible, shall only be used for new connections to existing manholes where external connections are not practicable. Internal backdrops are not permitted on manholes that are less than 1.5m in diameter since this would restrict access to an unacceptable degree.

Benching and channels in manholes shall be formed to permit safe access and to maximize hydraulic efficiency through the manhole. Smooth transitions between inlet and outlet pipe diameters and inverts are required.

The recommended maximum spacing between manholes is presented in **Table 3-9**.

Table 3-9—Maximum Spacing between Manholes

Pipe diameter (mm)	Maximum spacing (m)
D ≤ OD 315 mm	100
From 350mm to 500mm	150
From 600mm to 800mm	200
From 900mm to 1000mm	250
From 1100mm to 1300mm	300
From 1400mm to 1500mm	400
Pipe size > 1500 mm	600

Any alteration in the above specified spacing of manholes, consultant has to obtain pre-approval from DM. Manhole shall be of sufficient size to permit access for maintenance activities. In addition, their design and material selection shall be such that to guarantee maximum performance for an extended service life.

Benching and channels in manholes shall be formed to permit safe access and to maximise hydraulic efficiency through the manhole. The correct manhole sizes shall be used in hydraulic model. For size of the manholes, consultant can refer to manhole drawings and specifications.

Table 3-10— Manhole Cover Levels (ADM, 2016)

Location	Cover Level
Paved areas	Final Paved level
Landscaped areas	Final Ground Level +0.1m
Open, unpaved areas	Final Ground Level +0.25m

4. PROPERTY CONNECTIONS

4.1.1 Layout of Works

4.1.1.1 Future connection provision:

A. A chamber to be constructed in the approved reserve at the boundary of each known plot such that a connection can be made at any time in the future. Approval is required from DM for each connection.

B. Also, stub pipes to be incorporated in selected manholes to facilitate system extension and property connection of possible future development.

C. The Gate locations and Future inspection chamber location must be identified while providing sewer connections to the existing built properties.

4.1.1.2 Chamber Spacing:

Spacing of collection chambers and inspection chambers shall be between 20m and 50m where practical.

4.1.1.3 General Arrangement:

Each plot to drain separately to an inspection chamber outside the boundary.

4.1.2 Design of Chambers

Refer to standard drawings.

Non-standard chambers may be required to accommodate the arrangement and number of outlets from the property internal drainage layout, and in restricted areas where plan area/depth requirements are not available.

4.1.3 Hydraulic Design of Property Connections

Table 4-1— Hydraulic Design of Property Connections

Description	Parameter
Minimum diameter:	DN 150mm.
Design Gradient:	Min = 1%
	Max = 10%

4.1.4 Trade Effluent Control Regulations

For trade effluent control regulations, follow Federal Law for the protection and development of the environment and its executive order regarding the handling of hazardous materials, medical and radioactive wastes.

4.1.4.1 Restricted Substances

Table 4-2— General characteristics (ADSSC, 2015)

Substance	Unit	Maximum allowable concentration or characteristic
Chemical Oxygen Demand (COD)	mg/l	1000
Total Suspended Solids (TSS)	mg/l	500
Total Dissolved Solids (TDS)	mg/l	3000
Temperature	Degrees Celsius	45
pH	unit	> 6 and < 9
Grease & oil (hydrocarbon)	mg/l	60
Grease & oil (non hydrocarbon)	mg/l	100
Maximum physical size of non-fecal matter	mm in 2 dimensions	15

Table 4-3— Inorganic compounds (ADSSC, 2015)

Substance	Unit	Maximum allowable concentration or characteristic
Chloride (as Cl- ion)	mg/l	1000
Cyanide (as CN-)	mg/l	2
Fluoride (as F- ion)	mg/l	15
Sulphate (as SO4)	mg/l	1000
Sulphide (as S)	mg/l	1
Total Kjeldahl Nitrogen	mg/l	150
Total Phosphorus	mg/l	50

Table 4-4— Organic compounds (ADSSC, 2015)

Substance	Unit	Maximum allowable concentration or characteristic
Detergents (Linear Alkylate Sulphonate as Methylene blue active substances)	mg/l	30
Phenolic Compounds (as Phenol)	mg/l	0.5
Polycyclic Aromatic Hydrocarbons (PAH)	mg/l	0.05
Organophosphrus Pesticides	mg/l	0.01
Organochlorine Pesticides	mg/l	0.01

Table 4-5— Metals (ADSSC, 2015)

Substance	Unit	Maximum allowable concentration or characteristic
Aluminium	mg/l	100
Arsenic	mg/l	5
Barium	mg/l	10
Beryllium	mg/l	5
Boron	mg/l	5
Cadmium	mg/l	1
Chromium (Total)	mg/l	5
Cobalt	mg/l	5
Copper	mg/l	5
Iron	mg/l	50
Lead	mg/l	5
Lithium	mg/l	2.5
Manganese	mg/l	10
Mercury	mg/l	0.5
Molybdenum	mg/l	10
Nickel	mg/l	10
Selenium	mg/l	10
Silver	mg/l	5
Tin	mg/l	10
Vanadium	mg/l	1
Zinc	mg/l	10

4.1.4.2 Low Risk Trade Effluents

Following Trade Effluent Types are considered to be Low Risk Trade Effluents

- Small Laundry services
- Restaurants and cafes (including fast food and takeaways)

The Trade Effluent as generally of low volume, low strength, possessing a low risk to the Sewerage and Treatment Systems receiving.

