CHAPTER 4

DESIGN CRITERIA

4.1 INTRODUCTION

This chapter summarizes the basic design criteria necessary to develop options and sizing estimates for the components of centralized wastewater collection systems. The design criteria are based on "Criteria for Sewage Works Design" Publication #98-37, published by the State of Washington Department of Ecology and other accepted standards for sewer system design and construction.

4.2 ABBREVIATIONS AND DEFINITIONS

In this section, a number of common technical terms and expressions have been abbreviated. These terms and their abbreviations are presented below.

<u>Units of Measure</u>:	
Acre(s)	ac
Cubic feet per second	cfs
Feet per second	fps
Gallons(s)	gal
Gallons per acre per day	gpad
Gallons per day	gpd
Gallons per minute	gpm
Gallons per capita per day	gpcd
Million gallons per day	mgd
Parts per million	ppm
<u>Abbreviations:</u>	
Operation and Maintenance	O&M
Sequencing Batch Reactor	SBR
Membrane Biological Reactor	MBR
Clinton Water District	CWD
Wastewater treatment plant	WWTP
Equivalent residential unit	ERU
Washington State Ferries	WSF
Washington Department of Ecology	DOE
Washington Department of Health	DOH

4.3 REFERENCE DATUM

Various components of a centralized wastewater collection system are functionally dependent upon the topography, relative elevations and land slope. Hydraulic capacities of gravity sewers are based on pipeline slopes. Pump stations must lift flow uphill to specific discharge points and grinder pumps have practical limits for conveyance into low pressure sewer systems, etc. Consequently, it is important to establish a common datum to be used for planning and operational purposes. For the purposes of this study, approximate land elevations are known and based on mean sea level at elevation zero. Subsequent planning can more precisely determine the reference datum for the service area.

4.4 DESIGN PERIOD

In planning for centralized wastewater collection systems and treatment facilities, it is necessary to evaluate both present and future service needs and to design a system compatible with reasonably variable demands over a given future length of time. This time span is known as the Design Period. A 20-year design period is normally used for municipal infrastructure such as water, sewer and transportation facilities.

Economy in design and construction cost is achieved by building conveyance pipes or treatment units with sufficient capacity or expandability to meet the present and future loadings from the service area. This is especially true in congested areas where duplication and paralleling of facilities at some future date would be extremely difficult and costly. Pump stations and treatment plants are best suited for phased construction because the service life of mechanical equipment is usually less than 20 years. Basic pumping structures are often designed to meet ultimate needs but use equipment compatible with nearer term demands. Some basic treatment process components follow a similar phased construction and equipment replacement schedule, but, in some cases, entire facilities are simply removed and replaced or augmented when additional capacity is needed.

The design of centralized pipeline conveyance facilities that will not operate at full capacity for many years needs to address the impact of relatively small initial flows in a high-capacity line built for future loadings. For example, gravity sewers and force mains should have adequate velocity at initial low-flow conditions in order to avoid sedimentation and odor production. Similarly, wastewater treatment facilities that are under-loaded may be difficult to operate and mechanical equipment may deteriorate or become obsolete prior to full utilization.

Wastewater management planning for the Clinton community and its proposed service area involves addressing a set of particular characteristics that describe the Clinton community. Examples of these characteristics might include:

- limited number of initial customers,
- seasonal residential occupancy,
- current utilization of on-site wastewater systems,
- limited economic viability of a segment of the current residents,
- diversity of land types (upland vs. beachfront),
- different soil types and varied topography, and
- land use limitations set by various regulatory agencies.

Included in this plan are options for onsite systems (Appendix B, Option 1), decentralized wastewater systems (Option 2) as well as traditional centralized collection and treatment (Options 3, 4 and 5), thus providing flexibility in future decision-making for implementation. The information in this chapter is applicable to Options 2 through 5 which incorporate sewer collection networks and centralized or decentralized wastewater treatment plants.

4.5 DESIGN LOADING FOR SEWER FACILITIES

The flow in a typical centralized sewer collection system is comprised of predominantly residential sewage together with commercial and industrial wastewater, groundwater infiltration and surface water inflows. All segments of the sewer system must be capable of carrying the peak rate of flow from these sources. Table 4.2 summarizes the design criteria including the estimated quantities of the various components, which are included in the flow in sanitary sewers, and is shown at the end of this chapter.

