

## 4. DESIGN CRITERIA

### 4.1 Summary of Sizing Criteria

Table 4-1 summarizes the application of the sizing criteria throughout the regional project based on a *design* population, average daily water use, and a maximum daily water use employing a factor of 2.25 times average. The design population within the Fort Peck Indian Reservation was projected in Chapter 3. The existing population was used in the Dry Prairie area, rather than the projected declining population. This will permit service to the existing population in the early years of the project and thereafter if the Dry Prairie population stabilizes. Chapter 9 addresses the potential cost to water users if the Dry Prairie population does not stabilize and declines along the historic trend as presented in Chapter 3. The resulting design population was 31,102 (Table 4-1).

Average daily per capita water requirements of 180 gallons were applied to the design population in the communities, and 135 gallons were applied to the design population in the rural areas. An additional livestock demand of 12 gallons per animal unit per day for 36,300 animal units was also applied. This resulted in an average day demand of 5,535,746 gallons. Design for maximum day increased the demand to 13,099,339 gallons based on application of a factor of 2.25 for community and rural demands and an increase from 12 to 16 gallons per animal unit for livestock. Demands were derived based on a 22 hour day. When converted to flow rate, the maximum day demand is equivalent to 9,133 gallons per minute (gpm) based on 22 hours of operation at the treatment plant.

### 4.2 Residential Water Use Criteria

The introductory remarks in this section place residential water uses in context with non-residential uses. A more detailed discussion of residential water use criteria begins in section 4.2.1. The determinations related to nonresidential purposes are discussed further in section 4.3.

The Bureau of Reclamation found that water used in Montana in 1985 for residential, commercial, public and industrial purposes was about 220 gallons per capita per day (gpcd), including losses and unaccounted for water.<sup>1</sup> The Bureau of Reclamation looked more closely at *residential* water use in Montana and determined that average use of 130 gallons per capita per day (gpcd) in 1985 could be expected to increase to about 135 gpcd by year 2000. The year 2000 projection of 135 gpcd was considered reasonable and was adopted as a basis for residential water use for the regional project discussed here. As will be shown below, the U.S. Geological Survey has found that residential water use in Montana has averaged 129 gpcd as contrasted with other regional states where residential water use has averaged from 66 to 117 gpcd. EPA finds that normal residential water use, with some lawn and garden watering, averages 60 gpcd nationally, but this value does not compare well with reported experience in the region. Johns Hopkins University, as will be shown, found that residential water use averaged 123 gpcd in the metered West during the mid 1960s.

By the beginning of the 20th century, municipal water use in the United States was 90 gallons per capita per day. In London by 1912, per capita use was 40 gallons per day, suggesting lower water use in Britain than in the United States. By 1955 residential water use averaged 67 gpcd in the

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<sup>1</sup> U.S. Bureau of Reclamation, May 1996, p. 72.

TABLE 4-1

## DESIGN WATER REQUIREMENTS

	1990 Population	Design Population	Average Day (gpd)	Design Maximum Day (gpd)	Design Flow Rate (gpm)
Residential Average Day, gpcpd			135		
Commercial Average Day, gpcpd			45		
Maximum to Average Day Factor			2.25		
Hours per Day			22		
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Fort Peck Public Water Systems					
Wolf Point	3,518	5,579	1,004,247	2,259,555	1,712
Poplar	2,114	3,353	603,461	1,357,788	1,029
Frazer	422	669	120,464	271,044	205
Brockton	507	804	144,728	325,638	247
Oswego	--	--	--	--	--
Fort Kipp	--	--	--	--	--
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Subtotal	6,561	10,405	1,872,900	4,214,025	3,192
Fort Peck Rural	4,161	6,590	889,650	2,001,713	1,516
Total Fort Peck	10,722	16,995	2,762,550	6,215,738	4,709
Dry Prairie Public Water Systems					
Glasgow	3,652	3,652	657,360	1,479,060	1,121
Plentywood	2,119	2,119	381,420	858,195	650
Scobey	1,160	1,160	208,800	469,800	356
Culbertson	784	784	141,120	317,520	241
Nashua	379	379	68,220	153,495	116
Medicine Lake	381	381	68,580	154,305	117
Westby	265	265	47,700	107,325	81
Froid	253	253	45,540	102,465	78
Bainville	166	166	29,880	67,230	51
Opheim	144	144	25,920	58,320	44
Outlook	143	143	25,740	57,915	44
Flaxville	77	77	13,860	31,185	24
Whitetail	--	--	--	--	--
Peerless	--	--	--	--	--
Raymond	--	--	--	--	--
Antelope	103	103	18,463	41,541	31
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Subtotal	9,626	9,626	1,732,603	3,898,356	2,953
Dry Prairie Rural	4,481	4,481	604,993	1,361,234	1,031
Total Dry Prairie	14,107	14,107	2,337,596	5,259,590	3,985
Total Project					
PWS	16,187	20,031	3,605,503	8,112,381	6,146
Rural	8,642	11,071	1,494,643	3,362,947	2,548
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Total MRI	24,829	31,102	5,100,146	11,475,328	8,693
Livestock	--	--	435,600	580,800	440
Total Project	--	--	5,535,746	12,056,128	9,133

United States, and total municipal requirements averaged 155 gpcd.<sup>2</sup> Water use in public systems in 1970 averaged 166 gpcd across the United States. Throughout the Missouri River Basin, water use in public systems averaged 152 gpcd, and in individual rural households, water use averaged 63 gpcd.<sup>3</sup> The difference between rural household water use and water use in public systems of the United States and the Missouri River Basin is attributed to differences in lawn watering, commercial and industrial water uses.

In 1960 and 1970, the U.S. Geological Survey wrote, in marked contrast between the two decades, as follows:

*... People living in the average electrified farm or urban home in the United States use an average of 60 gpd or more per person for household purposes and watering of lawns. The corresponding average for homes without running water is only 10 gpd per person. Others investigators report that only 50 gpd per person is used in homes with running water. ...*<sup>4</sup>

*The per capita rate for rural domestic use is about 63 gpd; this represents a quantity intermediate between estimated low withdrawal rates in homes without running water and estimated withdrawal rates in rural homes that have running water and are equipped with modern high-water-requirements appliances. ...*<sup>5</sup>

In 1990 the U.S. Geological Survey reported water use from public supplies for domestic, commercial, industrial and thermo-electric power<sup>6</sup> uses at 226 gallons per capita per day in Montana.<sup>7</sup> Other Great Plains states reported as follows:

Montana	226 gpcpd
South Dakota	137
North Dakota	158
Nebraska	251
Iowa	154
Minnesota	176
Wyoming	260

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<sup>2</sup> Linaweaver, 1967, p. 2.

<sup>3</sup> Missouri River Basin Inter-Agency Committee (MRBIAC), June 1969, Vol. 6.

<sup>4</sup> MacKichan, 1960.

<sup>5</sup> Murray, 1970.

<sup>6</sup> Public suppliers in South Dakota do not provide water for thermo-electric power use.

<sup>7</sup> Wahl, *et al*, 1995 <A HREF = Circular 1081>

Domestic water use (drinking, food preparation, bathing, washing cloths and dishes, flushing toilets and watering lawns and gardens) was reported in the source states as follows:

Montana	129 gpcpd
South Dakota	81
North Dakota	87
Nebraska	115
Iowa	66
Minnesota	117
Wyoming	75

Commercial water use for motels, restaurants, office buildings, and civilian and military institutions was reported as follows:

Montana	42 gpcpd
South Dakota	29
North Dakota	33
Nebraska	42
Iowa	28
Minnesota	8
Wyoming	47

The following sections examine water needs in the project area for residential, school, commercial, industrial and livestock purposes. The water needs may be compared with historic uses presented in Chapter 5 and with water needs identified from other sources.

