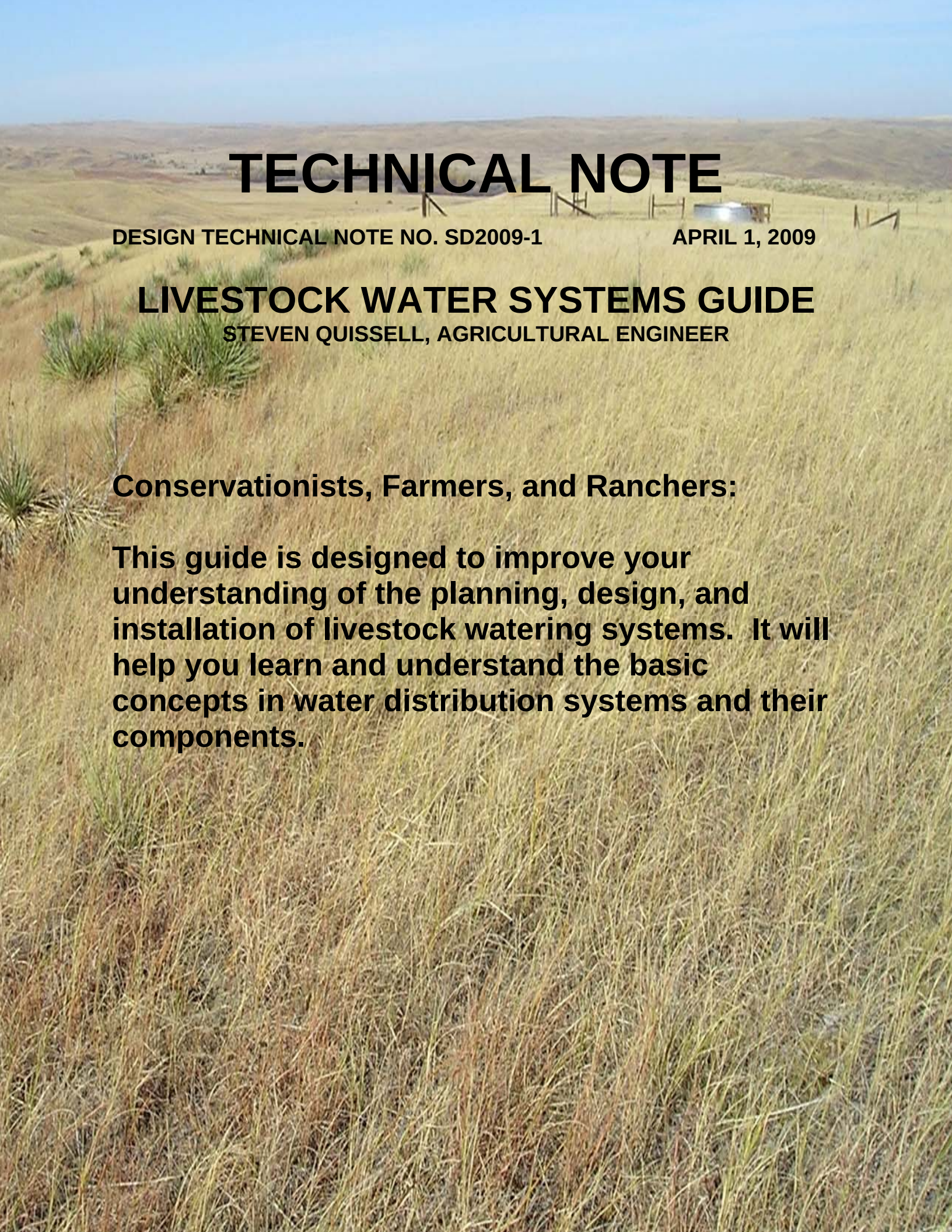

TECHNICAL NOTE

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LIVESTOCK WATER SYSTEMS GUIDE

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Conservationists, Farmers, and Ranchers:

This guide is designed to improve your understanding of the planning, design, and installation of livestock watering systems. It will help you learn and understand the basic concepts in water distribution systems and their components.

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CHAPTER 1

INTRODUCTION

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CHAPTER 1

INTRODUCTION

1.1 Purpose and Objectives

The purpose of this South Dakota (SD) Livestock Water Systems Technical Note is to provide Natural Resource Conservation Service (NRCS) personnel and others, where appropriate, with detailed technical information and procedures which may be used for planning, design, and installation of water supply systems for livestock in SD.

Pipelines are now the most common form of water development in SD. Proper planning and design, together with quality construction, will insure a dependable water system which will supply the water needs of the livestock and serve the conservation needs of the grazing unit for many years.

Livestock watering systems are installed to (1) provide a distribution system for a dependable water supply; (2) to distribute grazing to allow proper grazing use on rangelands; (3) to provide for efficient utilization of water supplies; (4) to maintain and improve plant growth and cover; and (5) to prevent erosion resulting from overgrazing near water sources. Other domestic water use such as household or farmstead uses are commonly planned and incorporated into the distribution system design. Consideration must be given to the effect these “other uses” may have on eligibility of any applicable funding programs.

This technical note may serve as a reference and guide for planning, design, installation, and operation. It does not set NRCS policy or standards. Policy and standards are referenced by the NRCS in the National Planning Procedures Manual, the National Engineering Manual, or applicable program manuals. The practice standards are contained in Section IV of the South Dakota Technical Guide (SDTG) located on the electronic Field Office Technical Guide.

1.2 Introduction

Stockwater pipelines, in SD, can vary from relatively short lines of a few 100 feet installed on relatively level terrain for one individual; to systems of 100 or more miles installed through terrain of extreme elevation differences for water user groups involving many users.

The advantages of stockwater pipelines are demonstrated by the thousands of miles of line constructed in recent years. Pipelines offer excellent dependability and provide water even during drought years when surface water may be nonexistent. Watering sites and tank placement have very few limitations; therefore, pipelines offer the most alternatives for grazing distribution. Also, water quality and availability for piped systems will usually provide economic benefits through increased gains and livestock health when compared to surface water alternatives.

Planning and design of a livestock watering system may be complex. These systems can be a significant investment. It is very important that they be correctly planned, designed, and installed to be economical, functional, and last for the planned life of the project. This technical note is dedicated to providing some of the information and tools needed to accomplish this job.

1.3 Glossary

Acidity	A condition of water when the pH is below 7. See pH.
Alkalinity	A condition of water when the pH is above 7. See pH.
Air Gap	Separation of one water source from another by air to eliminate any chance of backflow.
Air lock	A blockage of water flow caused by trapped air.
Air Release Valve	A device in pipeline to release collected air.
Air-Vac-Air Release Valve (3 way)	Valve which releases air as well as allows air to enter a pipeline.
Aquifer	A water-saturated geologic unit or system that yields water to wells or springs at a sufficient rate that the wells or springs can serve as practical sources of water.
Artesian Well (Flowing and Nonflowing)	A well where the water rises above the surface of the water in the aquifer. It is a flowing artesian well if the water rises above the surface of the earth.
Automatic Pressure System	A system controlled by a pressure switch. A pressurized tank stores water between cut-in and cut-out pressure settings.
Back Pressure	A pressure that can cause water to backflow into the water supply when a user's water system is at a higher pressure than the source.
Barometric Variations	Atmospheric pressure changes due to changes in weather and high or gusty winds.
Check Valve	A special valve with a hinged disc or flap that opens in the direction of normal flow and is forced shut when flows attempt to go in the reverse or opposite direction of normal flows.
Cistern	A nonpressurized tank (usually underground) for storing water.
Clearance Head	Certain vertical distance above the natural ground at which the hydraulic grade line passes.
Coliform Bacteria	A group of bacteria present in fecal waste. If found in water, the water is likely unsafe to drink because of the possible presence of disease causing bacteria.
Cone of Depression	As water approaches a well that is being pumped, the slope of the water table increases. As distance from the well increases, the slope becomes flatter until it merges with the water table level beyond the influence of the well. The water surface within the influence of a pumped well is an inverted cone with its apex in the well and its base in the static water table. This is known as the cone of depression.

Consolidation Formation	A naturally occurring geologic formation that has been lithified (turned to stone). The term is sometimes used interchangeably with the word "bedrock." It includes rocks such as basalt, rhyolite, sandstone, limestone, and shale. Commonly, this type of formation will stand at the edges of a bore hole without caving in.
Contamination	The introduction into water of microorganisms, chemicals, toxic substances, wastes, wastewater, or radioactive material that will degrade water quality. Also included is the introduction of heated or cooled water into the ground water if the changing of the water temperature renders the water less usable.
Contaminated Water	Water that contains a disease-causing toxic substance.
Control Point	A feature elevation or pressure setting which controls or necessitates minimum system operating pressures
Cross Connection	A link or channel between pipes carrying contaminated water and pipes carrying potable water. Contaminated water, if at higher pressure, enters the potable water system.
Delivery Rate	The rate at which a quantity of water is delivered in a certain time period to a given location.
Design Factor (DF)	The multiplier that is used to reduce the hydrostatic design basis to arrive at the hydrostatic design stress, from which the pressure class is calculated. Unless otherwise noted, the design factor used in this standard is 0.5. NOTE: Because the strength of polyethylene (PE) materials depends on the duration of loading, the effective safety factor based on a design factor of 0.5 will vary with end-use conditions. For the PE materials covered in this standard, when subjected to loading at maximum system working pressure and service temperature, the effective safety factor ranges from three or more for short-term loading to two for long-term loading.
Design Water Surface Elevation (hydraulic grade line)	The line showing the pressure head or piezometric head, at any point in the pipe.
Diaphragm-Type Tank	A flexible diaphragm separating air and water in the tank. This type of tank may be buried.
Dimension Ratio (DR)	The ratio of the specified average inside diameter to the specified minimum wall thickness.
Domestic Use	As defined by SD State Water Law – drinking, washing, sanitary, and culinary uses by an individual or household; irrigation of a noncommercial garden, trees, etc., not exceeding one acre in size; stock watering; use in schools, parks, and public recreation areas. Domestic use may not exceed 25,920 gallons per day (gpd) or a peak pump rate of 25 gallons per minute (gpm).

Drawdown	The vertical distance the water level drops in a well pumped at a given rate. The water storage in a pressure tank available for use between the high and low pressure operating points
Elongation	Extension or lengthening of a pipe.
Encrustation	A mineral scale chemically or physically deposited on wetted surfaces, such as, well screens, gravel packs, and in tea kettles.
Energy Grade Line (EGL)	A line that represents the elevation of energy head (in feet) of water flowing in a pipe, conduit, or channel. The line is drawn above the hydraulic grade line (gradient) a distance equal to the velocity head ($V^2/2g$) of the water flowing at each section or point along the pipe or channel. Also see Hydraulic Grade Line.
Evaporation	The loss of water from an area into the atmosphere.
Flexible Plastic Pipeline	Material, which comes in coils, is used for most "pull-in" type systems. PE pipe is a commonly used material.
Float Switch Operated System	A pumped pipeline system in which the pump is turned on or off with a float switch located at the highest tank in the system.
Float Valve Box	A small tank with a float valve strictly used for pressure regulation.
Flow Rate	The quantity of water available and/or needed per minute, per hour, or per day to satisfy the requirements of people, livestock, and water fixtures.
Flushing	A method used to clean water distribution lines. Hydrants are opened and water with a high velocity flows through the pipes, removes deposits from the pipe, and flows out the hydrants.
Friction Losses	The head, pressure, or energy (they are the same) lost by water flowing in a pipe or channel as a result of turbulence caused by the velocity of the flowing water and the roughness of the pipe, channel walls, and restrictions caused by fittings. Water flowing in a pipe loses pressure or energy as a result of friction losses. Also see Head Loss.
Frost Depth	The maximum depth at which soil material will freeze.
Frost Proof Concrete Tank	A tank that is predominantly buried with insulating earth cover and stores livestock water that seldom freezes.
Gage Pressure	The pressure within a closed container or pipe as measured by a gage. In contrast, absolute pressure is the sum of atmospheric pressure (14.7 lbs./sq. in.) plus pressure within a vessel (as measured by a gage). Most pressure gages read in "gage pressure" or **p**ounds per **s**quare **i**nch **g**age pressure (psig).

Grains Per Gallon	The weight of a substance, in grains, in a gallon. Commonly, grains of minerals per gallon of water as a measure of water hardness.
Gravel Pack or Filter	A gravel envelope surrounding the well screen designed to prevent sand from entering the well.
Gravity Pipeline System	A watering system in which the water supply is higher than all points in the pipeline and no pump is required.
Ground Water	Water that has filtered down to a saturated geologic formation beneath the earth's surface.
Hardness Minerals	Minerals dissolved in water that increase the scaling properties and decrease cleansing action--usually calcium, iron, and magnesium.
Hazen - Williams Formula	A formula widely used for computing pipe flow in waterworks design. It is an empirical equation based in laboratory and field observations.
Head	A measure of water pressure, in feet of water or pounds per square inch (psi). 1 psi = 2.31 ft. of water.
Head Loss	The head, pressure, or energy (they are the same) lost by water flowing in a pipe or channel as a result of turbulence caused by the velocity of the flowing water and the roughness of the pipe, channel walls, or restrictions caused by fittings. Water flowing in a pipe loses head, pressure, or energy as a result of friction losses. Also see Friction Losses.
High Density Polyethylene Pipe – HDPE	Tougher high density polyethylene plastic material, able to be used for above ground installations.
High Head Gravity System	This system is often located at the end of a pumped pipeline, starting at a storage tank at the top of the hill for drawing water from a water source.
Hydraulic Grade Line (HGL)	The surface or profile of water flowing in an open channel or a pipe flowing partially full. If a pipe is under pressure, the hydraulic grade line is at the level water would rise to in a small vertical tube connected to the pipe. Also see Energy Grade Line.
Hydraulic Gradient	The slope of the hydraulic grade line. This is the slope of the water surface in an open channel, the slope of the water surface on the groundwater table, or the slope of the water pressure for pipes under pressure.
Hydraulic Ram	A water pump in which the downward flow of naturally running water is intermittently stopped by a valve so that the flow is forced upward through an open pipe into a reservoir.
Hydrostatic Design Basis (HDB)	The categorized long-term hydrostatic strength in the circumferential or hoop direction as established from long-term pressure tests performed in accordance with ASTM D2837.