A centralized sewer collection system (pipes and pump stations) must be able to hydraulically convey the peak wastewater flows that could occur during any given day but still function satisfactorily under average and minimum flow conditions. The range of sewage flow is usually categorized as ratios of the average annual flow rate called “peak factors”. The magnitude of the peaking factor will vary with the size and development density of the area served. For this study, a maximum flow peak factor of 3.0 (ratio of peak flow to average flow equals 3.0/1) has been assumed. A more definitive estimate of peak factors would be developed if the Engineering Report or Facilities Plan is produced for this project.

4.6 INFILTRATION/INFLOW SOURCES

The quantity of water, which may enter a system through infiltration and inflow (I/I), is rather indeterminate and will generally increase with the age of the sewer. However, the design of the sewer system, careful construction and inspection techniques has considerable impact on the amount of I/I that can enter a sewer system. Surface water management will be addressed for any centralized wastewater collection system.

For infiltration, the porosity of the pipe material and the type of pipe joint influence the amount of groundwater that enters a sewer. The use of long pipe lengths, impervious pipe materials, high-quality side sewer lateral connections and well designed manholes, reduces infiltration. Current construction and inspection techniques take into account the need for having as watertight a system as possible. Poorly installed manholes and improperly aligned manhole covers are common sources of extra stormwater flow into the sewer system. Infiltration values of 600 gpad are used for new sewer systems. Pressure sewer systems are not subject to infiltration because pressure inside the sewer pipe generally exceeds groundwater pressure and there are no manholes (in a conventional sense).

Inflow is generally comprised of connections from roof gutters, footing and area drains (French drains), as well as broken side sewers or open connections left uncapped during construction. Some of these inflow connections are considered illegal in most jurisdictions. These inflow sources are of concern in the design of a centralized sewer system since the amount of flow from these sources can be significant, causing the sewer to become surcharged and creating sewage spills to the environment. Even though illegal connections are strictly prohibited, they are difficult to locate and permanently remove. Pressure sewers are subject to inflow sources from the customer's roof gutters, footing and area drains (French drains) etc. Inflow values of 500 gpad are used for new systems.

Inflow and infiltration flow quantities do not need to be added to the rated "average" capacity of the wastewater treatment plant because such flows are of temporary duration. However, the wastewater treatment plant can process I/I flows (and other short-duration peak flows) by means of flow equalization and/or temporary high-capacity operation methods.

4.7 DESIGN OF CENTRALIZED WASTEWATER COLLECTION FACILITIES

In order to provide an overview of various wastewater treatment options consistent with the purpose of this report, the paragraphs below describe preliminary design specific to the implementation of centralized wastewater collection systems that would require the installation of interceptors, trunk sewers, force mains, inverted siphons and pumping stations. Also a low pressure sewer (STEP) system is described which relates to both centralized and decentralized wastewater collection.

<u>Collection and Pumping Facilities:</u>

The traditional method of a centralized collection system is by gravity sewers. This is usually the most economical method when physical conditions permit. Sewage collection by this method is dependent upon favorable trenching conditions and suitable topography of the service area. Frequently, the topography is not suited for sewage collection solely by gravity in which case pumping stations are often constructed. Pumping stations may be less expensive to construct than a deep gravity relief sewer, but operating costs are higher. There are situations however, where the capital construction costs and physical parameters associated with gravity sewers become so overwhelming, that pumping facilities must be installed regardless of the topography.

Many communities in the Puget Sound use a combination of gravity and pumped sewage facilities to collect and convey sewage because the topography does not accommodate a strictly gravity conveyance system. In particular, waterfront areas, isolated low area basins and jurisdictional boundaries necessitate the use of pump stations. Gravity sewers require a steady downward slope that is equal to a drop of about 100 feet per horizontal mile. To eliminate the costly excavation that comes with deep sewers, pump (lift) stations are utilized to move the sewage up to elevations that allow further conveyance by gravity. In general, it is advantageous to minimize the length of pumped conveyance piping.

Waterfront developments are seldom sewerable by conventional gravity pipelines and must therefore be served by alternative collection systems such as vacuum systems or individual grinder pumps. The developed Clinton waterfront area extends for nearly three miles in length and cannot realistically be sewered by gravity mains.