#### 4.2.1 Residential Water Needs

Residential water use is defined as water used inside the household for drinking, cooking, bathing and other purposes and outside the household for gardening or lawn sprinkling. The Environmental Protection Agency (EPA) presents the following levels of residential or domestic water use as a basis for assessing the level of water conservation.<sup>8</sup> Actual domestic water use reported by the U.S. Geological Survey (Section 4-2) in most neighboring states (with the possible exception of Iowa) significantly exceeds the “normal” water conservation level given by EPA.

<u>Level of Water Use</u>	<u>gpcd</u>
Very heavy, no conservation evident	100
Heavy, including lawn and garden watering	75
Normal, with some lawn and garden watering	60
Moderately conservative, with little or no lawn watering and some selective garden watering	45
Very conservative, no outside watering	30

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<sup>8</sup> EPA, 1985. p. 85.

Sources for assessing residential water needs provide highly variable statistics. The *guidelines* of EPA, for example, suggest smaller amounts than actual *reports* of water use. U.S. Geological Survey water use statistics by state for residential use range from 66 gpcpd (Iowa) to 129 gpcpd (Montana), but little data exists to explain reasons for differences. If lawn watering were a major factor affecting residential water use, Minnesota and Nebraska, with higher precipitation amounts than South Dakota, for example, would seemingly require less total residential water per capita. Also, unknown is the effect of the availability of high quality drinking water on per capita residential consumption. Western Montana, Minnesota and Nebraska may have greater access to better quality water than South Dakota, North Dakota or Wyoming, but analyses of reasons for these differences are not available.

For assessment of this project's needs, *guidelines* were examined, but *reports* of actual water use were also examined. Specifically, the 1967 report of residential water use by Johns Hopkins University for the Department of Housing and Urban Development<sup>9</sup> was relied upon, subject to information from other sources, as will be discussed. Residential water use for the unmetered West (Table 4-2) was considered applicable to this project, assuming that water needs are intended as a measure of reasonable water use in housing that meets national standards for plumbing, fixtures and appliances.

Table 4-2 presents the results of the Johns Hopkins investigation. The metered West had residential water use of 123 gpcpd. Meters are commonly used as a water conservation device. Billing is based on the amount of water used, and water becomes more expensive (in representative rate structures) as more water is used. As shown in Table 4-2, the absence of increasing cost of water for greater use (flat rate) results in more lawn watering and greater residential use (193 gpcpd). Metering does not have as great an effect on household water use (47 to 67 gpcpd, Table 4-2). Household water use is highest in the west and lowest where water users are apparently attempting to increase the longevity of septic tanks.

This project arrives at a residential water requirement of 135 gpcpd: 69 gpcpd for in-house use and leaks and 66 gpcpd for lawn or garden water for an average yard/garden of 50 by 50 feet per household, including leakage. The chief difference between the residential requirement (135 gpcpd) used

TABLE 4-2  
PER CAPITA RESIDENTIAL WATER USE  
AS DETERMINED BY JOHNS HOPKINS UNIVERSITY<sup>10</sup>

Residential Component	41 Study Areas	Metered West PWS	Metered East PWS	Metered With Septic	Flat Rate PWS
Household	59.0	67.0	51.0	47.0	66.0
Lawn Watering	43.9	50.5	19.5	10.3	117.5
Leakage	6.1	5.5	5.5	3.7	9.5
Total	109.0	123.0	76.0	61.0	193.0

<sup>9</sup> Linaweaver, 1967.

<sup>10</sup> Linaweaver, 1967.

here and the Johns Hopkins metered west (123 gpcd) is the lawn watering and gardening determinations (66 gpcd here and 50.5 gpcd for the metered west). Sections 4.2.2 and 4.2.3 describe the findings of residential water needs for this project.

#### 4.2.2 Household Water Needs

The following are the basic categories of household water use:

Toilet	Clothes washing
Lavatory sinks	Cooking and drinking
Baths and showers	Utility sink
Dish washing	Leakage

Toilets account for the highest water use in the home. For each person in the home, there are an average of 5 flushes per day with water use ranging from 3.5 gallons per flush with water conservative devices to 6.0 gallons per flush without conservative devices. Daily need of 25 gpcd was used for without conservation, and daily need of 18 gpcd was used with conservation.<sup>11</sup>

Lavatory sinks are used an average 4.5 times per day per household. Each use consumes approximately 1.7 gallons. Standard faucets flow at a rate of 4 to 5 gpm, and a faucet with conservation devices flows at 1.5 gpm. Daily water use ranges from 1 gpcd (with conservation) to 7.6 gpcd (without conservation). Need without conservation by sinks for this project was estimated at 3 gpcd.<sup>12</sup>

Baths and showers are taken 2.5 times per day for a family of four. Showers range from 5 to 7.5 minutes in duration and use 20 to 35 gallons per shower. Showers or baths require a flow rate of 3 gpm (with conservation) to 12 gpm (with standard devices). Showers or baths require 8.0 to 21 gpcd.<sup>13</sup> For this project, 20 gpcd was used to estimate shower and bath water needs with standard devices (without conservation) and 15 gpcd was the estimated need with conservation.

Clothes are washed .3 times per day per person or .7 times per day for a family of four. With conservation, clothes washing requires 17.5 gallons per use, and without conservation, clothes washing requires 50 gallons per use. Water requirements for washing clothes ranges from 1.3 to 14 gpcd.<sup>14</sup> A value of 10 gpcd was used for needs without conservation, and a value of 6 gpcd was used with water conservation.

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<sup>11</sup> EPA, 1980.

<sup>12</sup> *Ibid.*

<sup>13</sup> *Ibid.*

<sup>14</sup> *Ibid.*

Dish washing events average from .16 to 1 time per day per capita. The frequency of dish washing depends on the presence or absence of a dishwasher. Water used for washing dishes ranges from 7 gallons to 20 gallons per use. Per capita water use for dish washing ranges from 1.1 to 3.8 gpcd.<sup>15</sup> Values of 4 and 3 gpcd were used for needs without and with water conservation, respectively.

Estimates of per capita use for cooking and drinking range from 3 to 7 gpcd.<sup>16</sup> Values of 5 and 3 gpcd were used for need without and with water conservation, respectively.

A value of 2 gpcd was used for utility sink needs with and without water conservation.<sup>17</sup> Utility sinks may or may not be in use.

Leaks in households fixtures are the largest variable in household water use, irrespective of water conservation measures. The elimination of all leaks is desirable, but may not be practical from the standpoint of planning a comprehensive water system. Kitchens, lavatory faucets, baths, showers and toilets are all sources of leaks. One drop per second will result in a daily water use of 7 gallons. A leak that has developed to a steady stream of 1/16 inch in diameter under 40 pounds of pressure will consume 2,500 gallons per day. Leaks in toilet tanks are estimated to range from 160 to 200 gallons per day. For purposes of estimating the quantity of water required for leaks, a *steady drip* was used. The steady drip will consume 20 gallons per day.<sup>18</sup> Based on a future average 2.69 persons per household, the *steady drip* is equivalent to approximately 7 gpcd.

