Appendix D

Cost Estimation Methodology

COST ESTIMATION METHODOLOGY

The cost estimation methodologies for conventional gravity and alternative collection systems, as well as centralized treatment, cluster treatment, and onsite treatment systems, are presented in this appendix. The cost estimates include the capital cost necessary to install the system(s) and the annual cost to repair and maintain the system(s). Capital costs are annualized over 30 years (the life of the system) using a discount rate of 7 percent (OMB, 1996). All costs are presented in 1995 dollars. Cost data for the different technologies have been obtained from various sources, as documented in each section. Because the data reflect costs from different years, they have been indexed to 1995 dollars using the Means Historical Cost Indexes, as printed in the "Engineering News-Record (ENR)"(Means Heavy Construction Cost Data, 1996). Costs are indexed using the following equation:

$$1995\ Cost = 1987\ Cost\ x\ \frac{1995\ Index}{1987\ Index}$$

Indexes applicable to the costs presented in this appendix are:

Table D-1. Cost Indexes

Year	Index
1976	46.9
1978	53.5
1987	87.7
1991	96.8
1992	99.4
1995	107.6

COLLECTION SYSTEMS

Conventional Gravity Collection

A conventional gravity collection sewer collects and transports sewage to a centralized treatment facility via gravity. The system includes lateral pipes, collection sewers, interceptor sewers, manholes, and pump stations. Laterals are the pipes that transport wastewater from homes to the collection main sewers. Collection sewers are the pipes which carry the wastewater to interceptor sewers, which carry wastewater to the treatment system with the help of pump stations if needed. Manholes are included along the collection sewer to allow access for cleaning.

Because the pipes in a gravity collection system must continually slope downward, pump stations may be required to avoid excessive excavation for pipes or to reach a particular elevation at the system outfall. Pump stations (or lift stations) include pumps, valves, and a well to hold incoming sewage.

Cost Data

Cost estimates were developed for a conventional gravity collection system using cost equations developed by Dames and Moore. These equations were derived from actual installation and annual operating and maintenance (O&M) costs (Smith, 1978). The cost estimating procedure calculates costs in 1978 dollars because these were the best data available; the costs were then indexed to 1995 dollars.

Pipe Diameter - Dames and Moore provide an equation for estimating the capital costs of the lateral, collection main, and interceptor sewer pipes on a dollar per foot basis. This equation relates the cost of the pipe to the diameter of pipe required:

$$\frac{\$}{foot}\ (1978\ dollars) = 3.2 \times (pipe\ diameter)^{1.1667} \times 1.03$$

Dames and Moore also provide an equation to determine the diameter of pipe required for the collection and interceptor sewer, based on the flow of wastewater through the pipe:

$$Pipe\ diameter = 17.74 \times Flow\ (mgd)^{0.3756}$$

A minimum pipe diameter of 8 inches was used for the collection and interceptor sewers (Fact Sheet, n.d.), unless a larger pipe size was required for the design flow. A pipe diameter of 4 inches was used for on-lot lateral pipes.

Pipe Length - The length of collection sewer required is dependent on the population density. Dames and Moore provide an equation for estimating this length:

$$\frac{feet\ of\ sewer}{capita} = 54 \times \left(\frac{persons}{acre}\right)^{-0.65}$$

The length of interceptor pipe needed to transport the wastewater to a newly constructed treatment facility in the rural community is estimated to be about one mile. The length of interceptor pipe for the fringe community needed to transport wastewater to an existing facility in the metropolitan center was estimated between one and five miles. On-lot lateral pipes are estimated to be about 50 feet per home in the rural community, and 25 feet per home in the fringe community.

Lift/Pump Stations - The number of pump stations required in a system is dependent on the site topography. Dames and Moore estimate the number of pump stations to be one for every 18,000 feet of collection and interceptor length; however, additional pump stations are necessary if the topography is hilly or steep. The cost to install pump stations is dependent on the flow of wastewater and is estimated by the following equation:

$$\textit{Cost per station } (1978\ \$) = 0.168 \times (\textit{flow, mgd})^{1.08} \times 1.03$$

A minimum cost of $50,000 (1995$) was used for construction of pump stations.