One of the problems encountered with the construction of gravity sewers in the Puget Sound area has been difficult soil conditions. Construction of gravity sewers that require deep excavations, usually in excess of 15 feet, have been impeded by either high groundwater or sloughing of the trench walls or poor foundation soils or some combination of all factors. Besides the difficulties and safety concerns of construction, these problems can result in poorly placed sewer pipe. These conditions increase construction costs considerably on deep gravity sewers, making the use of lift stations and shallower gravity lines more economical in some cases. Prior to final design, the economics of a deep gravity system versus a pump station and shallow gravity line should be reviewed in order to determine the most economical approach from a life-cycle cost.

Vacuum Sewer Systems:

Vacuum systems are designed to serve flat topography where gravity service is impractical because of excessive depths. Waterfront development is an ideal application for a vacuum sewage collection system. A vacuum system typically consists of three main components: vacuum station, vacuum lines, and valve pits. The vacuum station is the central vacuum source of the system, which maintains the constant vacuum within the vacuum lines. A typical operating vacuum range for vacuum systems is between 16 and 20 inches of mercury. The valve pit is the interface between lateral side sewers originating from customers residence (or business) and the main collection vacuum pipelines. Valve pits generally connect one to two homes with the vacuum system. Wastewater exits the home or business by gravity in a conventional manner and enters a sump located near the property line. As the sewage level within the sump rises, it eventually triggers a switch that opens a valve, and the sewage and some air is propelled into the vacuum main at a high velocity. The sewage and air is driven by the difference between the higher atmospheric pressure in the valve pit and the low vacuum pressure within the vacuum collection line. After a preset interval, the valve closes. After time, friction slows down the sewage which eventually collects at low points in the system. The conveyance pipelines for vacuum systems are configured in a “sawtooth” profile pattern that produces an alternating chain of sewage and air within the pipeline. When the next valve opens, both sewage and air again enter the system. This time the trapped air pocket in the conveyance line propels the previous slug of sewage further down the pipeline. Eventually all sewage and air reaches the vacuum station where it is conveyed further in the system.

Grinder Sewer Systems:

Grinder pumps located at each customer's home or business can be utilized for either low pressure sewer systems or small diameter gravity sewers. In general, such systems are comprised of sewer service laterals and main lines that operate under pressure. Grinder pumps macerate the solids in wastewater into small enough particles that it can discharge into small diameter conveyance pipes. Grinder pumps discharging into pressure lines are found in low pressure systems where a large number of homes are served by the pumps. One grinder pump, according to some manufacturers, can serve up to five homes. However typical applications are for a single grinder pump to serve one home. In these low pressure systems, the sewer district has the responsibility for operation and maintenance (O&M) of the grinder pumps.

Alternatively, an individual grinder pump discharging into a gravity sewer is not considered to be a low pressure system. In this case the individual property owner has the full responsibility for O&M of the grinder pump system.

Septic Tank Effluent Pump (STEP) Systems:

STEP systems are comprised of three main elements: septic tanks, septic pumps, and small low pressure sewer lines. All generated sewage enters the septic tank the same as a traditional on site septic system. All solids settle out to the bottom of the septic tank while the liquid portion of the sewage is pumped out into the low pressure sewer lines and subsequently carried to the wastewater treatment plant. With low pressure sewer lines, topography is not a major issue; consequently, they can be installed at relatively shallow depths similar to water lines. Typically for STEP systems, the septic tank along with the pump components are owned and maintained by the sewer district.

Trunk and Interceptor Sewers:

Sewers are usually designed with sufficient capacity to carry the peak flows from the ultimate development of the tributary area. This flow represents the sum of the several loadings calculated separately for each section of sewer or tributary area. The loadings consist of the peak flow of sanitary sewage, groundwater infiltration, surface water inflow and any special quantities that must be considered. The larger the area served by a particular trunk or interceptor, the lower the peak factor or ratio of peak instantaneous flow to average flow due to the "averaging" of flows over the larger area.

The ability of a sewer to transport suspended solids contained in sewage is related to the velocity of flow in the sewer. A velocity of 2 feet per second at average daily flow rate is generally considered to be the minimum which will keep pipe surfaces relatively free of deposited material. Table 4.1 presents the minimum allowable slope of various sizes of sewers to obtain a cleaning velocity under average flow conditions. Minimum slopes are not acceptable for all sewers. Sewers with low flow rates should have increased slopes or they may become maintenance problems due to deposition of solids.

TABLE 4.1

MINIMUM PIPE SLOPES

Pipe Size in Inches	Slope* (Ft/Ft)
8	0.0040
10	0.0028
12	0.0022
15	0.0015

*Minimum slope (vertical ft. per horizontal ft.) for various sized sewer pipe necessary to maintain a cleansing velocity of 2 fps, at full pipe conditions.