Total household need, based on the criteria presented above, is 81 and 57 gpcd (without water conservation and with water conservation, respectively) as presented in Table 4-3. The literature presents household water use in the range of 41.9 gpcd (with conservation) to 63.8 gpcd (without conservation devices).<sup>19</sup>

Household water use, studied by Johns Hopkins University for typical conditions in the United States in the 1960's, was in the range of 47 to 67 gpcd (Table 4-4).<sup>20</sup> Lowest household water use was in areas with septic tanks. Residents on septic tanks probably strive to use less water in an effort to lengthen the time required for replacement of drain fields. Highest water use was in areas of the

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<sup>15</sup> *Ibid.*

<sup>16</sup> *Ibid.*

<sup>17</sup> *Ibid.*

<sup>18</sup> *Ibid.*

<sup>19</sup> *Ibid.*

<sup>20</sup> Linaweaver, 1967.

Western United States with meters. While meters are generally considered a water saving device, they apparently had less effect on in-house uses than on lawn sprinkling as discussed earlier (Table 4-2). In public water systems of the Western United States, metered water systems used 247 gallons per household per day (3.69 persons per household). Public water systems in the Eastern United States on meters used 209 gallons per day per household. This compares with average daily household needs of 218 gallons per household per day based on 81 gpcd from Table 4-3 and an average 2.69 persons per household in 1990 without water conservation. With water conservation, average household water need would total 153 gallons per day. The household water need, in the absence of water conservation devices, is higher than nationwide statistics developed by Johns Hopkins.<sup>21</sup>

TABLE 4-3  
PROJECTED HOUSEHOLD WATER NEED

Activity	Average Daily Water Need (gpcpd)	
	W/O Conservation	W Conservation
Toilets	25	18
Lavatory Sinks	8	3
Baths and Showers	20	15
Clothes Washing	10	6
Dish Washing	4	3
Cooking	5	3
Utility Sinks	2	2
Leaks	7	7
<b>Total</b>	<b>81</b>	<b>57</b>

Metered public water systems included in the Johns Hopkins studies were the East Bay Municipal Utility District in California, the City of San Diego, Des Moines, Iowa Water Works, City of Fort Worth, Washington D.C., Baltimore City and County, City of Philadelphia, City of Sacramento, City of Great Falls, Montana, and Denver, Colorado, among others. Therefore, the water use estimates were derived from communities representative of conditions in the project area although the project communities are smaller.

Based on the foregoing, an average household water need of 69 gpcd was adopted for this project. This reflects the implementation and achievement of some water conservation measures but not all.

It was considered unrealistic to expect full implementation of water conservation measures and full success with those measures necessary to reduce the household water needs to 57 gpcd. It was considered realistic to eliminate leaks in household fixtures to reasonable levels and, with implementation of future plumbing codes and without retrofit of existing fixtures in existing homes, to

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<sup>21</sup> *Ibid.*

achieve a reduction in household water use from 81 to 69 gallons per capita per day. A high level of water conservation in the household was not adopted for the reason that implementation and enforcement may be unrealistic and, at some point, becomes more costly as greater conservation is achieved.

### **4.2.3 Gardening and Lawn Sprinkling**

In addition to household water use, residential water use includes gardening and lawn sprinkling for the purpose of watering grass, trees, shrubs, flowers and vegetables. Based on the Johns Hopkins study,<sup>22</sup> water needs range from 42 gallons per household in public water systems with septic tanks and meters to 420 gallons per household in public water systems that have a flat rate for the cost of water, (Table 4-4). Clearly, the effect of meters on the use of water for gardening and lawn sprinkling is significant with water use rising by a factor of 10 in public water system without meters. The average water use for public water systems in the Western United States was 186 gallons per day per dwelling. This is significantly greater than in the Eastern United States where average daily water use per dwelling was 80 gallons, (Table 4-4).<sup>23</sup>

The Montana Irrigation Guide<sup>24</sup> places the project in climate area 2. Grass requires 16.89 inches of net<sup>25</sup> irrigation water annually in climate area 2. Vegetables, such as dry beans, corn and potatoes consistently use less water than grass. For the project area, 22.52 inches of annual lawn watering and gardening need was used. This value was based on 16.89 inches of water use and a watering efficiency of 75 percent. Growing season was assumed to cover the period from April 4 to October 19, a period of 198 days. Therefore, the average water need is equal to 0.114 inches per day.

Assuming 186 gallons per household per day as a reasonable gardening and lawn sprinkling water requirement (Table 4-4, Metered West PWS), there will be adequate water to irrigate an average area per household of 2,600 square feet (50 feet by 50 feet, for example). Assuming 2.69 persons per household the need is 69 gpcd. Planned use of 66 gpcd was adopted to remain within the 135 gpcd for total residential use as discussed below.

### **4.2.4 Total Residential Use**

Combining the household and lawn/garden watering, the total residential water need is 138 gpcd. The Johns Hopkins study shows residential use ranging from 61 to 193 gpcd, including leakage,<sup>26</sup> (Table 4-4). Western United States public water systems were using an average 123 gpcd,

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<sup>22</sup> *Ibid.*

<sup>23</sup> *Ibid.*

<sup>24</sup> SCS, 1974, p. 3-8.

<sup>25</sup> "Net" irrigation requirement is the "gross" water requirement of the lawn less the "effective" precipitation. All values (net, gross and effective) apply during the growing season only.

<sup>26</sup> Linaweaver, 1967.

and in the east, 76 gpcd. Within public water system with flat rates, average water use was 193 gpcd. The residential water determined for this project is slightly higher than metered public water systems in the Western United States.

The foregoing validates the Bureau of Reclamation determination of 135 gpcpd as the average daily requirement for *rural* and *community* residential use,<sup>27</sup> which was adopted here.

TABLE 4-4

SUMMARY OF RESIDENTIAL WATER USE  
JOHNS HOPKINS 1965 STUDY

Use/Area	Date	Average Gallons		Average Gallons Per Dwelling Unit
		Per Capita Per Day	Persons Per Dwelling	
<b>Residential Domestic (Household)</b>				
41 Study Areas	1965	59.0	3.64	215
Metered West PWS	1965	67.0	3.69	247
Metered East PWS	1965	51.0	4.10	209
Metered Septic Tank	1965	47.0	4.06	191
Flat Rate PWS	1965	66.0	3.58	236
<b>Residential Sprinkling, (Lawn Watering)</b>				
41 Study Areas	1965	43.9	3.64	160
Metered West PWS	1965	50.5	3.69	186
Metered East PWS	1965	19.5	4.10	80
Metered Septic Tank	1965	10.3	4.06	42
Flat Rate PWS	1965	117.5	3.58	420
<b>Leakage</b>				
41 Study Areas	1965	6.1	3.64	22
Metered West PWS	1965	5.5	3.69	20
Metered East PWS	1965	5.5	4.10	22
Metered Septic Tank	1965	3.7	4.06	15
Flat Rate PWS	1965	9.5	3.58	34
<b>Residential Total</b>				
41 Study Areas	1965	109.0	3.64	397
Metered West PWS	1965	123.0	3.69	453
Metered East PWS	1965	76.0	4.10	311
Metered Septic Tank	1965	61.0	4.06	248
Flat Rate PWS	1965	193.0	3.58	690

<sup>27</sup>USBR, May 1996, p. 76.

### **4.3 Water Requirements for Non-Residential, Community Purposes**

This section of the chapter presents water requirements for communities for purposes other than residential. The section applies only to the communities based on the assumption that the water requirements for the purposes described are only located in the communities. In broad categories, these water uses are for schools, businesses, hospitals and other institutions and government. As in the case of residential water requirements, a standardized method of estimating non-residential water use was sought. However, there are differences in communities with regard to certain types of industry, such as food processing, that will require more water than other communities due to the nature of the industry. Those differences are not addressed in this section. A series of community enterprises or activities, representative of typical water consumers, was addressed to provide a common base for each community.