Hydrostatic Design Stress (HDS)	The maximum allowable working hoop stress in the pipe wall when the pipe is subjected to sustained long-term hydrostatic pressure. For use in this standard, the hydrostatic design stress is determined by multiplying the hydrostatic design basis by a design factor.
Hydrostatic Pressure	(1) The pressure at a specific elevation exerted by a body of water at rest, or (2) In the case of groundwater, the pressure at a specific elevation due to the weight of water at higher levels in the same zone of saturation.
Inside Dimension Ratio (IDR)	The ratio of the specified average inside diameter to the minimum wall thickness. The ratio shall be rounded off, when necessary, to the nearest 0.5 or 0.1, whichever is applicable.
Inspection Riser	A vertical pipe through which observations can be made, as to the condition and functioning of a closed conduit.
Inspector	The authorized representative of the purchaser, who is entrusted with the inspection of products and production records, and the observance of production operations and quality-control tests to ensure that products comply with the requirements of this standard and the purchaser.
Intermediate Storage	A holding tank included in a water system when the water source does not supply the peak use rate.
Internal Combustion Engine Powered Pump	A pump that employs a piston-type engine that uses a combustion process occurring at constant volume, at constant pressure, or by a combination of both.
Internal Friction	Friction within a fluid (water) due to cohesive forces.
Jet (or ejector) Pump	A pump, usually centrifugal type, with a jet or ejector assembly. It has few moving parts and both shallow-well and deep-well jets can be offset from the well. It can provide high capacity at low heads.
Kinetic Energy	Energy possessed by a moving body of matter, such as water, as a result of its motion.
Langelier Index	An index reflecting the equilibrium pH of a water with respect to calcium and alkalinity. This index is used in stabilizing water to control both corrosion and the deposition scale. Langelier Index = pH - pHs.
License	A certification, required by the state government, of a person or firm engaged in well drilling.
Lift (L)	The vertical distance from the water level in the well during pumping to the ground surface or some other specified point such as the center of the discharge pipe.
Low Pressure Gravity System	A system designed with line pressure below 15 pounds per square inch (psi) at all points in the line. The flow rate is usually whatever the water source will provide.
Manning's Roughness Coefficient	A roughness factor along a flow path. It is a function of Reynolds number, Weber number, and relative roughness.

Manual or Timer Operated System	System where high pressures make it impractical to use an automatic pressure system.
Measuring Wheel	A device having a circular wheel and a counter, used to determine distances between points.
Milligrams Per Liter (mg/l)	The weight of a substance, in milligrams in a liter. 1 mg/l = 1 oz. per 7,500 gallons. It is equivalent to parts per million (ppm); see Parts per Million.
Mineralized Water	Any naturally occurring ground water that has a high chemical content.
Neutrality	A condition of water when the pH is at 7. See pH.
Operating Head	The hydraulic pressure at the design flow condition
Operation, Maintenance, and Replacement (O,M, &R)	The processes of properly using, maintaining, and replacing components of conservation practices.
Orifice	An opening (hole) in a plate, wall, or partition. An orifice flange or plate placed in a pipe consists of a slot or a calibrated circular hole smaller than the pipe diameter. The difference in pressure in the pipe above and at the orifice may be used to determine the flow in the pipe.
Oxidation	A chemical reaction between a substance and oxygen.
Palatable Water	Water of acceptable taste. May also include nonoffensive appearance and odor.
Parts Per Million (ppm)	A measure of concentration; one unit of weight or volume of one material dispersed in one million units of another; e.g., chlorine in water, carbon monoxide in air. Equivalents to indicate small size of this unit: 1 ppm = 1 oz. per 7,500 gallons; 1 kernel of corn in 13 bushels; 6 1/4 sq. in. in an acre.
Peak Sun Hours	The equivalent number of hours per day when solar irradiance (solar energy) averages 1,000 watts/m^2.
Peak Use Rate	The flow rate necessary to meet the expected maximum water demand in the system.
Polyethylene (PE) Pipe	Plastic pipe based on polymers made with ethylene as essentially the sole monomer.
pH	Actual measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity.
Pipe Friction Loss	The loss of energy or head resulting from turbulence created at the boundary between the sides of the conduit and flowing water.
Pipe Joints	The fabricated connection between pipe lengths; this is a watertight junction.
Pipeline	A conduit or pipe used for conveying water.

Pipeline Drains — A controlled outlet at all low spots in pipelines that are subject to freezing.

Piston Pump — A double-acting piston pump that sucks water from the well [water source] during both strokes and forces the water out the pressure side.

Pitless Adaptor — A fitting attached to the side of a well casing below frost line used for providing a disconnect between pump drop pipe and pipeline without the need for a pit.

Plain Pressure Tank — In a plain pressure tank, air can be lost over time. There is no diaphragm or barrier between compressed air and water.

Plastic Pipe — A hollow cylinder of a plastic material in which the wall thickness are usually small when compared to the diameter and in which the inside and outside walls are essentially concentric.

Polluted Water — Water containing a natural or man-made impurity.

Pollution — The impairment (reduction) of water quality by agricultural, domestic, or industrial wastes (including thermal and radioactive wastes), to a degree that has an adverse effect on any beneficial use of water.

Polyethylene (PE) Plastic — Thermoplastic extrusion material prepared by polymerization of no less than 85 percent ethylene and no less than 95 percent of the total olefins by weight, plus the addition of compounding ingredients.

Potable Water — Water safe for human consumption and general household use.

Pressure Class (PC) — The design capacity to resist working pressure at 73.4 degrees Fahrenheit (23 degree Celsius) maximum service temperature with an allowance for surge pressure. The following expressions, commonly known as the ISO equations, * are used to calculate pressure class:

For OD-based pipe or tubing: $PC = \frac{2}{DR-1} \times HDB \times DF$

Pressure Control — A method of influencing or stabilizing the pressure at a certain point in a system.

Pressure Differential — The difference in pressure between the trip point (cut-out) and reset point (cut-in) pressure on an automatic pressure system

Pressure Head — The vertical distance (in feet) equal to the pressure (in psi) at a specific point. The pressure head is equal to the pressure in psi times 2.31 ft/psi.

Pressure Gauge — A device for measuring fluid pressure.

Pressure Rating (PR) — The maximum rating at which a component is able to perform in a system.

Pressure Regulator	An adjustable valve used to limit maximum water pressure.
Pressure Switches	They are designed for certain pressure ranges and electrical services.
Pressure System	Systems in which pressure is in excess of atmospheric pressure.
Pressure Tank	An enclosed pneumatic tank in which air can be compressed but water can not.
Pressure Test	A test in which current pressure can be estimated anywhere in a system.
Pounds per Square Inch Gage (PSIG)	**P**ounds per **S**quare **I**nch **G**age pressure. The pressure with a closed container or pipe measured with a gage in pounds per square inch. See Gage Pressure.
Pump Cycle	Period of time, between switch-on and switch-off controls, that a pump operates.
Pump Cycle Timer	A device used to control the pump cycle.
Pumping Level (h)	Static head or depth of water in well while pumping
Pumping Water Level	The vertical distance in feet from the centerline of the pump discharge to the level of the free pool while water is being drawn from the pool.
Photovoltaic (PV) Panel	A power supply made up of solar cells which generates direct current (DC) current from solar radiation
Polyvinyl Chloride (PVC) pipe	Polyvinyl chloride is a commonly used type of pipe used for stockwater pipelines. This is a rigid plastic pipe which usually comes in 20-foot lengths.
Quadrangle Map	The land area shown on one atlas sheet charted by the United States Geological Survey (USGS).
Reserve Storage	A volume of reserve water used in the system in the event of a water shortage.
Route Survey	A topographic measurement to determine relative differences in elevation between points, some distance apart.
Rubber Gasket Joint	A joint connection with a circular rubber liner, to aid in maintaining water tightness.
Saline Water	Water containing mineral salt.
Salinity	(1) The relative concentration of dissolved salts, usually sodium chloride, in a given water. (2) A measure of the concentration of dissolved mineral substances in water.
Saturation	The condition of water when if it has taken into solution the maximum possible quantity of a given substance at a given temperature and pressure.

Schedule (Pipe)	PVC pipe that has the same physical dimensions as iron pipe.
Seepage	The process of a fluid slowly passing through small openings or pores.
Shut-Off Valve	A pipeline valve with which flow can be interrupted.
Solar Insolation	The amount of solar radiation or solar energy per unit area on a horizontal surface.
Solar Powered Pump System	A pumping system employing solar panels containing photovoltaic cells to convert sunshine into electrical energy to power 12-, 24-, or 36-volt water pumps.
Softening	The process of removing hardness caused by calcium and magnesium minerals
Spring	A place on the earth's surface where ground water emerges naturally.
Spring Box	A formed box located near a naturally occurring spring. Box is used to control outflow for desired use.
Standard Dimension Ratio (SDR)	The ratio of the specified average outside diameter to the specified minimum wall thickness. This ratio is common to all pipe sizes of a specific standard dimension ratio series.
Static Water Table	The surface level of the ground water at the top of the saturated zone in a water-bearing formation.
Steel Pipe	An enclosed conduit made of strong durable material.
Stockwater Tank	An enclosed container used to store water for livestock consumption.
Static Head	When water is not moving, the vertical distance (in feet) from a specific point to the water surface is the static head. (The static pressure in psi is the static head in feet times 0.433 psi/ft.) Also see Dynamic Pressure and Static Pressure.
Static Pressure	When water is not moving, the vertical distance (in feet) from a specific point to the water surface is the static head. The static pressure in psi is the static head in feet times 0.433 psi/ft. Also see Dynamic Pressure and Static Head.
Static Water Depth	The vertical distance in feet from the centerline of the pump discharge down to the surface level of the free pool while no water is being drawn from the pool or water table.
Static Water Level	(1) The elevation or level of the water table in a well when the pump is not operating. (2) The level or elevation to which water rises in a tube connected to an artesian aquifer, or basin, or conduit under pressure.
Submersible Electric Pump	A electric powered pump that operates below the water level. It produces a smooth, even flow.

Suction Lift	The NEGATIVE pressure (in feet of water or inches of mercury vacuum) on the suction side of the pump. The pressure can be measured from the centerline of the pump DOWN TO (lift) the elevation of the hydraulic grade line on the suction side of the pump.
Sump	A hole at the lowest point of an appurtenance in a pipeline into which water is drained in order to be pumped out.
Sun Exposure	Radiation energy that may affect the characteristics of processed material, i.e., plastic, fiberglass, other materials.
Surge Pressure	The maximum positive transient pressure increase (commonly called water hammer) that is anticipated in the system as the result of a change in velocity of the water column.
Surge Chamber (control tank)	A chamber or tank connected to a pipe and located at or near a valve that may quickly open or close or a pump that may suddenly start or stop. When the flow of water in a pipe starts or stops quickly, the surge chamber allows water to flow into or out of the pipe and minimize any sudden positive or negative pressure waves or surges in the pipe.
Surging	Forcing water back and forth rapidly and with more than normal force in a well or other part of the water system.
Tank Pressure Rating	Maximum pressure that a tank will safely hold.
Timed or Manual Pressure System	A pipeline system in which a pump is used to pressurize the system and a timer to turn the pump on or off. It is used where high pressures make it impractical to use an automatic pressure system.
Total Dynamic Head (TDH)	When a pump is lifting or pumping water, the vertical distance (in feet) from the elevation of the energy grade line on the suction side of the pump to the elevation of the energy grade line on the discharge side of the pump.
Trenching	The process of excavating a long, narrow ditch embanked with its own soil and used for protecting an encased pipeline.
Trough	A long, narrow, generally shallow receptacle, especially one for holding water for animals.
Turbine Booster Pump	Pump with internal parts similar to a submersible pump. It can be used to boost pressure from sources such a domestic water supplies and storage tanks.
Ultraviolet Radiation	Of or relating to the range of radiation wavelengths form approximately 4,000 angstroms, just beyond the violet in the visible spectrum, to approximately 40 angstroms, on the border of the x-ray region.
Vacuum Relief	The ability to allow air to enter a pipeline thus, eliminating a vacuum situation.

Variable Speed Pump	A pump capable of varying is speed (rpm) and resulting discharge and thereby providing a constant discharge pressure as controlled by an electronic transducer (pressure sensing device)
Velocity Head	The energy in flowing water as determined by a vertical height (in feet) equal to the square of the velocity of flowing water divided by twice the acceleration due to gravity ($V^2/2g$).
Vented Cap	Cap is assembled with capability to allow air release.
Water Bars	A small diversion dike constructed across the trench locations where the trench is traveling up or down the slope. Normally, one to three feet high from bottom of channel to top of ridge.
Water Bearing Zone	A layer at some depth below ground surface that has the potential to produce water.
Water Distribution System	The distribution of water from a source to the locations where it can be used (includes pipeline, valves, vents, and other related appurtenances).
Water Hammer	The sound like someone hammering on a pipe that occurs when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can cause serious damage to the system.
Water Storage	A contained area used to store a volume of water for later use.
Water Treatment	A process to improve the quality of water.
Water Well	A man-made hole in the earth from which ground water is removed.
Weber Number	A dimensional ratio of the internal force to the surface tension force.
Wind Generator Powered Pump	Wind generators can be used to power low volume pumps. The generators may be more reliable than windmills because there are less mechanical components.
Windmill	A mill or other machine powered by a wheel of adjustable blades or slats rotated by the wind.
Winterizing	To equip or prepare for cold freezing weather.
Well Casing	A rigid pipe installed in the well to prevent the walls from sloughing into the well.
Well Development	A process to increase or maintain the yield of a well.
Well Driller	Any person who excavates, develops, or opens a well.