4.1.5 Special Requirements

4.1.5.1 Sand traps

Sand traps shall be installed on property connections, where required, and approved by DM.

a) Location:

The trap shall be installed at the upstream end of the property connection and upstream of the grit separator or petrol interceptor. It shall be located to afford adequate access for maintenance and emptying.

b) Capacity:

As per German Standard DIN 1999 Part 2, provide recommended minimum capacities for flows up to 6 l/s as given in **Table 4-6**.

Table 4-6— Sand Traps Capacities (ADSSC, 2015)

Flow (l/s)	2	3	4	5	6
Internal Dimensions mm	1000 × 800	1400 × 800	1750 × 1000	2000 × 1000	2500 × 1000
Minimum Capacity litres (l)	520	840	1400	1800	2500

In addition, the minimum capacity for car wash plants should be 5,000 litres even when the rate of flow is under 6.0 l/s.

These capacities assume an emptying schedule ensures that only half the trap capacity has been utilised and a maximum interval of six months.

For a more frequent emptying schedule of say once per month, the following guidelines can be used:

i. For every l/s wastewater through flow, a multiple of 100 litres of trap
ii. Capacity shall be provided for an anticipated small accumulation of sediment.
iii. For every l/s wastewater through flow, a multiple of 200 litres of trap capacity shall be provided for an anticipated normal accumulation of sediment.
iv. For every l/s wastewater through flow, a multiple of 300 litres of trap capacity shall be provided for an anticipated large accumulation of sediment.

4.1.5.2 Grease Separators

Where it is determined by the ADSSC that waste pre-treatment is required, an approved type of grease interceptor(s) complying with the provisions of this section shall be correctly sized and properly installed in grease waste line(s) leading from sinks and drains, such as floor drains and floor sinks and other fixtures or equipment in serving establishments such as:

i. restaurants,
ii. cafes,
iii. lunch counters
iv. cafeterias
v. clubs
vi. hotels
vii. hospitals
viii. sanatoriums
ix. factory or school kitchens

Any other establishments where grease is introduced into the drainage or sewage system in quantities that can affect line stoppage or hinder sewage treatment or sewage disposal system.

In general, the grease separators should be provided as closely as possible to the outlet from the premises and wherever possible in the open and away from traffic but readily accessible for cleaning.

Note: Water closets, urinals, and other plumbing fixtures conveying human waste shall not drain into or through the grease interceptor.

Grease Separator Design

1) Grease interceptor tank can be sized by using the peak design flow rates from all fixtures leading to the grease interceptor with minimum retention time of 30 minutes.
2) Minimum liquid depth shall be 760 mm and maximum liquid depth shall not be more than be 1800 mm unless otherwise approved by the engineer

3) The inlet pipe shall be no less than 100 mm in diameter and the difference between the invert of the inlet pipe and the invert of the outlet pipe shall be a minimum of 50mm but shall not exceed to 100 mm.
4) Baffles or tees shall be placed at the inlet pipe and outlet pipes, the inlet baffle or tee shall be submerged to a depth located in the middle and 25 % of the distance from the bottom of the tank to the water line and at least 125 mm above the liquid level. The outlet baffle, tee or filter shall be submerged to a depth 150 mm to 300 mm above the tank floor. It shall extend a minimum of 125 mm above the liquid level. Outlet filter (when used) shall be maintained in accordance with manufacturer's recommendations
5) Each access opening and inspection opening shall be provided with a cover and with a means to prevent unauthorized entrance and to be water and air tight for all the operations.
6) Owner must established a cleaning or pump-out routine for each grease removal devise. The maximum allowable period between pump-out and cleaning shall be 12 weeks.
7) Or, the grease separator tank shall be subject to the complete pumped-out for the removal of all the constituents if any of the condition have been observed during the inspector's inspection, These include:
   a) The surface layer of oil and grease in the interceptor is greater than 10% of the total depth of the interceptor at the measured position; or
   b) The bottom layer of captured solids in the intercept or is greater than 20% of the total depth of the interceptor at the measured position; or
   c) The total amount of floating and settled solids exceeds25% of the depth of the trap

WATER TIGHTNESS TEST METHOD

1) Testing for water tightness shall be performed using either vacuum testing or hydrostatic testing as instructed by the engineer.
2) For vacuum testing the tank shall be emptied and seal and a vacuum of 100 mm of mercury shall apply and will hold for 5minutes, during the initial 5 minute period the vacuum test, the test will considered as successful provided the pressure shall not drop beyond 13 mm of mercury, contrary to that that tank will again brought back to vacuum level of 100 mm of mercury and again will held for a further 5 minutes but this time no loss of vacuum is permitted. In case the tank fails to satisfy the these conditions the structure will inspected

to rectify the reason to be fixed as per approved manner and as per the manufacturer recommendations and engineer approval.