As discussed in the introduction to Section 4-2, Bureau of Reclamation investigated water used in Montana and determined that in 1985 residential, commercial, public and industrial purposes used an estimated 220 gallons per capita per day, including losses and water not included in public water system accounting. Bureau of Reclamation estimated residential, commercial and public water demands at 135, 36 and 9 gpcd, respectively, by year 2000, a total of 180 gpcd. The value of 45 gpcd for nonresidential (commercial and public) purposes was considered reasonable and was adopted for communities in the regional project. The remaining difference between 220 and 180 gpcd (40 gpcd) is water used in Montana in 1985 for heavy water using industries, such as coal-fired generation. These types of uses do not exist in the regional project service area and would be supplied from other sources if developed in the future.

Table 4-5 summarizes estimates of water requirements for non-residential purposes and the adoption of 45 gallons per capita per day as the average requirement for these purposes. Bureau of Reclamation used 180 gallons per capita per day in its initial planning of the project, reflecting 135 gallons per capita per day in the rural areas and 45 gallons per capita per day as an additional requirement in the communities. Therefore, the non-residential demand used here is consistent with estimates used by the Bureau of Reclamation. The total demand for non-residential purposes was estimated at 734,484 gallons per average day.

#### **4.3.1 Schools**

School enrollment in the project area in 1990 accounted for 6,186 persons from a total population of 24,829, 25% of the population. There were 559 persons in pre-primary education, 5,169 in elementary or high schools and 458 in regional colleges. Table 4-6 summarizes.<sup>28</sup>

The Indian population on the Fort Peck Indian Reservation had an enrollment of 1,925 persons or 33% of the population. The reason for the higher percentage of school enrollment in the Indian population is the median age of the population, 21.9 years, as contrasted with the median age in Dry Prairie, 38.5 years.

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<sup>28</sup> Bureau of Census, 1992, Table 223.

TABLE 4-5

## NON-RESIDENTIAL WATER USE

Average Daily Use, gallons													Total Per Capita (gpcpd)
Place/Rural	1990 PWS Population	Schools	Labor Force	Beauty Shops	Dentist Office	Hospital	Laundro	Motel	Cafe	Service Station	Parks/ Golf/ Other	Non- Resid Total	
Fort Peck		15	15	125	750	400	1,000	125	50	1,000			
Places													
Brockton	507	2,238	4,715	356	1,407	380	1,268	1,162	116	615	10,647	22,904	45
Frazer	422	1,863	3,925	297	1,171	317	1,055	967	97	512	8,862	19,064	45
Poplar	2,114	9,331	19,660	1,486	5,866	1,586	5,285	4,845	484	2,562	44,394	95,500	45
Wolf Point	3,518	15,528	32,717	2,474	9,762	2,639	8,795	8,062	806	4,264	73,878	158,925	45
Not Place													
Oswego	--	--	--	--	--	--	--	--	--	--	--	--	--
Fort Kipp	--	--	--	--	--	--	--	--	--	--	--	--	--
Subtotal	6,561	28,959	61,017	4,613	18,207	4,921	16,403	15,036	1,504	7,953	137,781	296,393	45
Dry Prairie		15	15	125									
Places													
Bainville	166	535	1,444	117	461	125	415	380	38	201	3,818	7,534	45
Culbertson	784	2,527	6,821	551	2,176	588	1,960	1,797	180	950	18,032	35,581	45
Flaxville	0	0	0	0	0	0	0	0	0	0	0	0	--
Froid	253	815	2,201	178	702	190	633	580	58	307	5,819	11,482	45
Glasgow	3,662	11,802	31,859	2,575	10,162	2,747	9,155	8,392	839	4,439	84,226	166,196	45
Medicine Lake	381	1,228	3,315	268	1,057	286	953	873	87	462	8,763	17,291	45
Nashua	379	1,221	3,297	266	1,052	284	948	869	87	459	8,717	17,201	45
Opheim	144	464	1,253	101	400	108	360	330	33	175	3,312	6,535	45
Outlook	143	461	1,244	101	397	107	358	328	33	173	3,289	6,490	45
Plentywood	2,119	6,829	18,435	1,490	5,880	1,589	5,298	4,856	486	2,568	48,737	96,169	45
Scobey	1,149	3,703	9,996	808	3,188	862	2,873	2,633	263	1,393	26,427	52,146	45
Westby	265	854	2,306	186	735	199	663	607	61	321	6,095	12,027	45
Not Place													
Whitetail	112	361	974	79	311	84	280	257	26	136	2,576	5,083	45
Peerless	17	55	148	12	47	13	43	39	4	21	391	772	45
Raymond	--	--	--	--	--	--	--	--	--	--	--	--	--
Antelope	79	255	687	56	219	59	198	181	18	96	1,817	3,585	45
St. Marie	--	--	--	--	--	--	--	--	--	--	--	--	--
Subtotal	9,653	31,110	83,981	6,787	26,787	7,240	24,133	22,121	2,212	11,701	222,019	438,091	45
Total	16,214	60,069	144,998	11,400	44,994	12,161	40,535	37,157	3,716	19,653	359,800	734,484	45

For the purpose of determining future water requirements for school enrollment, the percentages of enrollment in 1990 were applied to the design population. Estimates of average daily water use range from 6 to 10 gallons per student per day, depending on the age of the student. Nursery, kindergarten and elementary students can be expected to use 6 gallons per day, and high school and college students can be expected to use 10 gallons per student per average day.<sup>29</sup> Water needs for the student population in 1990 were estimated at 15 gallons per student per day or 60,069 gallons per average day, the equivalent of approximately 2.4 gallons per member of the total population, (Table 4-6).

TABLE 4-6  
STUDENT POPULATION AND WATER REQUIREMENTS  
FORT PECK INDIAN RESERVATION AND DRY PRAIRIE

Median Income	Fort Peck Indian	Fort Peck Non-Indian	Fort Peck Total	Dry Prairie	Project Total
1990 Total Population	5,822	4,900	10,722	14,107	24,829
1990 School Enrollment					
Pre-Primary	181	102	283	276	559
Elementary and High	1,503	1,057	2,560	2,609	5,169
College	241	71	312	146	458
1990 % School Enrollment					
Pre-Primary	3.1	2.1	2.6	2.0	2.3
Elementary and High	25.8	21.6	23.9	18.5	20.8
College	4.1	1.4	2.9	1.0	1.8
Gallons Per Student Per day					
Pre-Primary	6	6	6	6	6
Elementary and High	10	10	10	10	10
College	10	10	10	10	10
Total Water Use, gal	18,526	11,892	30,418	29,206	59,624
Per Capita Water Use, gpcpd	3.2	2.4	2.8	2.1	2.4

### 4.3.2 General Labor Force Requirements

The labor force on the Reservation consists of 58% of the Indian population and 66% of the non-Indian population, an average of 62%. In the Dry Prairie area, the labor force constitutes 58% of the population. While unemployment was high among the Indian population (30%) and low among the non-Indian population (4%), water requirements for the labor force were assumed to apply to the entire labor force, whether unemployed or not. This was a conservative estimate, more conservative for the reason that part of the labor force would be employed outside community facilities where water would be used during the course of the day. For example, individuals employed in the transportation industry or in agriculture, outside town, would not contribute to water use from community facilities.

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<sup>29</sup> Ameen 1974, p. 10. The citation does not provide average daily water use, it provides maximum day use of 16 gpcpd for college students. Average day use was estimated from maximum day use.

It was further assumed that the labor force employed within the communities would require 15 gallons per person per day in a standard employee environment, the equivalent of 3 trips to the wash room. Total labor force water requirements for the communities within the project are 144,998 gallons per day (Table 4-5).