A value of 0.013 is recommended for Manning's "n" value (pipe roughness) when calculating flow in a gravity sewer system.

Force Mains:

Force mains carry sewage that is pumped. The design of sewer force mains is predicated on the fact that they flow full and under pressure. Force mains must be capable of carrying the hydraulic peak flow without excessive friction and have proper cleaning velocities at normal flow rates. Sometimes, in consideration of sedimentation and scouring factors, it is necessary to install two force main pipes in order to meet initial low flows and higher ultimate flows.

Since the design flow is either pumped or divided between parallel lines, force mains are commonly of smaller size than adjacent gravity sewers. The empirical Hazen-Williams equation is commonly utilized for analyzing pressure flow conditions. A discharge coefficient "C" is used in the equation to account for the roughness and condition of the material. The typical value of "C" of small diameter pressure mains (PVC, HDPE or ductile iron) is 130. The appropriate pipe diameter is determined from the Hazen-Williams equation with consideration for the desired velocity of approximately three feet per second.

Pumping Stations:

Wastewater pumping stations are generally constructed underground either as factory assembled package units or custom designed stations. An on-site standby power generator is included as conditions warrant. Gravity overflow from the station's wet well to a downstream gravity sewer may be possible at some lift stations such that the solids are retained in the wet well during a power outage but the liquid flows downstream without causing sewage spills or causing backups. Once normal operation resumes, liquids and solids are pumped out of the wet well. Capacities of permanent pumping stations are based on the peak flow of all sewers tributary to the individual station. Stations can be designed to allow for staged increases in pumping capacities, with pumping units installed as required by growth and flow increases.

Pumps are usually driven by electric motors, are of a non-clog design, and are of a number of units sufficient to pump the design peak flow with any one unit out of service. Mechanical failures are avoided by providing a duplication of pumping capabilities in each pump station. Problems resulting from power outages are avoided by providing on-site standby power generators with automatic starting systems and electrical power failure alarm systems. The pump stations are usually monitored by the system operator via telemetry.

Sewer Materials:

The most common material for sewer pipe construction is polyvinyl chloride (PVC) for sizes from 4-inch to 27-inch diameter. For pipe diameters above 27-inch diameter, other pipe materials often become more economical. Ductile iron pipe is frequently employed where its use is justified due to abrasive conditions or high external loading. Pipe joints are usually a push-on type sealed with flexible, rubber gaskets. Trenchless sewer construction methods such as horizontal directional drilling or microtunneling will usually utilize High Density Polyethylene (HDPE) pipe materials. HDPE pipe segments are assembled by fusion joining.

Construction of manholes is done with precast, reinforced concrete bases, rings and cone sections with rubber gaskets between sections. The use of brick and mortar manhole construction is no longer practiced. Recent developments for groundwater infiltration elimination involve the use of mastic sealing devices around the outside of manholes at the joints. Cement mortar applied to the inside of manhole joints appears to be an effective way of reducing infiltration in wet soils. These favorable modifications have resulted in a significant decrease in infiltration in most manholes.

Sewer Locations:

In general, the trunk and interceptor sewers are located in existing public rights-of-way or in proposed street areas. Sometimes sewers must be located on easements within private property or in within rights-of-way of other public agencies (i.e. power line corridors etc.).

The location of the sewer lines in relation to other utilities must also be considered. There may be some conflict in final sewer locations due to interference with water mains, drains and electrical conduits. In most cases however, sewer lines would pass beneath the other utilities. This is especially true in the case of water mains, where it is desirable to have the sanitary sewer a minimum of three feet below the water main, with ten feet of horizontal separation. Reclaimed water distribution pipes must be located ten feet away from both water and sewer mains.

TABLE 4.2

DESIGN CRITERIA FOR SEWAGE FLOWS

Parameter	Criteria
Quantity of Sanitary Sewage (Average) Residential	85 gpcd
Population Density Rural Residential Rural Center Rural Park	 7.0 persons per acre 27.85 persons per acre .46 persons per acre 27.85 persons per acre
New systems in areas of average groundwater & assumed to have good storm drainage. -Infiltration -Inflow *I/I not included in areas of vacuum/grinder systems nor in wwtp capacity	 600 gpad 500 gpad 1,100 gpad
Peaking Factor	3.0