3) For hydrostatic testing the tank shall be sealed and to be filled with water to its operational level, and left for 8 to 10 hours (as instructed by engineer) at ambient condition, if there is a measurable drop in the water surface elevation the tank shall be refill and the test will be repeated for another 8 to 10 h, the tank shall be considered fit for use if there is not further drop in level otherwise the manufacture shall have to submit the method of repair to the engineer for approval and test will be repeated after the repaired job as per engineer approval.

4) The tank shall considered as rejected if the tank failed during the second testing or found to be non-compliance with the any section of the specification.

LIMITATION

Only wastewater containing organic grease and oils shall be discharged to a grease separator. In particular, the wastewater containing faeces, rainwater etc.

EFFICIENCY DETERMINATIONS

The minimum required efficiency of grease trap at all the conditions of operations shall require to exceed to the value of 80%.

Efficiency = (Grease Added - Grease Skimmed) / Grease added

An Independent laboratory tests and engineering calculations certifying the grease interceptor capacity and efficiency shall be provided.

4.1.5.3 PETROL / OIL INTERCEPTORS

Petrol interceptors shall be provided on the outlets from vehicle washing bays, maintenance areas and the like, prior to connection to the sewer. Adequate access is essential so that the removal of its contents can be conveniently and effectively carried out. Interceptors shall not be installed in closed premises. Other arrangements are as follow:

a. Adequate ventilation.
b. Odour seals at inlet and outlet.

c. Secure, non-inflammable covers.
d. Uniform flow through the separation compartment.

Design capacity for the interceptor shall be as follow:

a. For vehicle washing facilities allow 2 l/s per wash line.
b. Size of separator should be based on double the wastewater flow.
c. For light liquids, retention time shall be a minimum of 3 minutes up to a design flow of 20 l/s. For higher flows, an additional minute can be added per 10 l/s increase.
d. For vehicle maintenance bays where heavier liquids can be expected, the retention time should be increased to 6 or even 9 minutes.
e. Width to length ratio should be 1:1.8.

4.1.5.4 ACID NEUTRALIZATION SYSTEM

The Neutralization Tank is positioned so that acidic waste (pH below 6.0) is collected and passed through Acid Neutralization & Monitoring System prior to discharging into the public sewer system. All the acidic effluent should be gathered separately from other non-acidic waste and all the non-acidic waste should by-pass the neutralization system. The acidic waste is chemically neutralized in the neutralization system.

4.1.5.5 LINT INTERCEPTOR

Lint interceptors shall be used to remove excessive amounts of lint and silt that may cause blockage in the public sewer system. This interceptor must be fitted with a wire basket or similar device that is removable for cleaning and prevents the passage of solids which are 12.5 mm or larger lint. This interceptor shall be fitted at a point in the internal drainage network to prevent the discharge of solid wastes into the public sewerage system.

Any solid wastes removed from solids interceptors shall be placed in a leak-proof bag.

4.1.5.6 BOUNDARY TRAP

A boundary trap is a fixture to be installed within the property boundary where the customer's service drainage line is connected to public sewer, owner of the property shall be responsible for proper construction and periodic maintenance of boundary traps installed inside their premises. Boundary traps can either be of a 'P' or 'Running' type to provide the water seal that aerially disconnects the customer drain from public sewer. One of its main functions is to prevent sewer gases from entering the customer's drainage system.

5. PUMPING STATION

5.1 Design Consideration

Sewage pump stations shall be designed so as to optimise the collection and delivery of sewage to the treatment plant. The type and size of pump station depends on the pump duties, location, and control requirements. There are two main types of pump station for use in Dubai as follows:

- Type 1- Submersible pump stations for small to medium size facilities
- Type 2- Wet Well – Dry Well type station for large facilities

Both types of pump stations have advantages and disadvantages, and the design engineer shall determine the appropriate type for each pump station on case-by-case basis considering site condition, flows, pumping head, land availability, operation and maintenance requirement, life cycle cost etc.

Variable frequency drives (VFD) shall be considered for pumping applications particularly for stations with a wide variation in flow patterns and wide range of the system pressure. Use of VFDs can minimize detention time in wet well and allow smaller wet well volumes.

The following sections present design guidelines applicable for both type of pump stations.

5.1.1 Other Consideration

The pump station and pressure main system shall be designed based on whole life cycle cost (WLCC) basis. A large diameter pressure pipe will result in higher pipe cost, lower pump head and lower power consumption. Similarly, a smaller diameter pressure pipe will reduce the pipe cost but increase the pump head and power consumption.

Designer shall provide adequate provision for pump station rehabilitation, future expansion, health and safety issues, equipment lifting, access, lighting, HVAC, noise protection, odour control, security requirements and staff welfare.