Well Drilling	The act of constructing a new well or deepening or modifying an existing well.
Well Drilling Report	A written report concerning the log of a well.
Well Rig	Any power-driven percussion, rotary, boring, digging, jetting, or auguring machine used in the construction and development of a well.
Well Screen	A perforated or slotted section of pipe or screen used to separate the well water from the surrounding aquifer.
Well Stabilizer	Material or grout placed around the outside of the well casing to hold it in place.
Working Pressure	The maximum anticipated sustained operating pressure, in pounds per square inch gauge, applied to the pipe, exclusive of surge pressures.

1.4 Conversions and Abbreviations

CONVERSIONS

To Convert From	To	Multiply By
Acres	Square Feet	43,560
Acres	Square Yards	4,840
Acre Feet	Gallons	325,851
Cubic Feet	Gallons	7.48
Cubic Feet	Cubic Inches	1,728
Cubic Feet per Second	Gallons per Minute	448.8
Head (Feet of Water)	Pressure	0.434
Gallons	Cubic Inches	231
Gallons	Cubic Feet	0.133
Gallons	Pounds of Water	8.33
Gallons	Liters	3.785
Gallons Per Minute	Gallons Per Hour	60
Milligrams Per Liter	Parts Per Million	1
Milligrams Per Liter	Grains Per Gallon	17.1
Parts Per Million	Pounds Per Gallon	8.35×10^{-6}
Pressure (Pounds Per Square Inch)	Head (Feet of Water)	2.31

ABBREVIATIONS

ac.-ft.	acre-feet
in.	inches
ft.	feet
gal.	gallons
gpm	gallons per minute
gpd	gallons per day
gph	gallons per hour
gpg	grains per gallon
mg/l	milligrams per liter
ppm	parts per million
psi	pound per square inch

CHAPTER 2

PLANNING CONSIDERATIONS

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CHAPTER 2

PLANNING CONSIDERATIONS

2.1 General

The initial step in planning a system is doing a thorough job of identifying the problems and collecting information. It is quite common to be dealing with problems associated with developing a water source, developing or providing power, pump requirements, storage needs, easements etc., in order to develop a solid plan for the water system or pipeline which will distribute the water. Determine the landowner's objectives and determine if those objectives are consistent with the purpose of the conservation practice. The primary purpose of the conservation practices associated with developing a livestock water system is to provide water for distribution of grazing. Water for other domestic uses, such as, homes, farmstead corrals, etc., is commonly included in the system design. For systems which include water uses other than grazing, program guidelines may reduce funding eligibility.

2.2 Resource Inventory

A complete inventory of existing resources and conditions provides the basic information necessary to provide the operator with a competent, functional, and cost effective design that meets the intended objectives. Asking the right questions and collecting pertinent information during the initial stages of a project will be extremely beneficial during the design process and ultimately save time during the installation phase. Information which must be obtained for a water system can vary considerably depending on the complexity of the water sources to be utilized, existing installations, and the physical size of the area being served. Information should include:

2.2.1 Water Source information

- **If the water source is a new well**, obtain a copy of the well log from the operator or from the Department of Environment and Natural Resources (DENR). The well log contains the following information: well depth, casing size, depth to water, drawdown, estimated well yield and water temperature. Also, obtain a copy of the water quality analysis which is required by state standards for all domestic use wells. The water quality analysis will determine suitability for livestock and human consumption.

- **If the source is an existing well and water system currently in-service**, the following information should be obtained as applicable:

    1. Pressure switch settings, storage tank elevations;
    2. Pressure regulator settings at meter pit, well pit or in-line valves;
    3. Owner’s opinion of dependability and yield of well;
    4. Existing pump model and type (records should be available from the pump installer);
    5. Pressure, flow and temperature from flowing artesian wells;
    6. Existing line sizes, material and pressure rating;
    7. Pressure and flow at existing outlet where connection is planned;
    8. Pressure rating and volume of existing pressure tanks.

The pump and pressure tank information is crucial if operating pressures need to be increased substantially or if additional livestock are being added to the system. The pump model is needed to make the determination if the existing pump is adequate to serve the new line. A pump curve will show capacity vs. discharge head and can usually be obtained from the pump manufacturer's Web site or from catalogs if the model number is known. If an existing pump needs replacement to serve the new system, a copy of the well log available from the DENR (legal description required) may be useful.

Flowing artesian wells and existing outlets can be checked for pressure and flow using a pressure gauge and valve assembly as shown in **Figure 2.1**. Readings are then taken with the valve fully closed (static condition), and with the valve opened to a flow approximating the pipeline design flow (hydraulic or operating condition). Readings at intermediate flows could be obtained sufficient to produce a pressure/flow curve if desired (**see Figure 2.4**). Flow is usually measured with a five gallon bucket and watch to record time. If measurements are being taken at an existing outlet, pressure and flow will be affected by simultaneous water use at other outlets, homes, etc., and results must be evaluated accordingly.

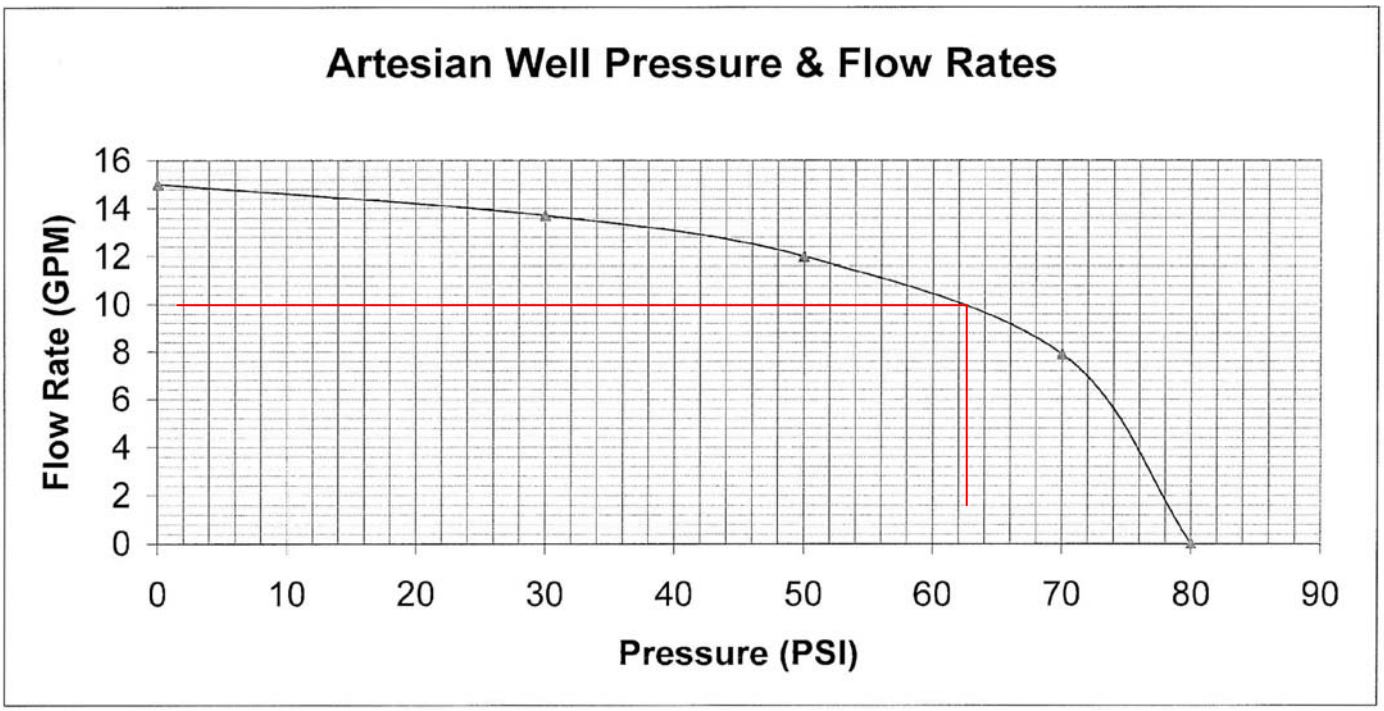
Figure 2.1
Pressure Gauge and Valve Assembly

Obtain a supply of various size adaptors suitable for the type of connections typically found in the local area. Use three-quarter inch pipe with full-flow one-quarter turn ball valve. Fitting shown (right of photo) is hose bib suitable for attaching to frost-free hydrant.

Figure 2.4
Plot of Pressure vs. Flow Measurements Example

Pressure (psi)	Time to fill 5 gal bucket (sec)	Flow Rate (gpm)
80	---	0
70	38	7.9
50	25	12
30	22	13.7
0	20	15

$$\text{flow rate(gpm)} = \frac{\text{(60 sec/min.) (container volume in gallons)}}{\text{(time to fill in seconds)}}$$



A plot such as this can be developed from field measurements and used to predict the pressure available at a given flow rate for an existing water source. In this example, if the water system design flow were 10 gpm, then approximately 62 psi hydraulic pressure would be available from this well (at the time of measurement).

Pressure regulators installed in meter pits for rural water systems may be set at a standard setting such as 50 psi. If the standard setting is inadequate for the planned line, consult with rural water district to determine if desired pressure can be obtained.

- **If the source being considered is an existing well that has no proven yield information** due to having been out of service for some time, or due to new owners having no knowledge of the well, etc., then the well should be test pumped. A pump should be temporarily installed capable of a flow rate approximately equal to the planned design flow of the system. The well should then be pumped and drawdown measured at various intervals if possible. Ideally, a well would be pumped for a 72-hour period, but lesser times may provide a strong indication of a dependable well yield particularly if the water level stabilizes and remains constant for 12 hours or more.

- **If the water source being considered is a new well,** ground water information can be obtained from a variety of sources for use in determining if development of a well is feasible such as:

  1. Presence of producing wells in the vicinity or lack thereof.
  2. SD DENR, Water Rights (water logs of existing wells, aquifer information).

3. USGS (publications, maps, well information), see Appendix A for a "Generalized Stratigraphic Column of Central and Northwestern South Dakota" showing geologic formations including the sedimentary bedrock aquifers.
4. Local well drillers.
5. USGS publications (see Appendix A for "South Dakota Ground Water Resources, U.S. Geological Survey Water-Supply Paper 2275" describing SD's principal aquifers).

Appendix A (page A-11) contains contour mapping of the top of the Dakota-New Castle Aquifer Contours from a mean sea level datum. If this aquifer is present in a given location in the state, it is commonly the first suitable producing bedrock aquifer encountered. Other producing aquifers may be encountered at greater depths. The usual order of occurrence assuming the presence of all aquifers at a given location would be:

1. Dakota-Newcastle
2. Inyan Kara
   - Fall River
   - Lakota
3. Sundance
4. Minnelusa
5. Madison

All of the above information are estimating tools only and operators should contact a geologist or driller with local well experience for a more specific estimate.

If water source is **from surface runoff or spring developments,** investigate thoroughly. Embankment dams and spring developments can be utilized as a source only if dependability is assured, since a considerable capital investment is at risk for all but the smallest of pipelines. Dams should have proven dependability structurally, as well as, for dependability of runoff. Reservoirs should have large storage volume (i.e., >75 ac.-ft.), a permanent pool approaching 25 foot depth or more, and located on a large drainage area. The dam should have a history of maintaining an adequate pool through extended dry periods.

A spring should have some "history" as well. Normally, a suitable spring for supplying a pipeline system would issue from a point source rather than a seep and would flow at a rate of 10 gpm or more. Site features for these springs would indicate the spring has been flowing for decades and usually these springs are known to local residents as being sources of water as far back as the dust bowl era in the thirties. There are exceptions, such as, very dependable springs issuing from "seeps" rather that point sources but these are usually located in close proximity to surface irrigation projects. Dependable springs typically are fed by an identifiable layer of clean sands as opposed to seeps which usually issue from a zone of saturated silts or clays.

2.2.2 Tank and outlet locations

Plan with the operator to determine the desired objective of water placement with due consideration of achieving the conservation objective of grazing distribution (if under current NRCS SDTG standards, the tank spacing affects the tank sizes which will ultimately be installed at the outlets, then these issues should be discussed during initial planning). Tank location will be affected by pipeline routing considerations which in turn is affected by ownership boundaries, federal and Tribal land, topography, cross fencing, highways, and railroads, etc. The final route

may be altered during the final design process, but an initial general routing should be determined during the planning phase. Proposed tank locations in excess of 300 ft. (130 psi) above well or pump locations should be given particular consideration of determining if alternate tank locations at lower elevation would serve the intended purpose adequately. Installations requiring pressures over 125 psi are more costly, may be prone to higher maintenance, and are more likely to require special order components. If an extension or expansion of the system is probable at some future date, the long-term needs should be considered during the initial planning and design of the system. The use of USGS 7½-minute quadrangle maps, digital ortho images, and Global Positioning System (GPS) units are among the most valuable planning tools available for water systems. Consider the following when selecting tank locations and pipeline route:

1. Select well drained tank sites away from riparian areas if possible
2. Locate tanks to distribute grazing.
3. Consider fence line locations for tanks allowing multiple pasture use.
4. Determine if existing surface water sources are dependable.
5. Avoid routing pipeline in narrow valleys or paralleling riparian areas due to the trench being subject to erosion.
6. Limit undulating terrain to the extent possible to minimize problems cause by air collecting at high points in line (artesian wells containing gas are most critical).
7. Favor ridges for routing lines (see 5 and 6 above).
8. Avoid extremely steep slopes, rocky soils, old slide areas, and other restrictive terrain.
9. Avoid diagonally crossing long slopes to minimize need for water bars (trench will intercept runoff and function as a diversion which can erode trench to the point of exposing the pipe.
10. Consider ownership and use a legally recorded easement for crossing neighboring land.
11. Avoid routes through depressional wetlands or crossing linear wetlands other than perpendicular to flow

2.2.3 Water Quantity Requirements

Determine the water needs of the system based on the operator's peak livestock numbers to be served. On smaller units, each outlet may need to provide water for the entire herd. Larger units may utilize grazing plans with herds spit between different pastures and; therefore, number of livestock served in each pasture, total herd size and season of use is important. If homes are involved, an important consideration is deciding if the pipeline will be designed to provide peak demand flow to each home or whether a storage reservoir will be utilized at the home site.