### **4.3.3 Beauty Shops**

Based on a count of beauty shops in limited areas of Montana, namely the Helena area, it was estimated that five shops are required per 4,000 population. It was further estimated that there are an average five chairs per shop with a daily water use of 125 gallons per chair. This results in a requirement of 11,400 gallons per day for the combined communities of the project.

### **4.3.4 Dentist Offices**

For each 1,000 members of the population, it was estimated that one dentist office is required with an average four chairs per office. Average daily water use per dentist chair was estimated at 750 gallons. On this basis water use for dentist offices was estimated at 44,944 gallons per day (Table 4-5).

### **4.3.5 Hospitals**

A finding was made that one hospital bed is required for every 400 members of the population. It was assumed that average occupancy does not exceed 75% of the available beds and that each patient requires 400 gallons per day. On this basis 12,161 gallons per day is required in the project area. As with other water uses, not every community in the project area has hospital facilities. Some may have nursing homes, and others may have clinics. Nevertheless, in an effort to provide balance in the estimates of water demand, each community was considered equal in this chapter, and Chapter 5 was reserved for investigation of actual water use within each community to determine if deviations from the standards proposed here should be applied on a community by community basis.

### **4.3.6 Laundromats**

It was estimated that one commercial laundry machine is required for every 400 members of the population. At 1,000 gallons per machine per day, commercial laundries will use 40,535 gallons per average day.

### **4.3.7 Motels and Restaurants**

Water use by motels was estimated at 125 gallons per room. It was estimated that 110 motel beds are required for every 4,000 members of the population and that two-thirds of the rooms have two beds. This resulted in estimates of 37,157 gallons per day through the project area.

The foregoing information results in the assumption that one motel room is required per 55 members of the population. It was further assumed that one table in a restaurant is required per 210 members of the population with a daily water use per table of 50 gallons. This resulted in a small estimate of less than 4,000 gallons daily for this purpose in the project area.

#### **4.3.8 Service Stations**

It was estimated that one service station, car-wash rack is needed for every 1,200 members of the population and that each rack uses 1,000 gallons daily. This kind of activity will consume slightly less than 20,000 gallons daily for the population of the project area.

#### **4.3.9 Total of Commercial Demands: Remaining Demand Available for Parks, Golf Courses And Other**

Each of the individual water demand estimates summarized in the foregoing subsections, from schools through service stations resulted in an average daily demand estimate of 24 gallons per capita for the population of each of the communities on the Fort Peck Indian Reservation and 22 gallons per capita for the population in each of the communities in the Dry Prairie area. Therefore, there remained 21 and 23 gallons per capita, respectively, for other community purposes for the non-residential water requirement to reach the 45 gallons per capita per day level used in project design. It was assumed that ongoing activities beyond those listed for the more notable water consuming commercial activities would include community parks, golf courses, food processing facilities, swimming pools and other water consuming enterprises. A total of 360,000 gallons per day was available for the communities of the project area to meet purposes other than those defined in the foregoing subsections. This would be equivalent to lawn watering of parks and golf courses, for example, of 116 acres throughout the project or 7.2 acres per census "place."

#### **4.4 Total Community Demand**

The total community water demand is summarized in Table 4-7, including both residential and non-residential demand. The 1990 population in public water systems within and surrounding the communities of the project region was 16,272. Average residential demand for the combined communities was 2,196,720 gallons per day based on 135 gallons per capita per day. Average non-residential demand for the combined communities was 736,955 gallons per day, and the total residential and non-residential demand was 2,933,675 gallons per day.

The values for community demand include leakage in individual households (Table 4-3). The values were also considered adequate to address leakage in the existing community distribution system and the regional water system of 10%. Leakage in the infrastructure delivering water through homes and enterprises would be approximately 13.5 gallons per capita per day for residential purposes and 4.5 gallons per capita per day for community enterprises.

TABLE 4-7

AVERAGE AND MAXIMUM DAY WATER REQUIREMENTS FOR COMMUNITIES

Place/Rural	Population	1990 PWS Population	Average Day				Maximum Day				Historic		
			Residential Demand (gal)	Non-Residential Demand (gal)	Project Total Demand (gal)	Historic Average Use (gal)	Maximum Day Project Demand (gal)	Historic Maximum Use (gal)	Historic Maximum Day/Hist Avg Day Factor	Historic Maximum Day/Proj Avg Day Factor	Maximum Month-Average Day Use (gal)	Historic Maximum Month- Proj Avg Day Factor	
													Historic
<b>Fort Peck Places</b>													
Brockton	339	507	68,445	22,904	91,349	--	205,535	--	--	--	--	--	
Frazer	394	422	56,970	19,064	76,034	--	171,076	--	--	--	--	--	
Poplar	878	2,114	285,390	95,500	380,890	339,561	857,002	543,298	1.60	1.43	--	--	
Wolf Point	2,881	3,518	474,930	158,925	633,855	1,121,701	1,426,174	2,916,422	2.60	4.60	--	--	
<b>Not Place</b>													
Oswego	--	--	--	--	--	--	--	--	--	--	--	--	
Fort Kipp	--	--	--	--	--	--	--	--	--	--	--	--	
<b>Subtotal</b>	<b>4,492</b>	<b>6,561</b>	<b>885,735</b>	<b>296,393</b>	<b>1,182,128</b>	<b>--</b>	<b>2,659,787</b>	<b>--</b>	<b>--</b>				
<b>Dry Prairie Places</b>													
Bainville	135	166	22,410	7,534	29,944	12,948	67,373	--	--	--	--	--	
Culbertson	780	784	105,840	35,581	141,421	110,544	318,197	624,848	5.65	4.42	218,484	1.54	
Flaxville	77	0	0	0	0	--	0	--	--	--	--	--	
Froid	230	253	34,155	11,482	45,637	18,722	102,684	--	--	--	42,419	0.93	
Glasgow	3,574	3,662	494,370	166,196	660,566	725,076	1,486,274	1,789,174	2.47	2.71	1,325,913	2.01	
Medicine Lake	362	381	51,435	17,291	68,726	--	154,634	--	--	--	--	--	
Nashua	371	379	51,165	17,201	68,366	93,992	153,822	--	--	--	271,116	3.97	
Opheim	141	144	19,440	6,535	25,975	--	58,444	--	--	--	--	--	
Outlook	113	143	19,305	6,490	25,795	16,445	58,039	--	--	--	--	--	
Plentywood	2,119	2,119	286,065	96,169	382,234	360,230	860,026	--	--	--	663,258	1.74	
Scobey	1,160	1,149	155,115	52,146	207,261	204,522	466,338	500,000	2.44	2.41	432,452	2.09	
Westby	265	265	35,775	12,027	47,802	--	107,554	--	--	--	--	--	
<b>Not Place</b>													
Whitetail	--	112	15,120	5,083	20,203	--	45,457	--	--	--	--	--	
Peerless	--	17	2,295	772	3,067	--	6,900	--	--	--	--	--	
Raymond	--	--	--	--	--	--	--	--	--	--	--	--	
Antelope	--	79	10,665	3,585	14,250	6,794	32,063	--	--	--	12,180	0.85	
St. Marie	--	58	7,830	2,471	10,301	3,538	--	--	--	--	37,097	3.60	
<b>Subtotal</b>	<b>9,327</b>	<b>9,711</b>	<b>1,310,985</b>	<b>440,563</b>	<b>1,751,548</b>	<b>1,552,811</b>	<b>3,917,804</b>	<b>2,914,022</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>	
<b>Total</b>	<b>13,819</b>	<b>16,272</b>	<b>2,196,720</b>	<b>736,955</b>	<b>2,933,675</b>	<b>--</b>	<b>6,577,591</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>	<b>--</b>	
<b>Communities Reporting</b>													
Average Day	--	14,424	1,947,240	653,280	2,600,520	3,014,073	--	--	--	--	--	--	
Maximum Day	--	11,227	1,515,645	508,348	2,023,993	2,501,404	4,553,985	6,373,742	2.55	3.15	--	--	
Maximum Month	--	8,727	1,178,145	396,066	1,574,211	--	--	--	--	--	2,953,642	1.88	

Actual water used by communities is presented in Table 4-7 for comparison with the project estimates. Note that in Scobey, for example, average daily water use was estimated at 207,261 gallons for the 1990 population. Actual water use from 1996 through 1998 averaged 204,522 gallons per day. During the last half of the 1900's, water use increased slightly when compared with the first-half.