5.1.2 Pump Types

For small to medium size pump station, the preferable type of pumps are the Submersible close-coupled pumps driven by a submersible motor and are generally a vertical installed type. For large size pump station, a centrifugal (non-clog) pump with a horizontal or vertical shaft can be used. The unit is either frame-mounted or close coupled with the motor on the floor of a dry chamber (dry well).

5.1.3 Pump Station Sizing

Sewage pumping stations must be sized to handle a range of flows over the service life of the station. Variable flow considerations are important in sizing the structure and selecting the pump. All sewage pump stations in Dubai shall be designed to handle the projected peak influent flow rate. The peak flow rate is determined by applying the peaking factor to the average flow by one of the following methods:

- Empirical formula for peaking factor as described in Section 3.2.1.
- Average peaking factor based on similar station flows.

The average peaking factor based on either a flow monitoring program or an evaluation of diurnal pattern of existing pump stations of similar catchment provides more realistic information. On the other side the peaking factor, calculated based on empirical formula will provide conservative values. Suitable selection of peaking factor is important for large capacity sewage pump station.

Table 5-1 is a summary of measured peaking factors for the main sewage pump stations in Dubai. This information is provided for information and actual design peaking factors shall be determined by the design engineer based on a complete understanding of the catchment. This may vary significantly depending on the type of development and size of catchment.

Table 5-1— Measured peaking factor - Main pumping stations (year 2012)

Main Pumping Station	Actual Peak Factor
C	1.27
E	1.45
G	1.29
K	1.56
Q	1.44
H	1.55
S	1.30
Sn	1.32
X1	1.28
V	1.36
I	1.80
X	1.34

5.1.4 Wet Well Volume & Sizing

The wet well sizing is a function of flow variation (diurnal pattern), control strategy for the pump station, the selected pumps and number of starts per hour permissible for the pumps.

Pump start/stop levels shall be spaced to suit a pumping regime that produces the best compromise between stop/starts and continuous flow. The minimum sump volume required for a constant speed pumping unit can be calculated as follows;

$$V = t \times Q/4$$

Where

V= storage volume between starts (cubic meter)

Q= pump discharge rate (cubic meter/sec)

t= time between starts (sec)

Time between starts, t

= 10 min (0.75-30 kW motor),

= 15 min (35-60 kW motor),

= 20min (65-300 kW motor) and

= 30 min (over 300 kW motor).

The time between starts given is for reference only. The allowable number of starts shall be considered as per pump manufacturer's recommendation.

For a pump station with several identical duty pumps, the start and stop levels of all the pumps differ by a constant value determined by the characteristics of the control system. The difference in levels shall be large enough to eliminate accidental pump starts and is normally in the range 200mm to 500mm.

The control philosophy of operation shall be set to ensure that the depth of the wet well has been set to the minimum. For the wet well with VFD driven pump the requirement for wet well size mentioned in the above equation is not mandatory required. The size of the wet well then shall be designed to ensure that the size and shape will provide smooth and homogenous flow pattern to the pump inlet.

The wet well arrangement shall be based on American National Standards for Pump Intake Design (ANSI/HI 9.8-1998). The inlet arrangement shall minimise turbulence and hence emission of gases.
Computation Fluid Dynamic (CFD) modelling is recommended to verify the wet well design in case of the following:

a) If the total number of proposed pumps (duty + standby) are 4 or more, or
b) If the total peak design capacity of pump station is 1000 lps or more

5.1.5 Pump Selection

Pump selection shall be made to optimise conditions over the projected range of flows – minimum, average, maximum. Selection is made to minimise the holding time in the wet well before pumping and maximising the pumping efficiency.
The pump selection shall be made by generating a system head- capacity curve for the proposed pump station. The following are to be considered:

- Required range head and flows
- Number of pumps
- Operating and control strategy
- Efficiency
- Potential for upgrading capacity

Considering the future up-gradation of pump station, as far as possible the selected pump shall be in the mid-range of the available impeller size so that the pump capacity can be upgraded in future by changing the impeller. The pump motor capacity shall also be selected accordingly.

For small to medium size, pump station a minimum of two pumps shall be provided including one number standby pump; each pump will take 100% of the design peak flow with 100% standby. Another pump configuration can be selected with three pumps each can take 50% of the design peak flow. Such design will provide two pumps to handle the full design capacity with additional 50% of the design peak flow as standby. If two pumps are out of service then the remaining pump can handle 50% of the design flow. In large stations, the number of duty and standby pumps shall be chosen appropriate to the strategic importance of the station. The possible consequences of pump failure at a time of peak incoming flow or with one pump undergoing maintenance at such a time shall be considered.

5.1.6 Net Positive Suction Head

Cavitation, Vaporisation of water occurs when the pressure in the fluid drops below the vapour pressure of the fluid. The pumps are likely places for cavitation because of high velocities and low pressures. Net Positive Suction Head Available (NPSHa) in the system shall be compared against the Net Positive Suction Head Required (NPSHr) by the pump. The system shall be designed such that NPSHa > NPSHr.

It is mandatory to plot the NPSHr requirement against NPSHa for all possible combination of pump operation of the system. As the NPSHr increases with pump flow, NPSHr requirement will be higher for single pump operation than multiple pump operation.