Storage reservoirs will result in smaller diameter pipeline between the source and home, but will require a booster pump and pressure system installation at the home. (Please refer Chapter 3, Section 3.2, on design flow rates for additional information.) Determine:

1. Type of livestock, number in each pasture and season of use.
2. Total number of livestock served by system.
3. Demands other than grazing (homes, dairy, etc.).
4. Storage reservoirs or cisterns available or planned.

2.3 Water Quality

Water quality should be a major consideration when evaluating possible water source alternatives available for developing a water system.

Generally, wells and rural water systems provide higher quality water than surface sources such as dams and dugouts. Many ponds are of less than desirable quality even after filling from a major runoff event due to contributing areas with saline soils (common with soils derived from Pierre shale). Surface water is then susceptible to degradation due to pollution from cropland and from livestock due to concentration of impurities from evaporation and drought, and due to stagnation and algae.

Water quality from wells, although generally of good quality for livestock, can, in some locations, be quite poor, even so poor as to be dangerous to livestock. Shallow glacial drift and alluvial aquifers are susceptible to pollution, usually isolated cases, commonly caused by contamination from feedlots, septic systems, or improper handling of fertilizer. Deeper bedrock aquifers (typically artesian), although commonly very mineralized, have quality ranging from good to very poor. Generally, bedrock aquifers are found at greater depths away from the Black Hills, with higher water temperatures and increased mineralization as distance from the Black Hills increases. Wells completed into bedrock aquifers in Dewey and southeast Ziebach Counties commonly have total dissolved solids (TDS) levels as high as 8,000-10,000 ppm (dangerous for livestock, potential health effects) and sulfates as high as 1,200-2,000 (marginal for livestock use). Water quality information for an aquifer planned for development can be obtained from a variety of sources such as:

1. Water analysis from existing wells in the vicinity.
2. The SD DENR, Water Rights (water logs of existing wells, aquifer information).
3. The USGS (publications, maps, well information).
4. The USGS publications (see Appendix A for "South Dakota Ground-Water Quality, U.S. Geological Survey Water-Supply Paper 2325" describing water quality in SD's principal aquifers).
5. The NRCS Range Technical Note No. 5 (Rev. 1) March 1, 2005.

When evaluating well information, some caution is advised in the label given a particular aquifer on the well logs or the slang used in the local area for the aquifer developed for a particular well (i.e., many wells logged as Sundance in western SD have depths consistent with the Dakota-Newcastle aquifer).

Appendix A contains publications by the SD Cooperative Extension Service (CES) covering water treatment systems for various water quality problems.

The NRCS Range Technical Note No. 5 provides information on recommended maximum mineral levels, possible health effects, and suggestions for dealing with poor quality water.

All new domestic wells drilled, in SD, are required to be tested for bacteria and several selected chemicals. When requesting a water test for a new well, most labs have a routine "new well" analysis which tests for bacteria and several selected chemicals, including nitrates, sodium, sulfates and electrical conductivity, which is an indication of total dissolved solids. Routine water tests which are to check a water source for being "safe" or "unsafe" for drinking typically test for bacteria (including coliform bacteria) and nitrates. Only water sample bottles provided by the lab doing the analysis should be used for collecting samples. The SD DENR, Drinking Water Program (http://www.state.sd.us/denr/DES/Drinking/certifie.htm), maintains a list of

laboratories certified for the analysis of drinking water in the State of SD. Many of these labs have Web sites and online ordering for sample bottles. The certified list includes a number of

private and governmental labs including the state health lab.

South Dakota State Public Health Laboratory
615 East Fourth Street
Pierre, South Dakota 57501
(605) 773-3368

2.4 Central Storage

Utilizing a storage reservoir in a water system may be done for a variety of reasons to insure a reliable, uninterrupted water supply. Central storage reservoirs are commonly used 1) to provide for peak demand flows which can not be met by a low producing well or supply source; 2) as a regulating/supply reservoir for a booster pump; and 3) as a "water tower" when placed at a location of high elevation, as well as, various other uses.

A tank or "cistern" installed at a farmstead is a very common application used to provide the storage necessary to serve a peak demand for one or more homes, but allowing the pipeline and water supply serving the farmstead to be relatively low volume. If a water system is to serve a farmstead with household use, a key part of the design will be working with the operator to determine if a cistern is currently in use or is an option for the planned system.

Size of the storage reservoir will vary depending on the specific situation and purpose; however, tanks sized to provide one-half day to one day of storage are common. Applications, such as, supply reservoirs for booster pumps may require tanks of less volume, and applications, such as, central storage for solar systems may require multiple days of storage volume. Each application needs to be evaluated based on the specific need and the availability of appropriately sized tanks. Examples of various applications for central storage, the appropriate locations, and common methods of pump control are shown in **Figure 2.2** below.

Reservoirs utilized for year round use on individual water systems are usually installed underground in a shallow bury installation with earth fill cover over the tank ranging from 0-2' depending on the type of tank. Locally manufactured pre-cast concrete tanks are available from a number of suppliers around the state in sizes up to approximately 5,000 gallons. Pre-cast tanks of 2,500 gallons or less can usually be handled and set in place with a standard sized backhoe/loader; however, tanks larger than this such as the 5,000 gallon size will require an industrial sized loader or crane. Commercially produced tanks suitable for direct burial manufactured from PE are available in sizes up to approximately 1,500 gallon and are stock items for distributors. Fiberglass tanks suitable for direct burial are available by special order in a full range of sizes up to 40,000 gallons or more.

Manufacturers of the PE and fiberglass tanks have specific backfill requirements for installation of their tanks which usually requires granular backfill. Concrete cast-in-place tanks can be constructed onsite and sized to the exact need and are usually installed with the lid exposed and the earth backfilled or mounded to within a few inches of the top.

Storage tanks utilized for seasonal nonwinter use may be installed above ground and may result in a lower cost for the initial installation compared an underground tank. However, consideration should be given to the factors such as susceptibility to vandalism, degradation from UV rays, wind forces, and protection from livestock. Above ground tanks to be used for a permanent water system should manufactured of materials with a potential design life consistent with the other water system components such as high quality UV resistant PE or heavy gauge steel.

Central storage is at times mistakenly viewed as a way to alleviate almost any water supply problem or is perceived as needed in situations were the only real effects are increased capital

cost, system complexity and maintenance. Examples of situations were tanks are both appropriate and not appropriate for use in a system:

1. A well produces 5 gpm and daily well production would equal
   5 gpm x 60 min./hr. x 24 hr. = 7,200 gal/day

   Daily water need: 500 hd. livestock @ 20 gal./day minimum = 10,000 gal./day

   Central storage will not eliminate this water storage problem regardless of how large the storage tank volume, more water is being used than is being re-supplied on a daily basis and the tank will run dry in a relatively few days.

2. A well produces 5 gpm and daily well production would equal
   5 gpm x 60 min./hr. x 24 hr. = 7,200 gal./day

Peak demand required:	10 gpm for house
	3 gpm for livestock
	13 gpm total

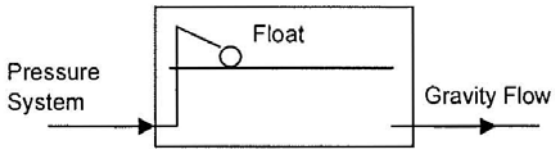
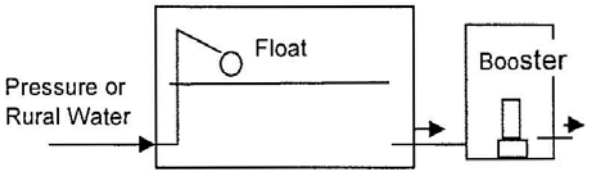
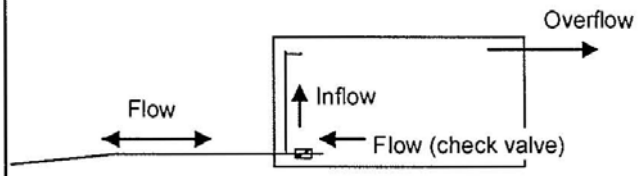
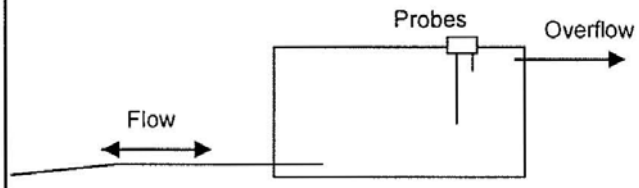
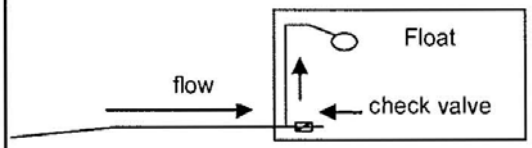
Daily Water Need:	360 gal./day @ house
	3,000 gal./day livestock
	3,360 gal./day Total

   Central storage <u>is</u> beneficial in this situation were a low producing water source can meet the daily water need but not the peak demand required primarily by the house. A storage tank will provide the reservoir necessary to supply the peak. The daily water production is more than adequate.

3. A bedrock aquifer (Inyan Kara) well produces 30 gpm. The water system is designed for 14 gpm.

   Central storage is not needed and will only add to the complexity and cost of the system but serve no practical need. In effect the aquifer is a huge storage reservoir.

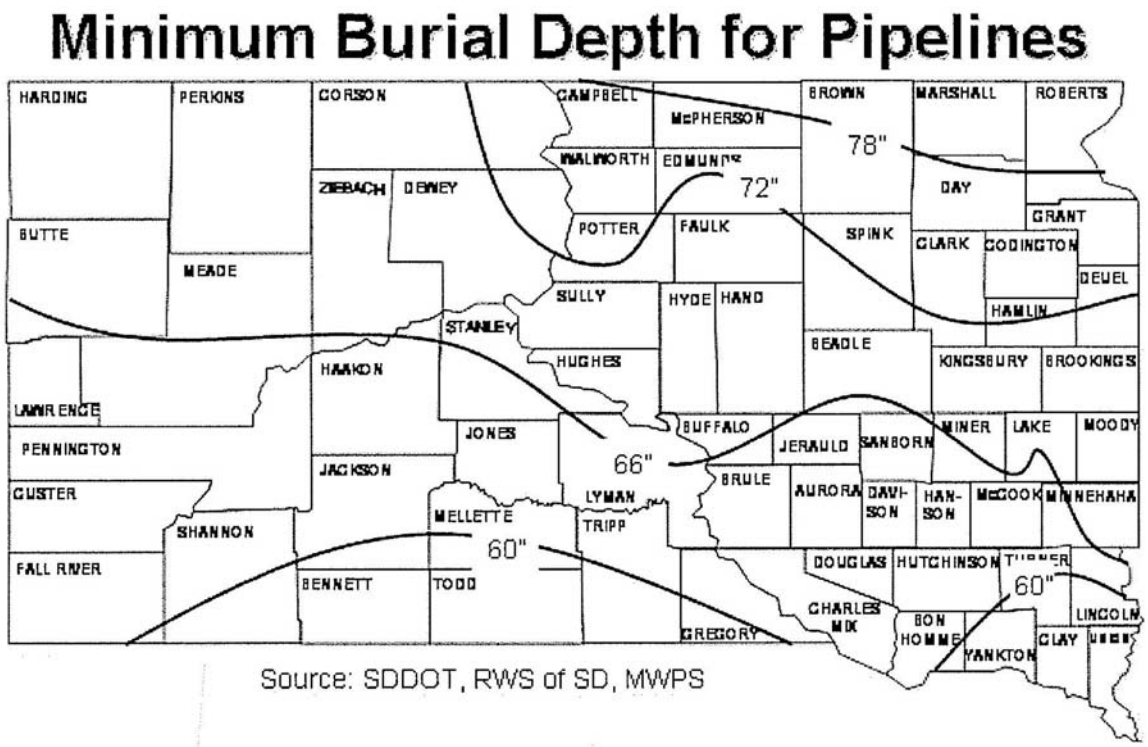
Figure 2.2 Central Storage Options

Uses - Low producing wells, water systems or rural water taps where flow is not adequate to meet peak demand. Tank must be located higher than any part of system served beyond tank. No power required. Pump is controlled with pressure tank/pressure switch. Approximately 1/2 to 1 day storage is typical.	 **Storage on High**
Uses - Low producing wells or water systems where flow is not adequate to meet peak demand or for pressure boost installations. Tank may be located anywhere power is available. Approximately 1/2 to 1 day storage typical. Second pit with in-line booster required. May be used on group systems . Pump may be primary pump as in the case of a tank located near a rural water tap, or as a secondary booster as when used on systems with extreme elevation differences.	 **Storage w/ power**
Uses- Systems needing over 150 psi (350' lift) at well or booster pump. Pump is controlled with timer rather expensive pressure tank rated over 150 psi. Storage is located on highest point of system and gravity feeds system when timer is in off cycle. Line to storage has flow in either direction. Optional check valve on inflow allows use of float valve if needed on some installations (ie with multiple tank installations) or provides improved circulation on larger tanks.	 **Storage on High Point**
Uses - Storage tank is used in lieu of pressure tank to control pump by means of probes hanging in tank. Pump cycling is kept to minimum. Storage also provides peak flows if well is marginal. Works well for systems where hill which tank is located is fairly close to well (<3/4 mi.). Electric wire for probe must be run back to pump in trench. Common installation on group pipelines. Radio communication is an alternative (more expensive) to connecting storage to pump controler with wire in trench.	 **Storage on High Point**
This system can work but must be evaluated very carefully. The tanks are not on the highest point, but are selectively placed to provide additional system capactity to some of the stock tanks. Once tank fills and the float shuts water cannot flow back out unless demands on the system are great enough that hydraulic pressure on incoming line is close to zero since the pressure switch controlling the pump will maintain pressure at the check valve. If a tank is situated just right and demands on the system are so great that pressures at the storage tank are near zero, they may work intermitently. **These can be expensive mistakes if situated improperly.**	 **Storage anywhere** Pressure System

2.5 Shallow Bury versus Installation Below Frost

The standard installation depth for stockwater pipelines, in SD, is to place the pipeline below frost depth or to a depth of five feet, whichever is greater. Shallow bury lines are also used in some installations, usually because of soil conditions which make below frost installation impractical. **Figure 2.3** provides the minimum burial depth for pipelines, in SD, based on projected frost depth in the state.