Annual costs to repair and maintain gravity collection sewers were also estimated from Dames and Moore data; average operating and maintenance costs for sewers is $1,502 per mile of sewer line (1978 dollars).

System Design and Cost

The following conventional gravity collection systems were designed and costed for the fringe and rural communities using the methodology presented above:

1) Installation of a conventional gravity sewer in the fringe community, with an additional 1-5 miles of pipe to connect this system to the existing sewer system in the metropolitan center.

2) Installation of a conventional gravity sewer in the rural community to be connected to a new rural community treatment plant located within one mile of the community.

Fringe Community Costs (1995 $)

The collection system for the fringe community is estimated to require about 25,000 feet of 10-inch diameter collection pipe, between 5,280 and 26,400 feet of 10-inch interceptor pipe, 11,000 feet of 4-inch lateral pipe, and three pump stations. The capital cost to install this system ranges from $3,322,900 to $5,377,800, depending on the distance of interceptor pipe required. The annual O&M costs are estimated to range between $23,000 and $35,000.

Rural Community Costs (1995 $)

Population density has a significant impact on the cost of collection, and ultimately makes up a large percentage of the cost to connect an area to centralized treatment. For this reason the cost of collection for the rural community was calculated using two population densities: a moderate density of 1 home per 1.5 acres and a low density of 1 home per 5 acres.

The collection system for the rural area when the population density is moderate is estimated to require about 15,500 feet of 8-inch diameter collection pipe, 5,280 feet of 8-inch diameter interceptor pipe, 6,800 feet of 4-inch diameter lateral pipe, and two pump stations. The capital cost to install this system is estimated to be $1,882,800 and the annual O&M costs are estimated to be about $15,750.

The collection system for the rural area when the population density is low is estimated to require about 34,000 feet of 8-inch diameter collection pipe, 5,280 feet of 8-inch diameter interceptor pipe, 6,800 feet of 4-inch lateral pipe, and three pump stations. The capital cost to install this system is estimated at $3,311,500 and the estimated annual O&M costs are about $26,300.

Alternative SDGS Collection

Alternative collection sewers are used in place of, or in conjunction with, conventional gravity collection sewers to collect and transport wastewater to a central treatment facility. Small diameter gravity sewers (SDGS) are a system of interceptor pipes and tanks and small diameter PVC collection mains. Onsite tanks are used to remove grease and settleable solids, allowing for the smaller diameter collection pipe to be used. The settled wastewater is discharged from the septic tank via gravity into the collector mains (EPA, 1991) . The collector mains then transport the wastewater to a local cluster system, a centralized treatment facility, or a conventional collection system. The main components of an SDGS are 3-inch to 8-inch PVC mains, cleanouts or manholes, vents, and septic tanks.

Cost Data

Several sources were reviewed to obtain cost data on SDGS systems. These sources include :

- EPA Manual on Alternative Collection (EPA, 1991)
- Fountain Run Case Study (Abney, 1976)
- Region IV Survey (EPA, n.d.)

The EPA alternative collection manual provides unit cost data (mid-1991) for interceptor tanks and 4-inch mains. The manual also contains design data and SDGS systems for several small communities; these communities were located in areas with steep and hilly topography. These systems were also designed to feed into central treatment facilities, instead of local cluster treatment systems. These differences are the reason why the sewer designs for these communities were not applied to the hypothetical communities.

The Fountain Run case study provides design information for a community divided into clusters ranging from 3 homes to 34 homes. The study did not indicate any prevailing topographic conditions which would hinder the construction of a SDGS. The study also provided unit cost data (1976) for the SDGS components, but these were not used since more recent unit cost information is available from the EPA alternative collection manual.

The Region IV survey contains design and project cost information on alternative collection systems. The SDGS projects were all designed to feed into centralized treatment facilities, therefore, these projects are not applied to the hypothetical communities.

System Design and Cost

The SDGS system was chosen to collect and transport wastewater to a local cluster treatment system. The homes in the fringe and rural communities were divided into smaller groupings, or clusters, based on their proximity to each other. Homes located in areas with poorly drained soils or high water table were also clustered together.