NPSHa can be calculated using the formula

$$NPSHa = Hbar + Hs - Hvap - HL$$

Where:

Hbar = Atmospheric Pressure, m

Hs = Suction Head, m

Hvap = Vapour Pressure of water, m

HL = Head loss between wet well and Pump inpeller, m

5.1.7 Pump Station Structures

Structures shall be designed to ensure a safe working environment for operation and maintenance staff as well as maximizing performance and minimizing costs. The following shall be observed:

1. Isolation - Wet wells shall be isolated from dry wells and/or superstructures by impermeable walls. Ventilation system shall be independent
2. Equipment Removal - Provisions shall be made to facilitate removing pumps, motors and other mechanical and electrical equipment
3. Access - Suitable and safe means of access must be provided to dry wells and to wet wells
4. Construction Materials - Due considerations shall be given to the selection of materials because of the presence of hydrogen sulfide and other corrosive gases, greases, oils and other constituents frequently present in the sewage.
5. Wet wells shall be configured to minimize turbulence, especially near the intake of the pumps
6. Wet well controls are typically of the encapsulated float-type; although more sophisticated control may be considered. In all cases, control sensors shall be located away from the turbulence of incoming flow and pump suction
7. Equipment : All mechanical and electrical equipment in the plant shall be designed based on Hazardous Zone classification
8. Dubai Civil Defence requirement: The pump station structure shall be designed incorporating the Dubai Civil Defence requirement for firefighting, lighting, access and exit requirements

5.1.8 Electrical and Instrumentation Systems

New sewage pump stations shall be designed and constructed based on the applicable standards for Dubai. International principles shall also be practiced. To enhance the operability of the pump station the following provisions shall be included:

a) Supply and control circuits shall allow for disconnection from outside the wet well. Terminals and connectors shall be protected from corrosion through proper location and/or the use of water-light seals. Separate strain relief is required
b) Motor control panels shall be properly sealed

c) Power cords shall be designed for flexibility and serviceability under conditions of extra hard usage. They shall also be such that field connections are facilitated

d) Ground fault interruption protection shall be used

Instrumentation system shall be consistent with Dubai Municipality monitoring and control strategies. Refer to literature on the Dubai Municipality system for requirements.

5.1.9 Odour Control

Odour control systems shall be designed at pump station to ensure that noxious gases (H_2S etc.) and odours are in concentration lower than the detection level. The acceptable odour control treatment technologies are:

a) Activated carbon filter

b) Bio-scrubbers

c) Chemical scrubber, and

d) Ozonation

The design engineer shall review the requirements and technology available at the time of design to provide an appropriate odour control solution. The most emphasis is placed on hydrogen sulphide. Investigation including odour sampling and analysis, if appropriate, shall be carried out to ascertain the average and peak concentration of gases in the sewage. In the absence of relevant information, odour control system shall be design for the following concentration:

Plant Inlet concentration:

H_2S average concentration = 50 ppm

H2S peak concentration:

Plant outlet concentration = 300 ppm

H_2S concentration less than 1 ppm at discharge stack

5.2 Pressure Mains

Pressure main diameters are dependent on the pump discharge rating, the allowable velocity range and the friction loss due to the length of pressure main and its associated fittings. Alternative diameters shall be considered which produce a range of velocities between the minimum and maximum acceptable velocities, and which adhere to acceptable pumping ranges indicated on manufacturer's pump characteristic curves. A cost comparison shall be performed to determine which pressure main size will result in the optimum whole life cost of the pressure main and associated pumping costs.

5.2.1 Sizing and Velocity Criteria

Pressure mains shall be sized to maintain velocities within an acceptable range for a variety of flow conditions. Selection of a size requires an understanding of the projected flows for the service life of the system. For cases where initial flows are significantly lower than future flows two or more rising mains may be warranted.

A minimum velocity of about 0.6 m/s is required to prevent sedimentation in the pipe. A velocity of about 1.0 m/s is required to re-suspend settled solids. The highly variable diurnal sewage flow pattern can mean very low flows at night.

The minimum and maximum acceptable velocity for the pressure main design is 1.0 m/sec and 3.0 m/sec respectively. However, the acceptable maximum velocity will depend on the type of the pipe material and the manufacturer recommendations for solids-bearing liquids and also depend on the length of the pipe (long length with create more flow resistance which means more pump head). The designer shall find the best selection of the pipe size to guarantee achieving optimum velocity. The preferred target velocity is 1.5 m/sec. The minimum velocity must be met on a daily basis to re-suspend the settled solids.

Pressure pipe velocities must be checked for each pumping scenario, especially when multiple pumps are in operation simultaneously. Minimum, average and peak flow conditions shall be considered before a final selection is made.

The minimum acceptable pipe diameter for pressure main is 200mm.

5.2.2 Head Losses

The head losses in the pressure main can be calculated using Colebrook-White or Hazen William equations.