Figure 2.3



Appurtenances for all year pipelines must be designed in a way that will reduce the chance of pipelines freezing during winter weather. Valves of all kinds must be protected from freezing. This is usually done by installing them below frost in a covered manhole or pit. Outlets such as frost free hydrants or stop and drain valves, which allow the pipe above frost line to “drain back” when not in use, must be used. Float valves for stock tanks can be installed under a protective cover as long as the float is used in conjunction with a stop and drain valve which will keep the pipe above frost depth from freezing due to the insulating effect of the stock tank installation.

The decision as to whether or not to use a shallow buried pipeline is most often dictated by how deep the soil is in a given area. Shallow soil over bedrock can make installation below frost depth not economically feasible if not impossible. A pipeline that is not used in winter can be buried at a shallow depth and drained during freezing weather. Such pipelines are usually buried 12 to 30 inches deep; however, above ground installations for permanent pipelines are used in rare situations where the pipe must be routed across exposed bedrock. With any shallow bury or above ground installation, durability of the pipe is an important consideration due to the harmful effects caused by freeze-thaw cycles, greater temperature fluctuations, soil shrink-swell, UV degradation, and possible physical damage from vehicles or livestock. One of the advantages of HDPE is the toughness of the PE material from which the pipe is manufactured, which makes HDPE ideally suited to any installation above frost depth.

It is usually advantageous to bury a pipeline below frost depth in terrain that will allow this even if the line is only going to be used in the summer. A shallow bury line will require draining every winter, and; therefore, practice life is dependent on the operation and maintenance reliability of the operator. Also, changes in ownership often result in the new owner being unaware of any special requirement of the water system which results in systems ruined by

freezing damage. Management practices can also change the season of use which would result in a system susceptible to freezing damage. Any installation cost-savings of a shallow bury pipeline compared to a system installed below frost should be fully evaluated to determine if there is a true cost advantage over the life of the practice when all factors are considered.

Shallow lines must be installed to facilitate draining at all low spots. Various sources claim the HDPE pipe is not damaged by freezing and in actual practice the pipe may seem unaffected by occasional freeze cycles. However, the effect of long-term fatigue from repeated freeze thaw cycles and how this affects the design life of the pipe has not been substantiated or guaranteed by any manufacturer. Therefore, NRCS specifications require the installation of drains at low spots. Drains for stockwater lines are typically seepage pit type drains were the water drains into a manhole setting on a gravel base or a drain line which "daylights" in a draw or low spot allowing surface drainage. Although it is possible to vary the pipeline depth to provide the slope necessary for drainage to the low points, it is easier for the contractor and more common to install the pipeline at uniform depth and then select a route which will keep the number of low points to a minimum. Shallow bury lines will require air vents which will allow air to enter the line if the system is to drain properly. The vents may be air release valves which automatically allow air release/entry upon filling or emptying of the line or the vents may be a manual vent such as a hydrant. Lines installed on extremely flat grades are susceptible to air lock caused by minor undulations in grade. PE pipe is more prone to air lock problems due to the tendency of the PE to "coil" and the resulting difficulty of keeping the pipe on a uniform grade during installation. Since PVC pipe will generally follow the trench and result in fewer small undulations, it may be preferred over PE for installations on very flat grades and durability can be improved somewhat by using a heavier walled pipe such as schedule 40. PVC, however, will not tolerate any freezing and can be ruined from a single freeze cycle.

2.6 Pipeline Installation Equipment

The type of equipment used to install a water system depends on a number of factors of which the single most important overriding factor is probably what equipment is available in the local area.

Backhoes and chain trenchers are common through out the state. Most projects typically use both a chain trencher and a backhoe. The trencher is used for the majority of the pipeline installation because of the speed (up to a mile per day) and efficiency of digging a trench of uniform width and depth. Chain trenchers dig a trench six to eight inches wide and six feet or more in depth. The machines can handle rock as large as the trench width encountered in the upper portion of the soil profile. Larger rock near the bottom of the trench is difficult to remove. Sandy soils can be difficult for a chain trencher because of caving problems. Backhoes are needed at all connection and appurtenance locations such as connections to existing water systems, manholes, valves, pits, oversize rock and any other situation which requires an excavation other than a narrow trench. The backhoe buckets are typically 12"-24" wide and the machines capable of excavations 10' or more in depth. Projects of relatively short length (<½ mile) or with soil containing large rocks or ledge rock may be installed entirely with a backhoe.

Trenchless plows are a more specialized type of equipment for pipeline installation used most often on larger projects. Due to the mobilization cost of heavy equipment required for this type of installation method, as well as, this equipment most often used only by the larger construction companies, makes use of the plow-in method impractical for smaller projects. The plow is mounted on the back of a D9 size crawler tractor and can plow in pipe (usually HDPE although PVC is also plowed) to depths of six to eight feet. The pipe being installed is either mounted on spools on the front of the crawler or pre-joined and laid out in front of the plow and guided up over the crawler canopy. The plow crawler is generally pulled by one or two other crawler tractors. Plows can generally work in soils with some occasional rock if the rocks are infrequent in the lower third of the soil profile, and the soil in the upper portion of the profile is sufficiently soft (usually needs good subsoil moisture) to allow occasional rocks encountered to be lifted clear or pressed back into the trench soil matrix. Surface soil disturbance is usually minimal requiring minor cleanup. The plow-in installation method is not suited to use in rocky soils due to the limitations of the equipment and the potential for the pipe being damaged or distorted by rock. Heavy clay soils may need to be pre-ripped ahead of the plow making it easier for the

plow train to install the pipe. The soil disturbance in very dry heavy clays may be severe and the restoration to original surface contours may take many years. Installation rates vary depending on pipe size (up to six inches), soil conditions, and equipment with average rates between two to three and one-half miles per day.

Wheel trenchers and large excavators on tracks are typically used only on systems using large diameter pipe (>6”) and requiring a wide trench for proper pipe installation.

2.7 Above Ground Pipelines

Pipelines installed above ground are considered a conservation practice only under very specific situations, usually involving high intensity, short duration grazing using each pasture multiple times per year. These above ground lines must be HDPE plastic and consideration must be given to routing and protection in order to protect the pipe at vehicle crossing locations and other potential damage areas.

2.8 Alternatives

Even though the landowner may have a very specific system in mind, take an overall look at other possible alternatives to make sure the alternative the land user wants is appropriate, the most feasible, and preferably the least cost.

We sometimes fail to fully investigate the operator’s plans before proceeding with a detailed water system design. Good, appropriately timed communication with the land user is always critical to success of the project. To do otherwise will usually waste everyone's time and money. Too much time is spent preparing good designs for projects that are subsequently installed with major alterations when compared to what was planned and designed and often the cause is lack of communication and failure to ask the right questions.

CHAPTER 3

PIPELINE DESIGN CAPACITY

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CHAPTER 3

PIPELINE DESIGN CAPACITY

3.1 Water Quantity

The quantity of stock water required during any given period depends on the type and number of stock, climatic conditions, and amount of natural water available. The pipeline must be designed to supply adequate water for the highest daily (peak) use period occurring during the year. Table 1 provides minimum daily water use for all types of livestock.

Table 1. - Minimum Water Supply Per Animal

Animal	Water, Gal./Day
Beef Cattle:	
Cows lactating with calves	18
Bred, Dry Cows and Heifers	15
400 lb. Growing Cattle	10
600 lb. Growing Cattle	13
800 lb. Growing Cattle	15
Bulls	19
600 lb. Finishing Cattle	15
800 lb. Finishing Cattle	18
1000 lb. Finishing Cattle	21
1200 lb. Finishing Cattle	23
Dairy Cattle:	
1400 lb. Dry Cow	16
1700 lb. Dry Cow	17
Lactating, 20 lb. Milk	18
Lactating, 60 lb. Milk	25
Lactating, 80 lb. Milk	28
Lactating, 100 lb. Milk	33
200 lb. Heifer	3
400 lb. Heifer	6
800 lb. Heifer	11
1200 lb. Heifer	15
Swine:	
Boars & Gestating Sows	3
Lactating Sows	5
15 – 50 lb. Feeder	0.75
50 – 120 lb. Feeder	1
120 lb. to Market	2
Horses:	
Mature	18
Weanling	8
Sheep & Goats:	
Rams & Dry Ewes	2
Ewes with lambs	3
Feeder Lambs	1.5
Suckling Lambs	0.3
Birds:	
100 Chickens	9
100 Turkeys	15

Table 1 figures should be considered minimum and particularly for beef cattle on rangeland, the 18 gpd value should be increased to meet the peak use occurring in western SD. In recent years, with metered rural water becoming more common, ranchers have documented daily water use varying depending on temperatures and forage. Early summer grazing averages of approximately 18–20 gpd are common but as monthly temperatures increase later in the summer and warm-season forage matures under drought conditions, daily use for cow/calf pairs has been documented from meter readings at 28-30 gpd. Undocumented reports of ranchers hauling water put water use in $+100^0$ temperatures at close to 40 gallons per day. The designer should consider local conditions. The design value for daily water use for grazing beef cattle (cow/calf pairs) can vary from 18 gpd in the eastern SD to 30 gpd or more in the west.

There is limited published data on water requirements for buffalo; however, it is generally assumed that the daily requirements are similar if not slightly less for buffalo cows, calves, and bulls as for beef cattle.

Household use can vary from 50 to 100 gallons per person per day for uses inside the home (kitchen, laundry, bathing, and sanitary use). The NRCS uses a design figure of 360 gallons per day per home or dwelling. Other "outside" uses around a farmstead would be in addition to the amount for each home.

3.2 Design Flow Rate

Minimum pipeline design gpm must at least equal the flow required to provide the peak daily water requirement for the system in a 24-hour period. A system designed with minimum capacity will require storage to provide an available supply of water when needed by the livestock or to provide for peak demands for homes and farmsteads. This

storage usually is provided in the individual stock tanks or in storage reservoirs or cisterns at the farmstead. It is customary and just good design to provide additional capacity in the pipeline to meet the daily requirement in a 16-hour period or less if possible. The actual design flow rate will depend on the flow available at the water source, the size of the herd, length of the system, and the demand at any farmsteads. Systems serving large herds may not have well capacity to deliver the volume required in a 12- or 16-hour period, and the larger pipe sizes required to deliver the higher flow rates is a cost consideration. Each system must be evaluated on its specific conditions. The design flow rate can be calculated from the following equation:

$$Q_{gpm} = (N_{hd})(G_{gpd/hd})/(H_{hrs/day})(60_{min/hr}) + F_{farmstead\ gpm}$$

Q = pipe design capacity (gpm)
N = number of head of livestock
G = daily water use (gallons per hd. per day)
H = desired delivery period (hours per day)
F = farmstead flow rate required (gpm)

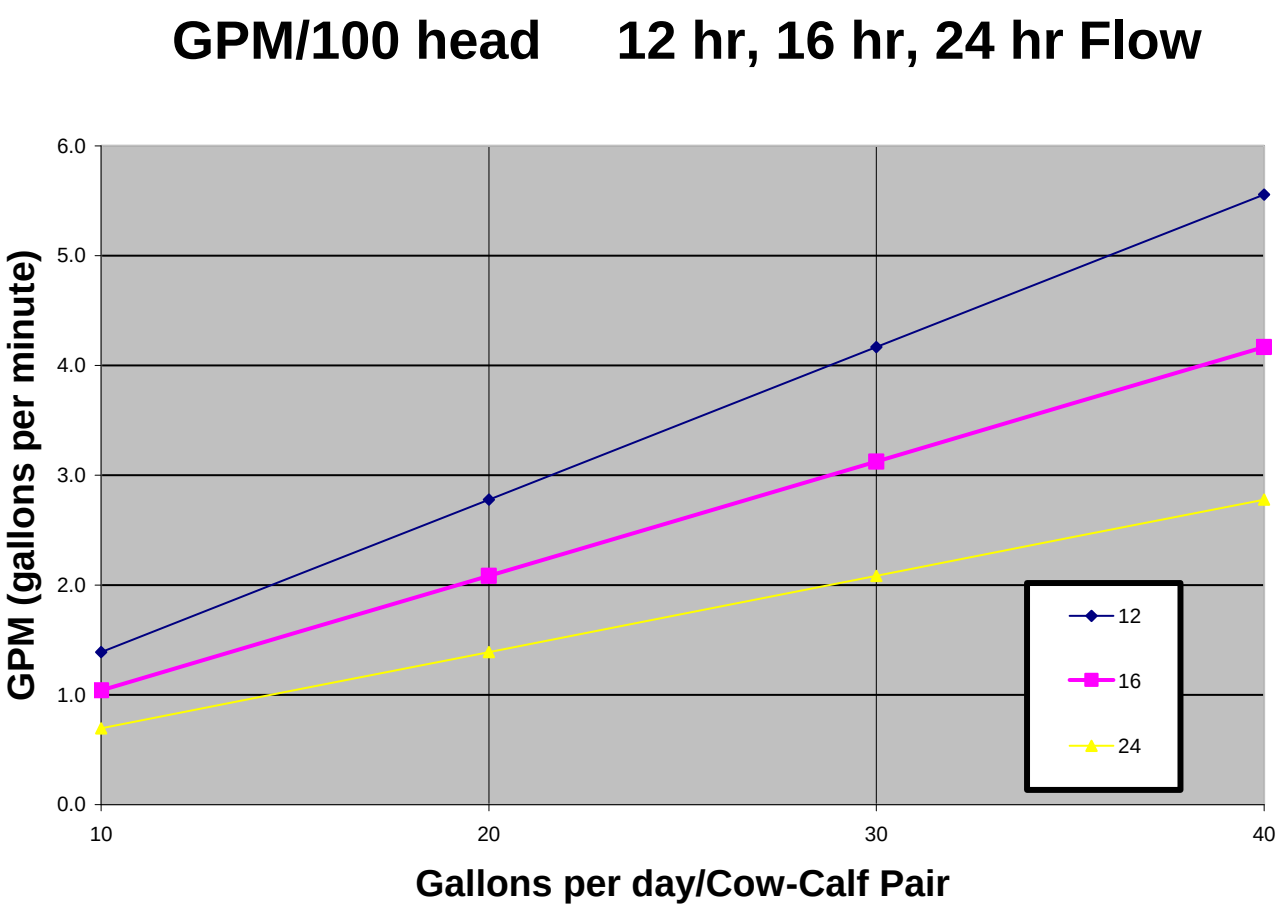
Example:
-200 hd. cow/calf pairs
-daily water use of 30 gallons per day
-provide daily water needs in 16 hrs.
-no farmstead use included

$$Q = \frac{(200\ hd.)(30\ gpd/hd.)}{(16\ hr./day)(60\ min./hr.)} = 6.3\ gpm$$

Figure 3.1 provides a graphical solution to pipe design capacity required for the minimum condition (24-hour flow), as well as, 16-hour and 12-hour flow delivery time. Using the example above for 30 gpd per cow/calf pair and the 16-hour period, the graph gives a design flow of 3.15 gpm/100 head. Therefore, for 200 head, the design flow = 6.3 gpm.