For communities reporting average water use, average day demand of 3,014,073 gallons (209 gpcd) are 16% more than the project demands of 2,600,520 gallons (180 gpcd) for those same communities (third line from bottom of Table 4-7).

Historic maximum daily water use was reported for Poplar, Wolf Point, Culbertson, Glasgow and Scobey. Historic maximum day use in those communities exceeded *historic average day* use by factors ranging from 1.60 (Poplar) to 5.65 (Culbertson) with an average factor of 2.55 (second line from bottom of Table 4-7) or 13% more than the factor of 2.25 used for planning. Historic maximum day use in those communities exceeded *project average day* use by factors ranging from 1.43 (Poplar) to 4.60 (Wolf Point) with an average factor of 3.15.

Monthly data were available for some communities not reporting maximum day use. As would be expected, maximum monthly use occurs in the June through August timeframe. August 1996, August 1997 and August 1998 were typically the months of highest water use among the reporting communities. Summer 1999 did not disclose monthly use higher than in previous years.

Table 4-7 shows that historic daily average use during maximum months exceeded projected average day demands by factors ranging from 0.93 (Froid) to 3.97 (Nashua). The average day use during maximum months was 1.88 times project average day demand estimates (last line of Table 4-7). Nashua and Westby do not have meters, and billing is by flat rate. Nashua, reporting the highest water use, does not have an incentive to restrain water use.

The planning estimates for the regional project were considered reasonable given the impact that water conservation, not water rationing, will have in the future to lower both average and maximum day demands. These comparisons underscore the need for implementation of effective water conservation measures.

#### **4.5 Livestock Demands**

The regional water project will also provide a water supply for livestock at pasture taps on the Fort Peck Indian Reservation and in the Dry Prairie region. Water requirements were based on an average 12 gallons per animal unit per day, adequate for 36,300 animal units or 435,600 gallons per day. At 30 to 40 acres per animal unit, the water supply is capable of serving 1,089,000 to 1,452,000 acres of rangeland. Much of the area in the project boundaries is cropland, and not all of the rangeland acres are intended for service where existing supplies from stock ponds are adequate and reliable during drought.

## **4.6 Design Criteria and Cost Analysis**

In this section of the report, general design criteria are summarized. The criteria deal with a variety of subjects including the sizing of facilities based on average day, maximum day and peak demands; minimum pressure allowances; hydraulic analyses; present value analysis and other topics.

### **4.6.1 Sizing Criteria**

All major project facilities in the regional water project were sized to meet maximum day requirements. The facilities that would be sized for maximum day demands include the intake, treatment plant, and main transmission lines. Maximum day is defined as the 24 hour period during the year when water requirements become greatest. The maximum day generally occurs in July or August when lawn sprinkling, gardening and in-house uses are at their peak. Facilities that would be sized for maximum day demand include the main transmission pipelines and pumping stations, as well as valves, meters and other appurtenances. Facilities on the branch lines are currently sized for peak instantaneous flow rate as defined below.

Reservoirs will be placed at each pumping station in the regional water system to supply the difference between the peak instantaneous flow and the maximum day flow. The peak instantaneous flow is the flow rate on the maximum day and at the hour of greatest use, such as the breakfast hour, when many are showering, cooking and beginning lawn sprinkling or the supper hour when many of the same activities are ongoing. The reservoir at each pumping station must meet the difference between the maximum day demand and the peak instantaneous demand. In addition to sizing of the reservoirs to accommodate instantaneous peak, the reservoirs will be designed to hold a portion of maximum day storage in the event the system is in repair and storage is needed until the repair can be completed.

### **4.6.2 Maximum Day Sizing Criteria**

Table 4-8 presents further results of the research at Johns Hopkins on residential water use.<sup>30</sup> For public water systems that are metered in the Western United States, domestic (household) water use averaged 67 gallons per capita per day, lawn watering averaged 50.5 gallons per capita per day, leakage averaged 5.5 gallons per capita per day, and total residential demand averaged 123.0 gallons per day, greater than all areas included in the study with the exception of public water systems with flat rates for water charges. The latter category had water use of 193 gallons per capita per day.

Table 4-8 also presents maximum day water use per capita. Maximum day water use ranges from 178.7 gallons per capita for metered residential use on septic tanks to 665.9 gallons per capita per day for public water systems with flat rates. The metered Western United States had a maximum day water use of 260.8 gallons per capita per day, 212% of average day use. The average factor between maximum day and average day use was 259% (2.59 times) for the 41 areas included in the study.

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<sup>30</sup> Linaweaver, 1967.

It is proposed for this project that meters would be installed on all service connections for the purpose of determining (1) zones of high leakage within the distribution system, (2) need to replace fixtures in homes and (3) the effectiveness of water conservation measures. Meters already exist within community distribution systems, and new meters are proposed primarily for the rural areas. These measures will assist in lowering the average and maximum day water use. The draft legislation will provide federal funds for all construction, operation and maintenance costs within the Fort Peck Indian Reservation. Therefore, incentives to limit water use may be based more on water conservation measures than on cost. For this reason, a maximum day factor greater than public water systems in the Western United States was considered appropriate, but a factor as high as public water systems with flat rates was considered excessive and not reflective of water conservation. Therefore, the average maximum day factor of 225% was adopted. The intake, treatment plant, main transmission pipelines, pumping stations and appurtenances along the pipelines were designed for the maximum day flow of 2.25 times the average day flow. This was only slightly higher than the factor

TABLE 4-8

SUMMARY OF RESIDENTIAL WATER USE  
Johns Hopkins 1965 STUDY

Use/Area	Date	Average		Average Gallons Per Dwelling Unit	Maximum Daily as a % of Average	Maximum Gallons Per Day	Peak Hourly as a % of Average
		Gallons Per Capita Per Day	Persons Per Dwelling				
Residential Domestic (Household)							
41 Study Areas	1965	59.0	3.64	215	154	90.9	373
Metered West PWS	1965	67.0	3.69	247	186	124.6	494
Metered East PWS	1965	51.0	4.10	209	131	66.8	260
Metered Septic Tank	1965	47.0	4.06	191	129	60.6	276
Flat Rate PWS	1965	66.0	3.58	236	180	118.8	414
Residential Sprinkling, (Lawn Watering)							
41 Study Areas	1965	43.9	3.64	160	536	235.2	1,407
Metered West PWS	1965	50.5	3.69	186	380	191.8	1,116
Metered East PWS	1965	19.5	4.10	80	695	135.7	1,918
Metered Septic Tank	1965	10.3	4.06	42	1,245	128.7	3,769
Flat Rate PWS	1965	117.5	3.58	420	496	582.5	1,146
Leakage							
41 Study Areas	1965	6.1	3.64	22	--	--	--
Metered West PWS	1965	5.5	3.69	20	--	--	--
Metered East PWS	1965	5.5	4.10	22	--	--	--
Metered Septic Tank	1965	3.7	4.06	15	--	--	--
Flat Rate PWS	1965	9.5	3.58	34	--	--	--
Residential Total							
41 Study Areas	1965	109.0	3.64	397	259	282.3	638
Metered West PWS	1965	123.0	3.69	453	212	260.8	542
Metered East PWS	1965	76.0	4.10	311	252	191.5	586
Metered Septic Tank	1965	61.0	4.06	248	293	178.7	752
Flat Rate PWS	1965	193.0	3.58	690	345	665.9	793

of 2.20 recommended by the Bureau of Reclamation in its Technical Report.<sup>31</sup> In the case of the water treatment plant, two hours of downtime was provided. Therefore, the treatment plant will only operate 22 hours per day. A reservoir near the treatment plant was sized to store sufficient water to provide continuous 24 hour delivery to the main transmission line.