5.2.2.1 Colebrook-White Equation

Darcy Weisbach equation was developed using dimensional analysis and gives the head loss as

$$h_L = f\frac{LV^2}{2gD}$$

Where:

f = friction factor

L = length of Pipe g = gravitational acceleration D = Diameter of Pipe

Colebrook-White equation gives an implicit relationship between friction factor and Reynolds number

$$\frac{1}{\sqrt{f}} = -0.86\left(\frac{K_s}{3.7D} + \frac{2.51}{Re\sqrt{f}}\right)$$

Where

Ks = Sand Grain Pipe roughness factor

Re = Reynolds Number

According to HR Wallingford Report SR641, Rev 1.0, March 2004, effective surface roughness (Ks) varies widely and depends on the instantaneous velocity through the pipeline rather than the pipe material. The equivalent sand grain roughness value (Ks) takes into account the loss of area due to the slime thickness as well as the surface characteristic of the slime layer. The recommended pipe roughness (Ks) value is presented **Table 5-2** below:

Table 5-2— Pipe Roughness Factor (Ks)

Velocity (m/s)	Sand Grain Pipe Roughness (Ks)	
	Rough Pipe	Smooth Pipe
< 0.75	3	1.5
0.75 - 1.0	1.5	0.6
1.0 - 1.5	0.6	0.3
1.5 – 2.0	0.3	0.15
>2	0.15	0.10

5.2.2.2 Hazen Williams Equation

Head losses can also be calculated using the Hazen Williams equation shown below.

$$Q = 0.278CD^{2.63}S^{0.54}$$

Where:

Q = Flow Rate (m^3/s)

C = Hazen Williams Coefficient (dimensionless)

D = Internal Pipe Diameter (m)

S = Slope (m)

The recommended C value for pipe design is 120 for rough pipe condition. For Smooth pipe (new pipes) a C value of 140 is recommended.

The Colebrook-White equation with a velocity-dependent roughness is recommended for wastewater pressure mains and other pipes that experiencing full flow.

5.2.3 Minor Losses

Head losses occurring at fixtures, such as valves, tees, bends, reducers, and other appurtenances within the piping system, are called minor losses. These losses are the result of velocity changes and increased turbulence and eddies caused by the fixture. Minor head losses are computed by multiplying a minor loss coefficient by the velocity head, as given by

Typical values of minor loss coefficient associated with the pumping system are presented in

Table 5-3.

Table 5-3— Pipe Minor Loss Coefficient (K)

Fitting details		K-value
Entry		
	Sharp edged	0.50
	Re-entrant	0.80
	Rounded	0.25
	Bell mouthed	0.05
Bends		

Fitting details		**K-value**
Elbow (R/D < 1)	22.5 deg	0.20
	45 deg	0.40
	90 deg	1.00
Short Radius	22.5 deg	0.15
(R/D = 1 - 2)	45 deg	0.30
	90 deg	0.75
Long Radius	22.5 deg	0.10
(R/D = 2 - 7)	45 deg	0.20
	90 deg	0.40
Swept Bend	22.5 deg	0.05
(R/D = 8 - 50)	45 deg	0.10
	90 deg	0.20
Mitred Elbow		
22.5 deg	2 piece	0.15
30 deg	2 piece	0.20
45 deg	2 piece	0.30
60 deg	2 piece	0.65
60 deg	3 piece	0.25
90 deg	2 piece	1.25
90 deg	3 piece	0.50
90 deg	4 piece	0.30
Sudden Enlargements		
Inlet : Outlet	4:5	0.15
	3:4	0.20
	2:3	0.35
	1:2	0.60
	1:3	0.80
	>1:5	1.00
Sudden Contractions		

Fitting details		K-value
Inlet : Outlet	5:4	0.15
	4:3	0.20
	3:2	0.30
	2:1	0.35
	3:1	0.45
	>5:1	0.50

5.2.4 System Resistance Curve

The system resistance curve or system head curve defines the relationship between flow through the system and the total resistance that the system offers to flow. System resistance curve shall be generated by summing up static head of the system plus the frictional head loss offered by the system to the flow. Generating system resistance curve is mandatory for the pumping system before selecting the pumps. A band of system resistance shall be generated for the system based on following parameters:

a) Minimum Static Head Plus frictional head loss based on the rough pipe condition
b) Maximum static Head Plus frictional head loss based on the rough pipe condition
c) Minimum Static Head Plus frictional head loss considering smooth pipe condition. Generally for few years after commissioning of project, pipes offers less resistance to the system

Pump selection shall consider the band of system resistance curve, and designer shall make sure that all selected pump/pumps will be able to operate within the complete range of resistance offered by the system in all possible pump operating combinations. Pump curve and system curve is illustrated in **Figure 5-1** below.