Any water system being evaluated; whether in the planning stages or discussing an existing system with a producer or designing a new system; can be evaluated very quickly for minimum capacity by utilizing a basic rule of thumb figure of 1.5 – 2 gpm for each 100 head of beef cattle. Use whichever value is appropriate depending on the where the project is located in the state.

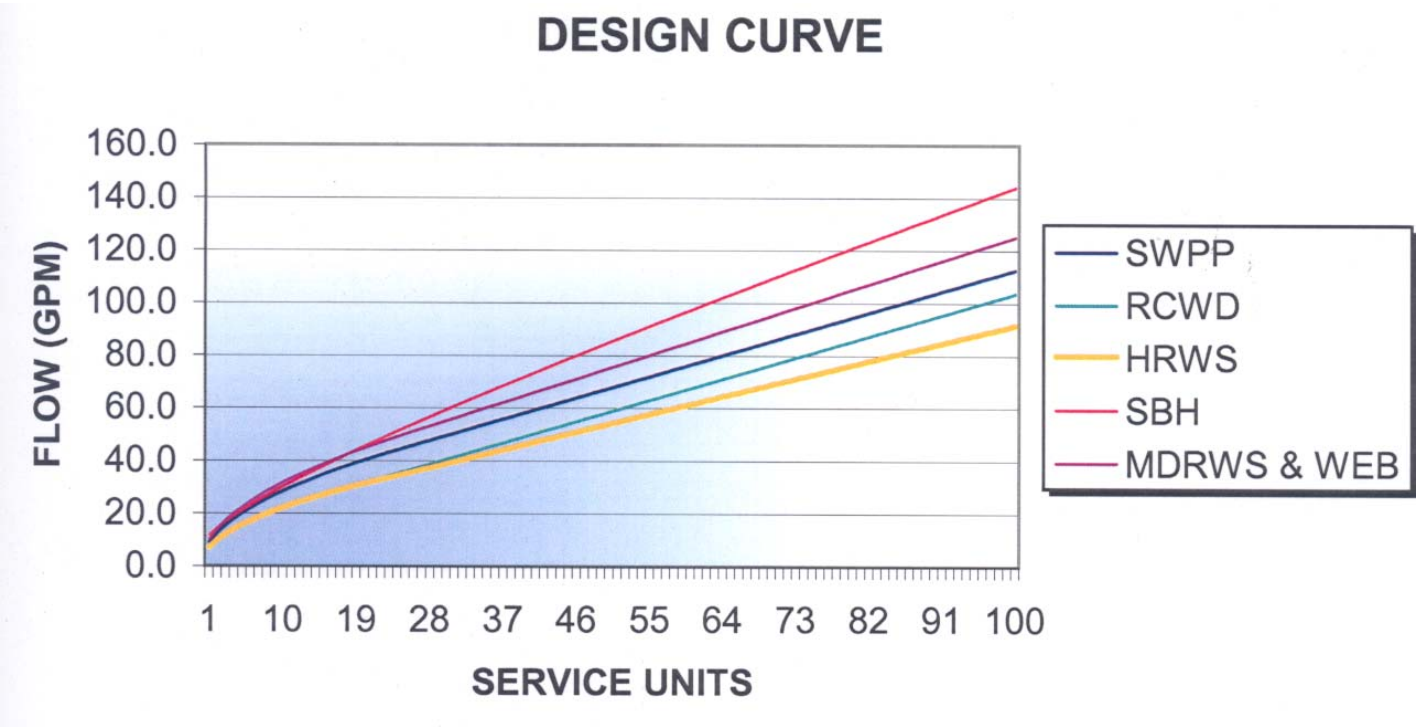
Figure 3.1
Gallons Per Minute Per 100 Head



The NRCS, in SD, uses a design flow rate for a single home of 10 gpm. The Uniform Plumbing Code calls for water to be delivered to homes for domestic us at a pressure of 50-70 psi. This provides adequate flow to have multiple fixture demand (i.e., dishwasher and shower) at a satisfactory pressure. Maximum pressures (static) over 70 psi should be controlled using pressure regulators. Systems delivering the design flow rate a pressures less than 50 psi may be acceptable, depending on the needs of the owner; however, pressures less than 35 psi will usually require a booster pump.

For systems serving multiple homes, the design flow is based on a "diversity equation" due to the design assumption that not all homes will be using water simultaneously. Since a household is expected to use a total of 360 gallons per day, a use rate within the home of 3-10 gpm would relate to water use occurring between 36 and 120 minutes of each day. This is normally intermittent use spread over a period of 12-16 hours. Therefore, a system would not have to supply 10 gpm to each home simultaneously. Consulting engineers on the larger rural water systems built in SD and surrounding states are using similar equations for peak design flow for multiple household systems. A graph of four such equations is illustrated in **Figure 3.2**. A tabular representation of the values in the graph is listed in **Table 2** showing the range from low to high. Use of design flow rates at the upper end of the range will provide the most conservative design.

Figure 3.2
Design Flow Rate for Residential Water Use
(Courtesy Bartlett and West Engineers, Inc., Bismarck, North Dakota)



For systems serving one or more homes where it is neither possible nor practical to provide pipeline capacity adequate to serve the demand required by the homes, storage is then required. The design daily water use for a home is 360 gallons per day which can be delivered over a period of 24 hours with a continuous flow of 0.25 gpm. By using a storage tank (cistern) at the farmstead and a small booster pump to draw water from the tank and deliver the demand rate for the homes, the pipeline serving the farmstead can be designed with a minimum additional capacity added from home needs. An additional one gpm increase over the design flow required for the grazing livestock will provide adequate water for one or more homes.

Table 2
Dwelling Minimum Design Flow

Number of Dwellings	Gallons Per Minute
1	10
2	12-15
3	13-17
4	14-19
5	16-21
6	17-23
7	19-25
8	20-27
9	21-28
10	22-30
15	27-38
20	31-45
25	35-52
30	39-59
35	42-66
40	46-72
45	50-79
50	54-85
75	72-115
100	91-144

CHAPTER 4

BASIC METHODS OF OPERATION AND CONTROL (WATER SYSTEM TYPES)

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CHAPTER 4

BASIC METHODS OF OPERATION AND CONTROL (WATER SYSTEM TYPES)

4.1 General

The operation of all water systems are governed by the same basic principles and the design of any water system is a function of head, flow, friction, and distance. A system may be considered a “pressure” system, a “gravity” system, or may have both pressure and gravity elements in the same system. The only basic difference between these systems is a gravity system provides the head at the source by virtue of the elevation of water in a tank or water tower, and a pressure system provides the head at the source by virtue of a mechanical pump. Therefore, the design of any pipeline system delivering water from either a gravity source or pressure source is identical beyond the source and is a function of pipe size, flow, and elevation difference. Water systems can be categorized by the type of water supply at the source or the methods used to pressurize the system.

4.2 Rural Water Connection

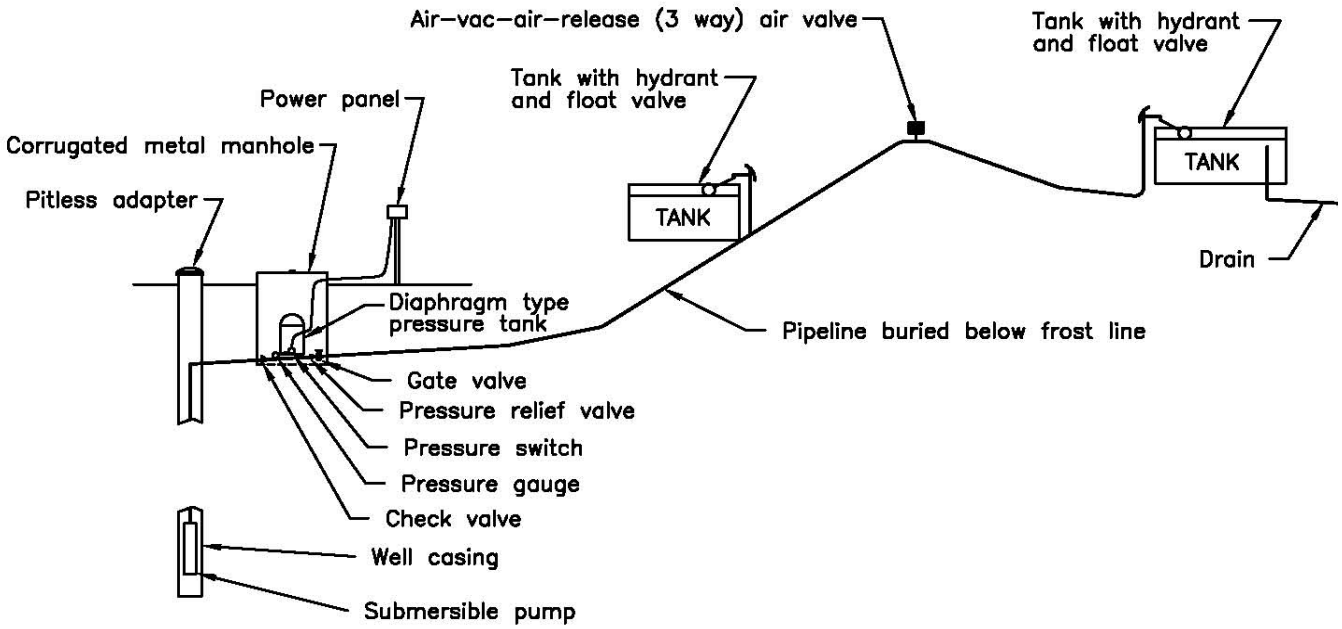
Rural water systems are pumped systems with one or more elevated towers spaced throughout the distribution system providing storage and pressure (elevation head). The pressure in the central distribution system will vary depending on demand (water use) but will normally be controlled by a pressure regulator in the meter pit and; therefore, will be fairly constant at the connection. The pressure for the pipeline design will be the pressure regulator setting. Rural water systems with demands that exceed the capacity of the system may be operating at abnormally low pressures. In these situations, the design pressure used at the meter connection should be less than the regulator setting to provide a realistic design.

4.3 Automatic Pressure System

An automatic pressure system is a pumped system which uses a pressure switch and pressure tank to control the operation of the pump. The purpose of the pressure tank is to control pump cycling and limit rapid on/off cycles which can cause pump overheating and lead to premature pump failure. Pressure systems are very common for controlling submersible pumps, but may be used for other pumps such as jet pumps or centrifugal boosters. The operating pressure for these systems is limited by the pressure rating of the pressure tank. Pressure tanks are commonly available with ratings of 100 psi, 125 psi, and 150 psi. Specialty tanks which carry an American Society of Mechanical Engineers (ASME) rating are available up to 250 psi or more but systems utilizing these tanks are rare. Consideration should be given to using pressure tanks with replaceable rubber bladders for any system operating over 100 psi due to the replacement cost of a tank if the bladder fails. An advantage of a pressure system is that it is automatic and requires little attention. See **Figure 4.1** for a sketch of a typical system.

Figure 4.1

TYPICAL AUTOMATIC PRESSURE SYSTEM



4.4 Timer or Manual Controlled System

A timer controlled system is a pumped system which uses a timer to turn the pump on or off. A central storage tank with an overflow that wastes excess water is usually located on a high point. Water flows from the storage tank to all other parts of the system during periods when the pump is off. A stock tank can also be used in lieu of the central storage at the high point and plumbed with an overflow, with all lower tanks controlled with floats. Water waste can be minimized by providing operators with figures showing pump hours per day required based on the livestock numbers and season of use (see example **Figure 4.2**). Timers are a relatively low-cost alternative for controlling high pressure systems where automatic systems may be impractical, with a disadvantage being the potential waste of water and energy.