Design information for cluster systems of 3 to 34 homes was obtained from the Fountain Run Case Study. This information was combined with unit costs obtained from the EPA alternative collection manual. Homes with existing onsite septic tanks in good working order were not costed for replacement. Cost estimates for the installation of SDGS in the fringe and rural areas are provided below.

Fringe Community

The fringe area was grouped into 20 clusters. Table D-2 presents a summary of the capital cost and the length of sewer required for each cluster. As an example, the calculation of the capital costs for the 34-home SDGS cluster is presented below.

Table D-2. Fringe Area Clusters

Number of Clusters	Number of Connections	Capital Cost per Connection	Feet of Sewer per Connection
1	7	$2,633	174
6	10	$2,271	147
3	12	$1,723	83
10	34	$2,372	148
Total	383	$827,631	63,440

Septic Tank Capital Cost. This cluster contains 34 tanks. The EPA manual estimates the average installed septic tank cost to be $800 (1991 dollars). This yields a capital cost of $27,200 in 1991 dollars or $30,235 in 1995 dollars for the septic tanks in this cluster.

Sewer Main Capital Cost. The 34-home cluster requires 5,040 feet of 4-inch main. The EPA alternative collection manual estimates the cost per foot to install 4-inch pipe to be $9 per foot (1991). This yields a capital cost of $45,360 in 1991 dollars or $50,421 in 1995 dollars for the collection main in this cluster.

Total Capital Cost for Collection. The capital cost for collection is the sum of the capital cost for the units in the system incremented to 1995 dollars. For the 34-home cluster system the capital cost is $80,818, or a cost of $2,372 per home. Two hundred twenty homes in the fringe community have existing tanks which will be utilized by these cluster systems; therefore, the cost to replace these tanks ($195,636) has been subtracted from the total collection cost. The capital cost for collection in the fringe area is $827,631, as shown in Table D-2.

Operation and Maintenance Costs. The operation and maintenance cost for the SDGS system is included in the description of treatment for cluster systems, described later in this appendix.

Rural Community

For estimating the cost of cluster systems, the failing systems in the rural community were grouped into 4 clusters. Table D-3 presents a summary of the capital cost and the length of sewer required for each cluster. The capital cost of the SDGS clusters in the rural area were calculated using the same process as the fringe area.

Table D-3. Rural Area Clusters

Number of Clusters	Number of Connections	Capital Cost per Connection[1]	Feet of Sewer per Connection
2	10	$2,271	147
1	12	$1,723	83
1	35	$2,372	148
Total	67	$149,122	9,116

Capital Cost. The capital cost for collection in the rural area is $149,122, as shown in Table D-3.

Operation and Maintenance. The operation and maintenance cost for the SDGS system is included in the treatment part of the cluster system.

TREATMENT SYSTEMS

Centralized Wastewater Treatment

Many treatment technology options are available to communities that wish to employ centralized wastewater treatment. Community-specific characteristics, such as land cost and availability, wastewater characteristics and flow rates, desired treated wastewater effluent concentration, and solids disposal costs affect whether a particular treatment train may be the most cost-effective and reliable system for a particular community. For the hypothetical fringe and rural communities, different treatment trains are costed based on their expected community characteristics. For the rural community, due to the very small wastewater flow and the relatively large amount of land available, the treatment train costed includes a facultative oxidation pond, which requires a large amount of land but is economical and requires relatively little maintenance, and a chlorination/dechlorination disinfection unit. For the fringe community, the treatment train consists of a grit chamber, comminutor, sequencing batch reactor (SBR), and chlorination/dechlorination disinfection unit. The SBR was selected for the fringe community because it is capable of handling small wastewater flows and requires only a small amount of land, which may not be readily available in a fringe area. If removal of additional nitrogen is required, the facultative oxidation pond in the rural community is replaced by a SBR that provides nitrification and denitrification, and the SBR in the fringe community is modified to provide such treatment. Waste solids from the SBR unit is costed for disposal of via land application.