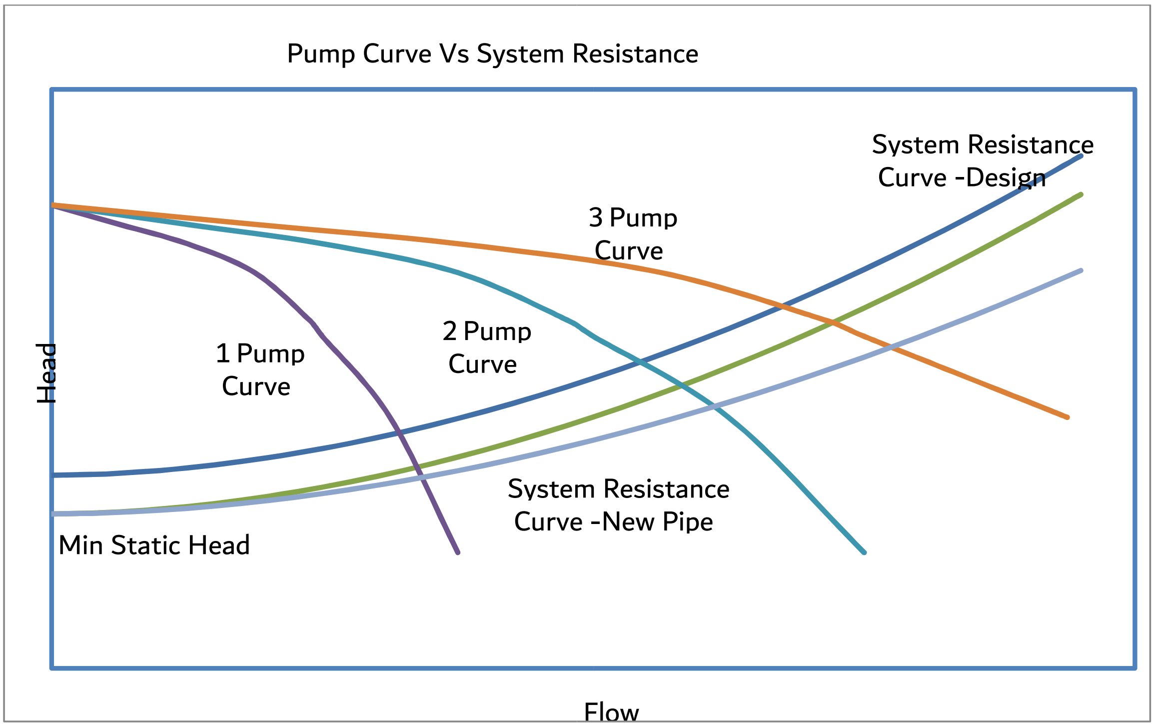


Figure 5-1— Typical Pump Curve and System Resistance Curve

5.2.5 Material Selection

Pipe Material shall be selected as suitable for the applicable area of service, resistance to corrosion and required pressure rating. The pressure will vary along the pressure main from the maximum pressure at the pump location and decreasing towards the discharge point. Appropriate specifications for pipe depth and cover shall be adopted.

The recommended material for the pipes and fittings within the pumping station shall be Ductile Iron. For small capacity pumping station (less than 100 L/s), pipe material shall be stainless steel.
The recommended pipe material for the pressure main is Ductile Iron, GRP and HDPE.

5.2.6 Air Valves and Washouts

In order to avoid air entrapment within pipelines with a varying gradient profile, appropriately sized air valves shall be installed at specific locations along the pressure main.

Air valves installed on transmission mains shall be double orifice type (unless surge control considerations dictate otherwise). The purpose of Air valve use shall be made to provide enough ventilation for the pressure main (remove any accumulated of air inside the pipeline). Air valve shall be installed at certain location to guarantee the evacuation of air from the system and the size shall be determined as per manufacturer's data sheets in reference to the pipeline diameter and the profile of the pipeline. If the Air valves are used to mitigate the transient pressure then the size, location and number shall be made according to surge analysis study.

Air valves are required at the following locations:

a) At the downstream end of an ascending length of pressure main
b) At a high point where the pressure main approaches, but then recedes from the hydraulic gradient
c) At increases in downward gradient iv) At a point of decrease in upward gradient
d) At intervals not exceeding 700m on a level or long descending stretch of main

Pipelines shall be laid to rise and fall even if the terrain is flat (1 in 750 is the minimum required gradient). The following considerations shall also be taken into account when designing and locating air valves:

1) Air valves can fail to function correctly if there is a lack of seating pressure. This can occur when the valve location closely approaches the hydraulic gradient, their location shall therefore be checked against these criteria.
2) All air valves shall be located so as to permit ease of access and maintenance.
3) Regular inspection is required to verify the correct functioning of air valves.

Air valves shall be provided with a separate isolation gate valve, with bevel gearing, to enable removal of the valve without shutting off the main.

Typical Air Valve Sizes based on the pressure main diameter is provided in the **Table 5-4** below. The engineer shall confirm these sizes based on operating conditions such as Normal Operation, Pipe Filling and Pipe Drain.