Figure 4.2
Example of Timer Setting and Pumping Hours

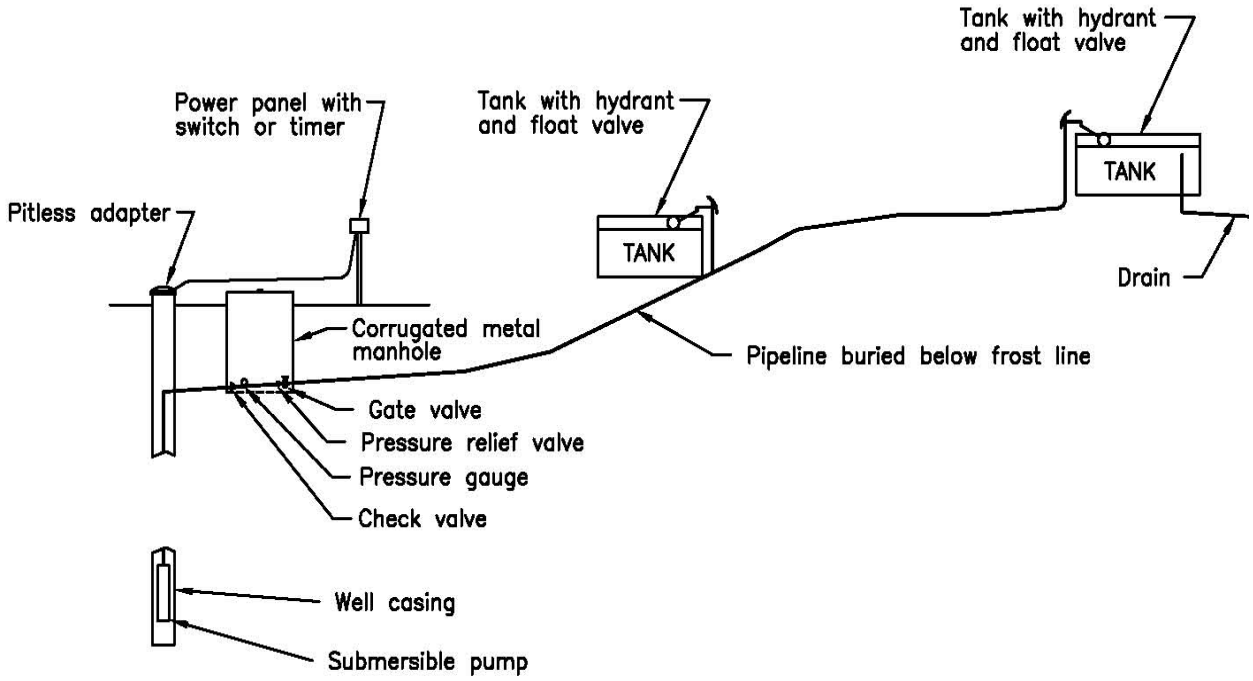
Timer setting **(hours per day)** based on 7 gpm pump

Number of Cattle	Season	
	Spring/Fall @ 15 gpd	Summer @ 25 gpd
50	1.8	3.0
100	3.6	6.0
150	5.4	8.9
200	7.1	11.9

A manually controlled system is similar to a timer system except that the operator must physically be at the pump site to turn the pump on or off. These systems are typically used on single tanks located at the well site and would rarely be used on a system of multiple tanks and larger livestock numbers because the number of pumping hours required would make monitoring the operation impractical. These are very simple systems with the disadvantage of being very labor intensive. See **Figure 4.3** for a typical system sketch.

Figure 4.3

TYPICAL MANUAL OR TIMER OPERATED SYSTEM



4.5 Float Switch or Probe Controlled System

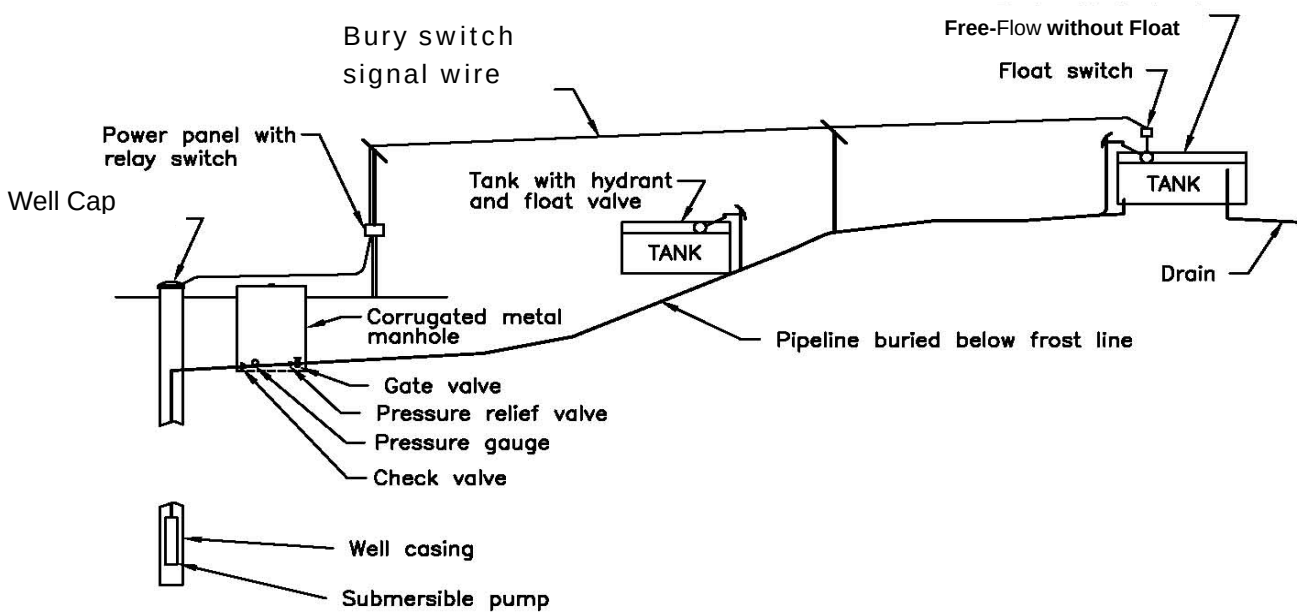
A float switch or electric probe operated pressure system is a pumped pipeline system in which the pump is turned on or off with a float switch or probe located at the highest tank in the pipeline.

This type of system requires that an electric control wire run between the pump and tank. The wire is usually buried in the same trench as the pipeline. The switches and probes are low voltage and utilize small gauge wire (possibly telephone wire) connecting the switch/probe to a relay which controls the pump. There may be limitations on the distance between the tank and pump relay depending on the equipment. Distances of one-quarter mile or less should work for most equipment.

These controls are common on solar systems to control a solar pump or when used in conjunction with a central storage tank. The separation between the high and low probes in the storage tank provide the storage necessary for proper pump cycling and eliminate the need for a pressure tank and pressure switch. This type of control is very useful for group pipelines and small rural water systems. See **Figure 4.4** for a typical system sketch.

Figure 4.4

TYPICAL FLOAT SWITCH OPERATED SYSTEM



4.6 Pressure Transducer and Constant Pressure Pump

An electronic pressure transducer is used to control a variable speed (constant pressure) submersible or in-line centrifugal pump. These systems are a variation of the automatic pressure system. Rather than a standard (constant speed) pump, the variable speed pump has an infinite speed range which can speed up or slow to meet the demand as sensed by the transducer (electronic pressure sensor). The advantage to these systems is they offer slow starts which will substantially reduce surge and water hammer, provide a constant discharge pressure which is easily adjustable, and are suited to operating pressures in the 150 psi range or over. Since the pressure tanks on the constant pressure pumps are quite small (usually 2.0 - 2.2 gallon), the cost of these tanks is not a major component of the system expense. These small pressure tanks are available in 200 psi rating. Costs for these systems are very comparable to conventional systems; however, they are not “off the shelf” and the pumps and controllers would normally be a special order from a supplier.

4.7 Gravity Flow System

A gravity flow system is normally a feature incorporated into one of the other operating methods described above. The elevation head is determined by the elevation of the water surface in the reservoir or storage tank. Examples of true gravity flow systems would be a spring development and the flow issuing from the spring box, or the gravity flow to a pipeline from a central storage tank. See Chapter 2 and Figure 2.2 for a discussion of typical uses for storage tanks.

CHAPTER 5

PIPE DESIGN

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CHAPTER 5

PIPE DESIGN

5.1 General

There are several types of pipe that may be used in stockwater systems. The most commonly used types are discussed below. The pipe selected for a system is dictated by soil conditions, water temperature, operating pressure, installation method, location (well pit, direct burial, etc.), and price.

When designing a pipeline, it is important to know the type of pipe to be used. Internal pipe diameters vary depending on material type and pressure rating for a given nominal pipe size. Due to differing internal cross sectional area and differing friction loss factors, friction loss in long pipelines can differ considerably from one type and rating of pipe to another.

Many plastic pipes are specified as having a Standard Dimension Ratio (SDR) or Dimension Ratio (DR). For these pipes, as SDR or DR increases, the pipe's wall thickness decreases. For Outside Diameter (OD) controlled pipes, SDR = average OD/minimum wall thickness. For inside diameter (ID) controlled pipes, DR = average ID/minimum wall thickness.

5.2 PVC Plastic Pipe

PVC is a commonly used type of pipe for stock water pipelines. This is a rigid plastic pipe that, in the configuration used for stock water pipelines, usually comes in 20 or 40 foot lengths. PVC is informally called “white plastic,” although it can be any color the most common which are white and grey. PVC is joined using socket ends and solvent weld cement (glue joint) or belled ends with integral rubber gaskets (gasketed joint). The gasketed joint is usually available in one and one-half inch diameter and larger sizes and is the preferred joining method due to the rubber joint allowing some movement for temperature expansion or contraction and also due to the gasketed method being less prone to installation related defects.

PVC is manufactured from natural gas and rock salt. The natural gas is heated under pressure to form ethylene. The rock salt is split by electrolysis to form chlorine and lye. The chlorine and ethylene are then combined to form a vinyl chloride monomer which is joined to form long chains of PVC polymer (plastic). Because the primary material used in the manufacture of PVC is a petroleum product, the price of pipe fluctuates somewhat in step with energy prices. Since all PVC pipes are manufactured using a similar extrusion process of very similar PVC resins, the cost of the pipe is approximately proportional to the weight of the pipe material (resin) used.

PVC pipe is known by its nominal diameter which differs somewhat from the actual ID. Early iron pipe manufacturers began with walls in the smaller pipe sizes much too thick. Later, in correcting this error in design for cost reduction, they took the excess thickness from the inside to avoid changing the sizes of companion fittings already in use. PVC was subsequently manufactured with outside diameters in iron pipe sizes.

When subject to long-term exposure to ultraviolet radiation (sunlight), PVC pipe will suffer slow deterioration. PVC pipe should be buried or installed in an enclosure. If PVC must be exposed, it should be coated or wrapped. The coating may be exterior latex paint. Make sure the pipe is thoroughly cleaned before painting.

Exposed pipe should be protected from mechanical damage by livestock or other hazards. Plastic pipe is particularly vulnerable when cold as it will easily shatter. Smaller pipe sizes with relatively thin walls can also be severely damage by large hail.

There are three types of PVC pipe used in pressure pipelines:

SDR pressure rated pipe may be classified as SDR or DR. Both classifications are based on a ratio of the OD to the wall thickness and there is no difference between SDR or DR pipe. All pipes manufactured with the same material (usually 1120 PVC) and same SDR have the same pressure rating. The pressure rating for SDR pipe is based on a 2.0 safety factor. For these pipes, as SDR or DR increases, the pipe's wall thickness decreases. SDR pipe is manufactured under specification ASTM D2241 with the OD based on the iron pipe size (IPS) system and available in sizes from ½" to 24." The IPS system is the standard used for dimensions for all types of valves, fittings, pumps, and other plumbing material, and; therefore; the OD of SDR pipe is compatible with these fittings. SDR pipe is the most common type of PVC used for stockwater pipelines and joints are either solvent weld or gasketed.

Schedule 40, 80, 120 PVC is also manufactured with IPS based ODs. The pipe wall thickness is exactly the same as steel pipe of the same diameter corresponding to the different steel pipe weights (standard, extra strong, double extra strong). Schedule pipe is used in pressure applications but does not carry a pressure rating stamped on the pipe. As pipe diameter increases, the pressure rating decreases since the wall thickness is not proportional to the diameter but rather is identical to steel pipe (1¼" Schedule 40 is rated at 370 psi, 1½" is rated at 330 psi, and 2" is 280 psi). Schedule 40, 80, and 120 PVC is manufactured under specification ASTM D1785 and commonly available in sizes from ½" to 12" diameters. PVC fittings used for pressure applications are either Schedule 40 or Schedule 80, and have identical thread and are compatible with all other IPS fittings such as steel or brass. Schedule fittings are also compatible with standard dimension ratio (SDR) PVC. Schedule pipe is commonly used in well pits and other plumbing applications where a heavy wall plastic is desirable for durability and corrosion resistance. Schedule pipe is also common for high pressure pipeline applications where SDR pipe (>200 psi) may be available by special order only, whereas, the schedule pipe is normally a stock item. Joints for schedule pipe are normally solvent weld.

Both SDR and Schedule pipe are available in different PVC materials. Type I, Grades 1 and 2, are designated PVC1120 and PVC1220, respectively. Type II, Grade 1, is designated PVC2120, PVC2116, PVC2112, or PVC2110. Normally, PVC stocked in large quantities for water system use is PVC 1120 or 1220. Usual practice for the designer is to specify both the type of PVC (i.e., SDR 21) and the pressure rating (200 psi) to insure the specifications are fully understood by the installer.

AWWA C900 PVC is manufactured based on either IPS ODs or cast iron pipe ODs and is a DR pipe. It is usually manufactured of PVC 1120. The DR classification is based on a ratio of the OD to the wall thickness and is manufactured in 4-12" sizes in DR 25 (100 psi), DR 18 (150 psi), and DR 14 (200 psi). The pressure rating for C900 pipe is based on a 2.5 safety factor which results in a thicker walled pipe in comparison to SDR pipe of equal pressure rating. C900 is common in municipal applications where an extremely durable pipe is desirable and where old cast iron fittings are common. C900 is also specified on many of the larger rural water systems.

For all three of these types of pipe, the OD is constant and the ID varies. Therefore, as the pressure rating or weight of pipe varies, so does the friction loss.