Cost Data

The costs for treatment of wastewater at centralized wastewater treatment facilities were estimated using the computer cost model Water and Wastewater Treatment Technologies Appropriate for Reuse (WAWTTAR) (Gearheart et al, 1994). WAWTTAR was developed to estimate the feasibility and cost of water supply, wastewater collection, and wastewater treatment. The WAWTTAR cost model estimates costs in 1992 dollars, which are then indexed to 1995 dollars. Inputs to the WAWTTAR cost model include the community wastewater volume and characteristic data, treatment trains, and land costs, as well as target treatment performance standards.

The cost of land for construction of treatment facilities varies significantly from location to location. In some areas, the local government may already own the land necessary for construction of treatment facilities. In these instances, the land cost for treatment facilities will be minimal. However, many communities may need to purchase additional land to construct treatment facilities. The cost of the land will vary greatly from location to location. In the state of North Carolina, for example, land costs may range from $5,000 per acre in rural communities to $50,000 per acre in more developed areas (Hoover, 1996). Land costs for this report are based on an approximate average cost of $25,000 per acre.

The basic SBR and disinfection treatment system for the fringe community and the facultative oxidation pond and disinfection for the rural community are expected to reduce the biological oxygen demand (BOD) of the wastewater, as well as reduce suspended solids and fecal coliform bacteria.

These are parameters that would be included in most NPDES permits for municipal wastewater treatment facilities. The following treatment standards were input to the WAWTTAR cost model:

BOD	≤ 30 mg/L;
Suspended solids	≤ 50 mg/L; and
Fecal Coliform	≤ 200/100 ml.

The SBR modified to provide nitrification and denitrification, which was used for both the fringe and rural communities to remove nitrogen would meet the above standards and also reduce total nitrogen in the wastewater to 6 mg/L.

System Design and Cost

The cost estimates for centralized treatment of the wastewater from the rural community includes construction of a new treatment system dedicated to the community's wastewater. The cost estimates for centralized treatment of the wastewater from the fringe community includes expansion of the existing metropolitan center treatment plant to accomodate the additional flow. The centralized treatment costs discussed in this section do not include collection costs to transport the wastewater to the treatment facility, which were presented earlier in this appendix. Capital costs include the cost to purchase land on which to construct the facility, design, construction materials and equipment, and labor costs. Operating and maintenance costs include treatment chemicals such as chlorine and sulfur dioxide, energy to run equipment such as mixers, pumps, and aerators, and labor.

In some communities, existing wastewater treatment facilities may have sufficient capacity to treat additional wastewater from nearby community developments, such as the fringe community. Other communities may be capable of upgrading or expanding their existing wastewater treatment facilities; such modifications may range from minor operational changes to extensive upgrades and/or construction of additional facilities. The extent to which existing facilities must be modified to accommodate additional wastewater is highly dependent on site-specific factors, such as the existing capacity of the sewer and lift stations and treatment plant, and the effluent standards that must be met by the facility. Due to these highly site-specific factors, little or no capital investment would be necessary in some communities to enable an existing facility to treat additional wastewater, while in others upgrading the existing facility would be more expensive than construction of a completely new facility. Where existing facilities are used to treat additional wastewater, additional operating and maintenance expenses would be incurred from the use of additional oxygen and treatment chemicals, disposal of additional sludge, possible permit modifications, and other costs that are primarily and secondarily related to the volume of wastewater treated.

Fringe Community Costs (1995 $)

The capital cost to expand the existing metropolitan centralized wastewater treatment system consisting of a grit chamber, comminutor, SBR, and chlorination/dechlorination unit to accomodate the flow from the fringe community is estimated to be $464,000. Annual O&M costs are estimated to be $61,000.

Rural Community Costs (1995$)

The capital cost to install a centralized wastewater treatment system consisting of a facultative oxidation pond and a chlorination/dechlorination unit to service the rural community is estimated to be $439,000, while annual O&M costs are estimated to be $14,000.

Cluster Systems

A cluster system treats wastewater from a localized group of homes and is often used in conjunction with an alternative collection system. Cluster systems may include a central leach field for subsurface discharge, or may discharge to surface waters. The cluster systems evaluated for the rural and fringe communities consists of onsite septic tanks, and central sand filters and leach fields. The main components of a central leach field are dosing siphons/tanks, pumps, adsorption trenches, and land. The main components of a sand filter are pumps, dosing tanks, and the filter.