Table 4-1 summarizes the application of the sizing criteria throughout the regional project based on design population, average daily water use as discussed above, and a maximum daily water use employing the factor discussed above. The design population within the Fort Peck Indian Reservation was as projected in Chapter 3. The existing population was used in the Dry Prairie area, rather than the projected declining population. This will permit service to the existing population in the early years of the project. Chapter 9 addresses the potential cost to water users if the Dry Prairie population does not stabilize and declines as projected in Chapter 3. The resulting design population was 31,102 (Table 4-1).

Average per capita water requirements of 180 gallons were applied to the design population in the communities, and 135 gallons were applied to the design population in the rural areas. An additional livestock demand of 12 gallons per animal unit per day for 36,300 animal units was also applied. This resulted in an average day demand of 5,535,746 gallons. Design for a 22 hour maximum day increased the demand to 13,099,339 gallons based on application of a factor of 2.25 for community and rural demands and an increase from 12 to 16 gallons per animal unit for livestock. When converted to flow rate, the maximum day demand is equivalent to 9,133 gallons per minute (gpm) based on 22 hours of operation at the water treatment plant.

### 4.6.3 Peak Use Rates

Table 4-8 also presents peak water use rates. For the 41 study areas of the Johns Hopkins study, the average peak was 638% of average flow or 2.46 times the maximum day requirement. While the Johns Hopkins research was used to estimate maximum day demand for the regional water system, the peak instantaneous demand was determined on the basis of the following equation.

$$Q_p = 4.8 \times N^{1/2} + .9 \times N + 5.9 \quad (1)$$

Where

- $Q_p$  = residential peak instantaneous, gpm
- $N$  = number of houses on service lines that must be sized for peak instantaneous flow between points a and b
- 4.8, .9, 5.9 = constants in regression equation

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<sup>31</sup>USBR, May 1996, p. 76

## 4.7 Pipeline and Pump Station Sizing Method

In this section, the methods of determining pipeline diameter are presented. The hydraulic gradeline was determined at the end of each section of pipeline. The hydraulic gradeline was compared with the ground elevation and pressures were determined as the difference between the hydraulic gradeline and the ground elevation. When the pressure in a particular segment of pipeline fell below 35 pounds, a pumping station was added to the system to provide up to 200 pounds of pressure.

Depending on pressures within the pipeline segments, different pressure ratings of the pipelines were required. Based on the pressure class of the pipeline, manufacturer specifications will be required in final design to determine the precise internal diameter of the pipeline associated with the pressure class. Friction loss along the pipeline route was determined using the *Hazen-Williams* equation with a coefficient of 150 to reflect the pipe roughness associated with polyvinyl chloride materials. It was assumed that polyvinyl chloride (PVC) material is available in pipe sizes for this project from 1.5 inches through 16 inches. For larger pipe sizes, ductile iron or welded steel may be considered in addition to PVC. Iron or steel has greater internal friction. A *Hazen-Williams* coefficient of 130 was used for metallic pipe material.

### 4.7.1 Trial Pipeline Diameter

Table 4-9 presents the preliminary or trial basis for selection of a pipeline diameter.<sup>32</sup> Note that for 1,000 gallons per minute, the present value of the initial construction cost of a 12 inch pipeline, initial cost of a pumping station, future pump station operation and maintenance and future electrical costs was estimated at \$25,914. If a 10 inch pipeline were selected for the flow rate of 1,000 gallons per minute, the present value of construction, operation, maintenance and electrical costs increased to \$26,338. If a 14 inch pipeline were selected for a flow rate of 1,000 gallons per minute, the present value of all costs increased to \$44,573. Therefore, the 12 inch pipeline diameter was the size that produced the least cost on a trial basis.

### 4.7.2 Final Trial Pipeline Diameter

The final pipeline diameter was determined by iteration beginning with the trial pipeline diameter. Briefly, the computations provided for increasing or decreasing the trial pipeline diameters between certain points of demand along the pipeline (for example from Poplar to Culbertson) until the least present value of construction, operation, maintenance and electrical costs was reached. The final pipeline diameter was the diameter that resulted in the lowest present value of construction and future OMR costs.

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<sup>32</sup> Modified from Oglala Sioux Tribe, 1993, pages 60 and 61.

TABLE 4-9

BASIS FOR SELECTING TRIAL PIPELINE SIZE

Pipe Size (inches)	Pipe Cost (\$/1,000)	gpm/	Head Loss, 1,000 feet											
			20	100	500	1,000	1,250	2,000	3,000	4,000	5,000	10,000	15,000	20,000
1.5	1,637	45	893	17,586	63,480	95,962	229,139	485,504	827,106	1,250,328	4,513,225	9,562,730	16,291,082	
2	1,949	11	220	4,332	15,636	23,637	56,442	119,590	203,734	307,983	1,111,704	2,355,505	4,012,842	
2.5	2,417	4	74	1,461	5,274	7,973	19,038	40,337	68,719	103,882	374,974	794,504	1,353,519	
3	2,573	2*	31	601	2,170	3,281	7,834	16,598	28,277	42,746	154,298	326,930	556,958	
4	3,352	0	8	148	535	808	1,930	4,089	6,965	10,529	38,007	80,530	137,191	
6	5,769	0	1*	21	74	112	268	567	967	1,461	5,275	11,177	19,041	
8	8,576	0	0	5*	18	28	66	140	238	360	1,299	2,753	4,690	
10	12,630	0	0	2	6	9	22	47	80	121	438	929	1,582	
12	16,996	0	0	1	3*	4*	19	33	50	75	180	382	651	
14	37,422	0	0	0	1	2	4	9	16	24	85	180	307	
16	43,659	0	0	0	1	1	2	5	8	12	44	94	160	
18	49,896	0	0	0	0	1	1	3*	5	7	25	53	90	
20	56,133	0	0	0	0	0	1	2	3*	4*	15	32	54	
24	71,726	0	0	0	0	0	0	1	1	2	6	13	22	
30	90,437	0	0	0	0	0	0	0	0	1	2*	4	8	
36	109,148	0	0	0	0	0	0	0	0	0	1	2*	3	