Table 5-4— Air Valve Size

Pipeline Bore (mm)	Nominal Air Valve Size (mm)
>= 300mm	80

300 - 500	80 – 100
600 - 900	150
1000 - 1200	200
1300 - 1600	2 X 200

Washouts shall be provided at low points for maintenance and flushing the build-up of sediment. An appropriate discharge point for the washout shall be included in the design. The sizing of the washouts shall be related to the size of the transmission main. The drain valve shall be sized to drain the isolated section of the pressure main within 4 hours. The minimum diameter of washout valve and associated piping is 100 mm. Following guidelines can be used as minimum requirement:

- Up to 400 mm – 100 mm washout pipe
- 500 mm to 800 mm – 150 mm washout pipe
- 900 mm to 1200 mm – 200 mm washout pipe
- 1200 mm and above – 300 mm washout pipe

All chambers shall be large enough to allow access for maintenance. Where possible, valve chamber shall be located to allow vehicular access.

5.3 Surge Analysis

Water hammer or surge or hydraulic transients is a phenomenon occurring in closed conduit or pipe flows, associated with rapid changes in discharge in the pipe due to the unplanned activities. The rapid change in discharge and the associated velocity is accompanied by a change in pressure, which is propagated through the pipe. The water hammer wave is propagated at acoustic speed, which varies with the material and wall thickness of the pipe. Sudden changes in flow and velocity occurs in the system due to the unplanned activities such as power failure at pumping station, pump failure, rapid closing of a valve (rather than manual operated valves), pump start, and pump shutdown, which generates the pressure transients. These pressure waves may leads to the unacceptable conditions such as

High Pressure – may rupture the pipelines, damage fittings

Low Pressure – may collapse the pipeline

Reverse flow – may damage pump seal, brush gear on motors

Pipeline Movement – may lead to overstressing and failure of pipe support, failure of pipelines

In order to fully understand the potential impact of transient pressures due to the unplanned activities in the system it is mandatory to undergo software based Transient Analysis of the system. Transient analysis software's such as InfoSurge, Wanda and Bentley Hammer can be used for detailed investigation.

Pressure changes can be calculated based on Joukowskey equation

$$\Delta H = \frac{c}{g}\Delta v$$

Where:

ΔH= Change in Pressure (m)

c = Wave Propagation speed (m/s)

g = Acceleration due to gravity (m/s^2)

ΔH = Change in flow Velocity (m/s)

"c" is the variable which is dependent on the physical properties of the pipe, and the liquid being conveyed.

5.3.1 Maximum and Minimum Pressure Criteria

The primary output from the surge analysis model is the predicted changes in pressure and flow at any point in the system as a result of a transient event.

The operation limits for the system are,

A. Vapour cavities and column separation shall not occur in the system
B. Minimum pressure in the system shall not exceed the allowable limit specified by the pipe manufacture or a maximum negative pressure of 0.2 bars (see the note below) below atmospheric, pressures whichever is highest.

NOTE: the minimum pressure shall be examined upon study the whole system hydraulically and depends also upon the value of the maximum pressure that the pipeline is subjected to>

C. Maximum Pressure shall not exceed the hydraulic test pressure of the pipeline or rated maximum pressure of any of the components such as valve fittings etc. in the system, whichever is the lowest.

The best design shall be based on avoiding create transient conditions or keep it to the minimum, failing to do that a surge suppression system shall be proposed to keep the system working at healthy and safe conditions. Following points shall be considered while designing the surge suppression system,

a) Pressurised surge arresting vessels connected to the pumping main to force water into the pressure main in the event of pump shutdown to convert a rapid fluid transient event into a controlled mass oscillation. Adequate balancing pressure shall be achieved in the vessels either by pressurised membrane bladder or by compressors. Total volume of vessel is determined by the extent to which the air expands as the pressure falls plus a minimum allowance of 20% or more to ensure that the vessel does not drain down completely.
b) Depending on the pumped system, Non-Slam Air Valves can be used as surge protection devices. However for large system air valves cannot be considered as surge suppression devices and hence, the Air Valves provided along the pressure main are not to be included in the surge analysis
c) Installation of bypass check valve with check valve from wet well/suction side to the delivery side

   Total Volume >= Maximum expanded Volume + 20%

d) Addition of Flywheel to pump to increase the inertia of pump-motor, the combined unit in turn prolong the run down time of pumps and reducing the initial down surge after the surge even associated with instantaneous pump stop.
e) Regulating Valves, consider only as a final option provided that such valves shall be suitable to be used with sewage flow.
f) In addition to the technical suitability and relative cost of the available options following factors shall be analysed, a. Reliability
   i. Space requirement
   ii. Power consumption
   iii. Maintenance and supervision

iv. Need of skilled labour to install and operate

The choice of the modelling software package shall be approved by DM prior to commencement of the modelling task.

a. be minimised by sharing pumps between tanks;
b. Easy access shall be provided to all motors to facilitate routine maintenance and repair;
c. In case of multiple tanks, even flow splitting between primary settlement tanks across the range of flows is vital to ensure proper performance;
d. Sufficient treatment capacity shall be provided, such that one unit can be taken off line and still achieve the desired performance under the peak process loading conditions;
e. The primary sedimentation tanks shall be covered with tight fitting trafficable GRP covers and ducted to the odour control facility. This is to prevent odour release and fine sand ingress.

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