Cost Data

Cost estimates were developed for a central leach field to serve a cluster of homes. The Fountain Run case study (Abney, 1976), which was used to develop alternative collection costs, also provides design information on leach field treatment. The case study provides capital cost data for a community divided into clusters ranging from 3 to 34 homes. The study includes unit cost data (1976) for leach field treatment, including construction of the adsorption trenches. More recent cost data were used for sand filter treatment for cluster systems (Otis, 1996) and for land. As with centralized treatment, the cost for land is based on the approximate average cost of $25,000 per acre for North Carolina (Hoover, 1996).

Operating and maintenance costs include pumpout of the individual septic tanks and replacement of distribution pump every 10 years, and quarterly inspections of the cluster systems. Cost data were obtained from the COSMO cost model (Renkow and Hoover, 1996) developed at North Carolina State University and are described in detail in the onsite system section, described later in this appendix.

System Design and Cost

The homes in the fringe and rural communities were divided into smaller groupings , or clusters, based on their proximity to each other. Homes located in areas with poorly drained soils or higher water table were also clustered together.

Design information on leach fields for cluster systems of 3 to 34 homes was obtained from the Fountain Run case study, and was combined with the average cost per acre of land to comprise the capital cost for the leach field system. The capital cost for sand filter treatment is based on wastewater flow, and is estimated to be $15 per gallon (Otis, 1996). Operating and maintenance costs were obtained from the COSMO cost model. Cost estimates for the installation of treatment systems in the fringe and rural areas are provided below.

Fringe Area

To correspond with alternative collection costs, the fringe community was broken into 20 clusters. In the fringe community, cluster systems were costed for sand filter treatment followed by a leach field. Table D-4 presents a summary of the capital cost for cluster systems in the fringe community.

Table D-4. Fringe Area Clusters

Number of Clusters	Number of Connections	Capital Cost per Connection
1	7	$6,598
6	10	$6,914
3	12	$6,529
10	34	$6,639
Total	383	$2,953,421

Capital Cost. The cost for the leach field treatment follows the methodology outlined in the alternative collection section. The sand filter treatment cost was estimated as $15 per gallon of wastewater treated. Using the basis of 175 gallons of wastewater produced per home, a sand filter treatment system is estimated to cost $2,625 per home. The capital cost for treatment in the fringe area is $2,953,421, as shown in Table D-4.

Operation and Maintenance Cost. The operation and maintenance (O&M) cost for the combined collection and treatment cluster was obtained from the COSMO cost model. Maintenance of the onsite systems, including yearly inspections and pumpouts every 10 years cost $32 per year. Quarterly inspections of the central leach field cost $100 per year; additional inspection time for the sand filter is expected to cost an additional $25 per year. Pump replacements are expected to occur three times over the life of the system and cost a total of $1,800.

Rural Community

To correspond with alternative collection costs, the failing systems in the rural community were broken into 4 clusters. Table D-5 presents a summary of the capital cost for each cluster.

Table D-5. Rural Area Clusters

Number of Clusters	Number of Connections	Capital Cost per Connection
2	10	$6,914
1	12	$6,529
1	35	$6,639
Total	67	$448,992

Capital Cost. The cost for the leach field treatment follows the methodology outlined in the alternative collection section. The sand filter treatment cost was estimated as $15 per gallon of wastewater treated. Using the basis of 175 gallons of wastewater produced per home, a sand filter treatment system is estimated to cost $2,625 per home. Sand filter costs are added to the costs for the 4 cluster systems (serving 67 homes) located in areas with poor soil conditions. The capital cost for cluster treatment in the rural community is $448,992, as shown in Table D-5.

Operation and Maintenance. The operation and maintenance (O&M) cost for the combined collection and treatment cluster was obtained from the COSMO cost model. Maintenance of the onsite systems, including yearly inspections and pumpouts every 10 years cost $32 per year. Quarterly inspections of the central leach field cost $100 per year; additional inspection time for the sand filter is expected to cost an additional $25 per year. Pump replacements are expected to occur three times over the life of the system and cost a total of $1,800.