Present Value

1.5	1,637	17,480	351,909	15,106,206	83,808,348	161,099,155	529,773,789	1,502,317,103	3,173,014,580	5,691,836,426	35,760,217,788	106,295,160,228	231,560,611,374
2	1,949	10,049	92,426	3,726,725	20,649,530	39,687,907	130,500,346	370,058,540	781,587,020	1,402,026,651	8,808,511,332	26,182,774,496	57,038,331,164
2.5	2,417	8,840	36,626	1,262,463	6,970,473	13,392,059	44,022,812	124,825,048	263,632,326	472,904,687	2,971,088,978	8,831,374,006	19,238,857,482
3	2,573	8,494*	19,927	524,346	2,873,128	5,515,538	18,119,750	51,368,964	108,486,602	194,599,833	1,222,574,656	3,634,016,234	7,916,578,987
4	3,352	9,009	11,825	136,074	714,629	1,365,512	4,470,198	12,660,190	26,729,484	47,941,013	301,153,172	895,142,749	1,950,029,443
6	5,769	11,351	11,742*	28,987	109,287	199,626	630,537	1,767,258	3,719,990	6,664,021	41,808,321	124,250,445	270,662,274
8	8,576	14,149	14,245	18,493*	38,273	60,525	166,668	446,666	927,666	1,652,843	10,309,635	30,616,892	66,681,253
10	12,630	18,201	18,233	19,666	26,338	33,843	69,645	164,088	326,327	570,928	3,490,837	10,340,411	22,504,808
12	16,996	22,566	22,580	23,169	25,914*	29,003*	43,735*	82,597	149,357	250,007	1,451,517	4,270,040	9,275,553
14	37,422	42,992	42,999	43,277	44,573	46,030	52,984	71,327	102,838	150,345	717,461	2,047,811	4,410,425
16	43,659	49,229	49,232	49,378	50,054	50,815	54,443	64,016	80,460	105,253	401,210	1,095,473	2,328,437
18	49,896	55,466	55,468	55,550	55,931	56,359	58,404	63,798*	73,064	87,033	253,796	644,989	1,339,724
20	56,133	61,703	61,704	61,753	61,981	62,238	63,462	66,691	72,237*	80,600*	180,425	414,598	830,473
24	71,726	77,296	77,296	77,316	77,410	77,516	78,019	79,348	81,630	85,071	126,148	222,508	393,636
30	90,437	96,007	96,007	96,013	96,045	96,081	96,251	96,699	97,469	98,629	112,484*	144,986	202,707
36	109,148	114,718	114,718	114,720	114,733	114,748	114,818	115,002	115,319	115,797	121,498	134,872*	158,624
Minimum Present Value		8,494	11,742	18,493	25,914	29,003	43,735	63,798	72,237	80,600	112,484	134,872	158,624

Velocity, fps

1.5	--	3.63	18.16	90.78	181.57	226.96	363.13	544.70	726.27	907.84	1,815.67	2,723.51	3,631.34
2	--	2.04	10.21	51.07	102.13	127.66	204.26	306.39	408.53	510.66	1,021.32	1,531.97	2,042.63
2.5	--	1.31	6.54	32.68	65.36	81.71	130.73	196.09	261.46	326.82	653.64	980.46	1,307.28
3	--	.91*	4.54	22.70	45.39	56.74	90.78	136.18	181.57	226.96	453.92	680.88	907.84
4	--	.51	2.55	12.77	25.53	31.92	51.07	76.60	102.13	127.66	255.33	382.99	510.66
6	--	.23	1.13*	5.67	11.35	14.18	22.70	34.04	45.39	56.74	113.48	170.22	226.96
8	--	.13	.64	3.19*	6.38	7.98	12.77	19.15	25.53	31.92	63.83	95.75	127.66
10	--	.08	.41	2.04	4.09	5.11	8.17	12.26	16.34	20.43	40.85	61.28	81.71
12	--	.06	.28	1.42	2.84*	3.55*	5.67*	8.51	11.35	14.18	28.37	42.55	56.74
14	--	.04	.21	1.04	2.08	2.61	4.17	6.25	8.34	10.42	20.84	31.26	41.69
16	--	.03	.16	.80	1.60	1.99	3.19	4.79	6.38	7.98	15.96	23.94	31.92
18	--	.03	.13	.63	1.26	1.58	2.52	3.78*	5.04	6.30	12.61	18.91	25.22
20	--	.02	.10	.51	1.02	1.28	2.04	3.06	4.09*	5.11*	10.21	15.32	20.43
24	--	.01	.07	.35	.71	.89	1.42	2.13	2.84	3.55	7.09	10.64	14.18
30	--	.01	.05	.23	.45	.57	.91	1.36	1.82	2.27	4.54*	6.81	9.08

### **4.7.3 Hydraulic Gradeline**

The dynamic hydraulic gradeline was determined as the difference between the final hydraulic gradeline in the previous pipeline section and the friction loss in the current pipeline section. If a pumping station was added in the previous pipeline section to boost pressure, the additional head created by the pumping station was added to properly adjust the hydraulic gradeline.

The elevation of the surface of the ground was determined at the beginning and the end of each pipeline segment based on U.S. Geological Survey digital elevation maps (DEM's) generally with elevations on a grid spaced at 30 meters. These elevations formed the profile of the surface of the land along all of the pipeline routes and were compared with the hydraulic gradeline (computed in the hydraulic calculations) to determine pressure on each segment of pipeline.

### **4.7.4 Pipeline Pressure**

Pipeline pressure was computed as the difference between the trial hydraulic gradeline (dynamic or static) from the previous computation and the ground elevation at this location. Proper conversions are made to express the pressure in terms of pounds per square inch (psi).

### **4.7.5 Pump Station Criteria**

Pressures were checked along each pipeline segment to determine if a combination of ground elevations and friction losses caused the pipeline pressure to drop below 35 pounds, the pressure selected as the minimum for the project. If the pressure was above 35 psi, no pump station was added. If the pressure had fallen to below 35 pounds, a pumping station was added. The horsepower required at the pumping station to raise the pressure to 200 psi was used as an initial trial. Based on site conditions, pump pressures were varies above and below 200 psi but did not exceed 250 psi.

### **4.7.6 Method of Applying Criteria**

All analyses were performed using KYRURAL™ models incorporating the assumptions from the foregoing sections.

The main transmission system was analyzed as a "hybrid loop", and the branch lines were analyzed as dead end branches. The "hybrid loop" connected all pipe segments in a "figure 8" configuration, but "valves" were placed at Opheim and Plentywood to prevent circular flow. The analysis as described insured the design of the main transmission system using maximum day criteria. The branch lines, on the other hand, were checked to determine whether maximum day or peak use rates (section 4.6.3) would govern.

Maximum day demands were achieved in the hydraulic modeling of the main transmission system and the branch lines by using a flow of 0.884 gpm for each existing household. The numbers of existing households on the Fort Peck Indian Reservation were increased by a factor of 1.5 to reflect future population increases, and each existing household in the Dry Prairie area was neither increased nor decreased to reflect future population. The effect of the increase in the number of households on the Fort Peck Indian Reservation was to provide a flow rate for each existing household of 1.362 gpm. The flow rate of 0.884 gpm per household is equivalent to 180 gallons per capita per average day increased by a factor of 2.25 to achieve maximum day for an average household with 3.00 persons. The application of the design criteria in the hydraulic modeling resulted in a flow rate of 10,324 gpm leaving the water treatment plant as compared with the computed flow of 9,133 gpm (Table 4-1). This provided a moderately conservative main transmission system design (13% greater than the design capacity of the intake and water treatment plant) and increased corresponding water treatment plant capacity from 12.06 to 13.63 million gallons per day.

Value engineering (VE)<sup>33</sup> was conducted by the Bureau of Reclamation on the design criteria presented in this chapter. Recommendations of the VE study were adopted, including elimination of pump station criteria that would constrain pressures and elimination of reservoir criteria that would hinder flexibility in the location of reservoirs between pumping stations. Both this Final Engineering Report and the VE study were directed at design criteria that will produce the lowest life-cycle cost of project facilities. Both favor criteria that will reduce future OMR costs in instances where life-cycle costs are lowest and several choices are available for investing more heavily in initial construction or future OMR.

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<sup>33</sup> Bureau of Reclamation, April 30, 2001.