Onsite Treatment

Onsite systems treat wastewater from individual homes, thereby eliminating the need for a centralized collection and treatment system. A conventional onsite system consists of a septic tank, gravity distribution leach field, and the soil beneath the leach field (Hoover and Renkow, 1997). Solids from the wastewater deposit in the septic tank where anaerobic decomposition occurs. The effluent is dispersed throughout the leach field where it infiltrates the soil. Additional treatment, such as aerobic decomposition, occurs in the soil.

Because of site-specific conditions, some onsite systems require additional treatment units or use different methods of distributing the wastewater to the leach field. Two system modifications evaluated for the hypothetical community were low pressure pipe (LPP) distribution and sand filter treatment. Systems that utilize LPP distribution include a pump, pump tank, floats and controls, and a pressure distribution system, including small diameter (1.25-inch) PVC lateral pipes with small perforations.

Cost Data

Onsite treatment costs were estimated using the COSMO cost model (Renkow and Hoover, 1996). Equipment and labor costs (1995 dollars) reflecting the Wisconsin area were obtained and entered into COSMO to develop cost estimates. However, it should be noted that onsite treatment costs vary by region and may in fact be more or less cost-effective depending on site-specific conditions and costs.

Onsite capital costs include upgrades (i.e., replacement systems) for failing systems in the rural and fringe communities, as well as new systems for the future development in the fringe community. Operating and maintenance costs include quarterly inspections of the onsite systems, including septic tanks, leach fields, and sand filters. O&M costs also include pumpouts of the septic tanks and replacement of the distribution pumps every 10 years. The establishment of one district to provide wastewater management to the fringe and rural communities assumes the district will take over maintenance of all existing and future onsite systems; therefore, the annual O&M cost estimates include costs for the existing onsite systems that are still functioning effectively.

System Design and Cost

Two onsite treatment systems were evaluated for the hypothetical community:

- Septic tank with low pressure pipe (LPP) distribution to a leach field
- Septic tank with sand filter treatment and LPP distribution to a leach field

LPP systems were chosen because they provide dosing and resting cycles in the leach field and distribute the wastewater more effectively throughout the system. LPP distribution is effective in areas with poor drainage, such as some of the homes in the hypothetical rural and fringe communities. Sand filters provide additional treatment to meet performance goals in systems located in ecologically sensitive areas and/or areas with high water tables, such as the homes located near the river in the rural community..

Rural Community

About half (67) of the 135 onsite systems currently in operation in the rural community are failing. Twenty of the 67 failing systems are located in an area near the river with a high water table. These systems need to achieve better quality discharge; therefore, the cost estimates include installing a new onsite systm equipped with a septic tank, a pressure-dosed single pass sand filter and a low pressure pipe distribution system to a leach field. Forty-seven of the 67 failing systems are located in areas with poor soils; the cost estimates include installing a new septic tank with a low pressure pipe distribution system to replace these systems. Capital costs for the rural area are estimated to be $510,000.

Annual O&M costs include maintenance of the 67 newly upgraded systems, as well as maintenance of the 68 current systems that still function effectively. These existing systems consist of a septic tank and gravity distribution system to a leach field. Annual O&M for the rural area is estimated to be $13,400.

Fringe Community

About half (110) of the 220 onsite systems currently in operation in the rural community are failing. Thirty-three of these failing systems are located in an area near the river with a high water table. These systems need to achieve better quality discharge; therefore, the cost estimates include installing a new onsite system equipped with a septic tank, a pressure-dosed single pass sand filter and a low pressure pipe distribution system to a leach field. Seventy-seven of these failing systems are located in areas with poor soils; the cost estimates include installing a new septic tank with a low pressure pipe distribution system to replace these systems. The cost estimates for onsite treatment in new fringe community homes also include installing new septic tanks with low pressure pipe distribution to a leach field for all future homes (223 systems). Capital costs for the fringe community is estimated to be $2,117,095; O&M costs are estimated to be $59,240.