5.3 PE Plastic Pipe

PE pipe is another commonly used pipe in stockwater pipelines. It is flexible, comes in coils, and is used for most "pull-in" type systems. The length of the coils varies with the diameter of the pipe from 100 ft. to 400 ft. or more. PE pipe is informally called “poly pipe” or “black plastic” and although PE pipe used for water systems is normally black, PE pipe could be almost any color. Where pipe is installed in trenches, it is harder to lay flat in the trench than PVC pipe. Since it comes in coils, PE pipe takes fewer fittings to lay. Connecting this type of pipe is usually done with a fusion process where the pipe coils are melted or “fused” together with heat or with "stab" type insert fittings held together with stainless steel band clamps. Frost heave in shallow pipelines tends to pull these insert fitting joints apart. Double clamping is usually necessary to combat this problem and is recommended in SD. Clamps must be placed over the insert barb and clamp screws placed 180^0 opposite each other.

PE is a thermoplastic material manufactured from methane gas which is then converted to ethylene, and then with the application of heat and pressure into PE. The polymer chain length, molecular weight, and amount of branching determine the mechanical and chemical properties of the end product.

This material is tough, flexible, abrasion resistant, and resistant to freeze damage. Although sometimes proposed for shallow, nondrained pipelines, it should not be used in this way. This pipe will usually withstand an occasional freeze without damage, but the system should not be knowingly designed to freeze while water is in the line since there is a potential of long-term fatigue and a shortened design life. PE will withstand exposure to sunlight due to the use of UV inhibitors used the manufacturing process and may be installed above ground where below ground installations are not possible.

There are several types of PE pipe commonly used for pressure applications in stockwater systems:

ID controlled SDR PE 3406 high density is pressure rated pipe and may be classified as SDR or DR. Both classifications are based on a ratio of the OD to the wall thickness and there is no difference between SDR or DR pipe. All pipes manufactured with the same material and same SDR have the same pressure rating. For these pipes, as SDR or DR increases, the pipe's wall thickness and pressure rating decreases. ID controlled SDR pipe is manufactured under specification ASTM D2239 in sizes from one-half-inch to six-inch with **IDs** corresponding to steel pipe (IPS). The pipe is ID controlled to facilitate insert fittings to join the pipe, which allows the same fittings to be used on all pipes of the same size regardless of pressure rating or wall thickness. PE 3406 designates a type of high density PE material used in manufacturing the pipe that has a HDS of 630 psi. PE3406 is available in pressure ratings of 80, 100, 125, 160, and 200 psi. Friction loss will be identical for all pipes of a given size, regardless of pressure rating since the ID remain constant.

ID controlled SDR PE 3408 high density is a PE pipe classified as SDR, manufactured under ASTM D2239 in IPS size **IDs**. It is similar to the PE3406 except that PE3408 designates a type of high density PE material used in manufacturing that has a HDS of 800 psi. The wall thickness of SDR PE3408 pipe will be thinner than PE3406 pipe for any given pressure rating and is available in 80, 100, 125, 160, 200, and 250 psi.

OD controlled SDR PE 3408 high density is a PE pipe classified as SDR and manufactured under ASTM D3350 in IPS **OD**. All pipes manufactured with the same material and same SDR have the same pressure rating. For these pipes, as SDR or DR increases, the pipe's wall

thickness and pressure rating decreases. OD controlled PE3408 is manufactured in sizes from ½" to 48" and in pressure ratings of from 80 psi to 250 psi. The pipe is OD controlled to facilitate the fusion process of joining coils or pipe sections together (butt fusion) with electrically heated dies. For a given size, the OD is constant regardless of pressure rating. Friction losses will increase as pressure rating increases since the ID varies (decreases). OD controlled butt fusion pipe has become extremely popular in recent years. The joint is as strong as the pipe and results in a very tough and durable pipeline.

ID controlled Schedule 40 PE 3406 is manufactured with IPS based ODs under ASTM D2104. The pipe wall thickness is exactly the same as steel pipe of the same diameter corresponding to Schedule 40 steel. Schedule pipe can be used in pressure applications but does not carry a pressure rating stamped on the pipe. As pipe diameter increases, the pressure rating decreases since the wall thickness is not proportional to the diameter but rather is identical to steel pipe (1¼" is rated at 120 psi, 1½" is rated at 100 psi, and 2" is 90 psi.). Schedule 40 PE is manufactured in sizes from ½" to 6" and uses insert fittings at the joints. This is not a common pipe for stockwater installations.

Over the past 5 years, **High Performance PE4710** has been introduced into the pipe and tubing market. Resin manufacturers have developed new manufacturing technologies for producing PE pressure pipe materials that have improved physical properties and performance. These new materials are frequently referred to as "bimodal," which is a type of molecular weight distribution; although other molecular structure characteristics are also changed.

High performance PE is an improved PE compound for pressure pipe that is designated PE4710. Compared to the older "uni-modal" resins such as PE3408, several performance characteristics are significantly enhanced.

- Higher density – PE4710 materials have higher base resin densities than PE3408 materials (0.956 to 0.964 gm/cc vs. 0.949 to 0.956 gm/cc with 2 percent carbon black). Higher density increases tensile strength, stiffness, and chemical resistance.

- Hydrostatic Design Basis (HDB) substantiation at 50 years – ASTM D 2837 determines the HDB, at 100,000 hours (11.4 years). The ASTM D 2837 method does not accommodate a downturn in the stress rupture curve that indicates a transition to wholly brittle-type failures. Therefore, PE materials must also undergo additional pipe tests to prove that a transition to brittle-type failures does not occur before 100,000 hours. To qualify as PE4710, it is necessary to prove by testing and analysis that a transition to brittle-type failures does not occur before 438,000 hours (50 years) – a 4 to 1 increase over other materials.

- PE4710 has **up to 10-fold increase in Slow Crack Growth (SCG) resistance**. ASTM F 2136 is used to determine SCG resistance of HDPE resins. It is used by the PE pipe industry when seeking the most durable HDPE materials. If the PE material has poor SCG resistance, failure could occur in only a year or two, but it can last for hundreds of years if the SCG resistance for the PE is good. Better PE3408 materials have SCG resistance of at least 100 hours. PE4710 materials must have at least 500 hours SCG resistance. This means that the potential for SCG failure, the long-term failure mode for PE pipe, is extremely remote in comparison to other PE materials. The extrapolated life expectancy of the PE 4710 resin is 100 years vs. 50 years for the older PE-3408 resin.

- Overall, the PE-4710 products have a 25 percent increase in pressure rating and in many cases the opportunity exists to select a higher SDR for a lighter weight pipe with a higher flow capacity.

The introduction of PE 4710 into the market has initiated changes in the standards and specifications beginning in 2002. Revisions to ASTM D3350 were completed in 2005; ASTM D3035 was completed in 2006; and ASTM D2737 and D2239 are expected to be completed in 2008. These changes were necessary to incorporate the new materials into the ASTM system, but unfortunately they also will create some confusion and will cause other material specifications to become obsolete. For the short-term, most manufacturers are now dual marking their HDPE pipe and tubing as follows:

1. **PE3408/PE3608 – this is for the standard materials and reflects the change in designation only.**

2. **PE3408/PE4710 – this indicates the manufacturer is using the new bi-modal resins and the pipe has improved physical properties and performance.**

Dual marking allows pipe to be used when the utility specification does not incorporate the new material designation codes or the new bi-modal resin code. Dual marking will eventually be eliminated and that will mean some utilities will no longer be able to purchase PE-3408 pipe that their standards call for.

5.4 Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe

Although listed in the standards as an acceptable pipe material, ABS pipe is used little in the transmission pipeline portions of stockwater pipelines. ABS pipe is frequently used in stockwater systems as drain, vent, and waste system components. This black pipe has the advantages of being tough with good strength and stiffness. It is not tolerant to ultraviolet light, so it should be painted or wrapped if exposed to sunlight. It ranges in size from 1/8 inch to 12 inches in diameter. Types of ABS include ASTM-D-1527 (ABS Schedules 40 and 80) and ASTM-D-2282 (ABS, SDR-PR).

5.5 Steel Pipe

Galvanized steel pipe is manufactured in IPS sizes in three weights (standard, extra strong, and double extra strong). Galvanized steel pipe is used occasionally in system plumbing in well pits and as drop pipes for submersible pumps. It is rarely used in main parts of the pipeline in buried installations. Steel pipe is used in buried applications only as a last resort due to its high cost, high friction loss, and because it easily corrodes. Alternatives to using galvanized pipe in high pressure applications would be Schedule 80 or Schedule 120 PVC, or for very short runs such as in a well pit, red brass could be used (longer runs would be cost prohibitive as red brass is quite expensive compared to other alternatives).

When buried, steel pipe should always be coated and wrapped. This is due to the corrosive nature of most soils. Steel pipe should never be connected to brass or bronze fittings unless a dielectric insulating coupler is used, since the steel will then corrode at a faster rate. Operating pressures in steel pipe should not exceed 50 percent of the rated bursting pressure.

5.6 Copper Pipe (Ref. CCBDA Publication No. 28E)

Copper plumbing tube is manufactured in accordance with the requirements of ASTM Standard B 88. Adding to its versatility is the fact that copper tube is available in drawn (hard) and annealed (soft) tempers, as well as, a wide assortment of lengths, diameters, and wall thicknesses.

Types K, L, and M copper tubes have actual ODs which are 1/8 inch (0.125 in.) larger than the nominal (standard) sizes. For example, a one-half-inch Type M tube has an actual OD of five-eighth-inch. Type K tube has thicker walls than Type L tube and Type L walls are thicker than Type M for any given size (diameter). Table B-15 (Appendix B) provides the dimensions and weights for Types K, L, and M copper tubes.

Table B-17 shows the rated internal working pressures for both annealed and drawn Types K, L, and M tubes, for service temperatures up to 400°F (205°C). The ratings for drawn tube can be used for soldered systems and systems using properly designed mechanical joints.

Most systems are installed with solder or brazed joints. Table B-16 covers the rated internal working pressures for such joints; the ratings are for Types K, L, and M tubes with standard solder joint pressure fittings. In soldered systems, the rated strength of the joint often governs the design.

For direct bury water lines, either Type K or L soft temper tube is used and is available in long coils of various lengths in nominal sizes up to two inches. With coils, intermediate joints can be eliminated or minimized. Soft tube can also be bent around any obstructions or unevenness in the trench, and it adjusts readily to ground settlement. Compression fittings have become the most popular choice for underground copper water services in recent years, because of their high strength and ease of installation. Systems above ground or in nonburied plumbing installations typically use hard temper Types L and M tubes. Depending on service conditions, hard Type K may be needed in some cases.

Galvanic or dissimilar metal corrosion of copper and copper alloys is exceptionally rare. Incidents often attributed to galvanic corrosion are usually erroneous. In the galvanic series of metals, copper is one of the most noble metals. This means that copper is the most corrosion resistant. In other words, when copper is in contact with iron, steel, or aluminum in water distribution systems, for example, the copper does not corrode; however, the other metal will eventually fail if the conditions for galvanic corrosion are present. This situation can be prevented by using a dielectric fitting between the copper and the less noble metal. It should be added that electrolysis should not be confused with galvanic corrosion. Underground copper lines are renowned for their excellent performance in a wide variety of soil conditions. Copper does not corrode in most clays, chalks, loams, sands, and gravels. Concrete is often thought to cause corrosion of copper but this is a misconception. Copper is unaffected by Portland cements which provide an alkaline environment. However, nonalkaline cements containing sulphurous ash or other inorganic acids should be avoided, as should foamed concretes which employ ammonia-containing foaming agents.

5.7 Red Brass

Red brass (an alloy of copper, tin and zinc) pipe is manufactured in IPS sizes in two weights (standard and extra strong). Red brass pipe is used usually used in system plumbing in well pits for occasional nipples connecting valves and appurtenances. It is an option to use for plumbing runs in exposed (nonburied) plumbing applications such as well pits for high temperature, high

pressure applications. The advantage of red brass is its relatively noncorrosive properties and strength. Red brass is very expensive and only practical for relatively short runs in specialized installations. Table B-14 (Appendix B) provides allowable working pressure for red brass pipe.

5.8 Plastic Pipe Characteristics

5.8.1 PR of Pipe

Plastic pipe is rated at approximately one-quarter to one-third its tested rupture strength. This means that under normal temperature conditions, it can withstand occasional surge pressures greater than its rated pressure. However, plastic pipe will weaken under repeated cycles of pressures in excess of those for which it is rated. The higher the surge pressure the faster the pipe will weaken and the long term life of the pipe will be affected. For this reason it is important to design the pipe system so that normal operating pressures are less than rated pressure of the pipe to allow for surges which may occur. If the surge pressure is not calculated, which is usually the case in SD, limit the maximum pressure on the pipe to 72 percent of its PR. This is an industry accepted method (ASAE S376.1). See Appendix B for PVC and PE sizes, dimensions, SDR, pressure ratings, and other pipe data.

$$PR = \frac{2f}{SDR-1} \text{ (OD Controlled)}$$

$$PR = \frac{2f}{DR+1} \text{ (ID Controlled)}$$

PR= Pressure Rating
f= Hydrostatic Design Stress (see TR-77)

Other sections of this manual describe ways limit surge pressures. The system should be designed and operated to limit the number and severity of pressure surges.

5.8.2 Expansion and Contraction of PVC and PE Pipe

All pipe products expand and contract with changes in temperature. Linear expansion and contraction of any pipe relates to the coefficient of thermal expansion for the specific material used and the variation or change in temperature (**T**). The wall thickness of the pipe has no effect on the rate of expansion assuming the material remains constant. The coefficients of thermal expansion for PVC and PE pipe and the resulting change in length for per 10^0F are presented below:

Table 5.1
Coefficients of Thermal Expansion

Material	Coefficient in./in./^{0}F	Expansion per 10^0F
PVC	3.0×10^{-5}	0.36 in./100 ft. 19.0 in./mile
PE	8.0×10^{-5}	0.96 in./100 ft. 50.7 in./mile

For pipelines of miles in length, the effect of temperature change on the total length of the pipe is substantial if the temperature change is more than a few degrees. An example of a plastic pipe joined and laying beside the trench on a hot summer day could easily reach 80^0F, which is then placed in the trench (55-60^0F) and quickly covered could have a temperature change of 20^0F. If the pipe is PVC, the reduction in length would be over 3 ft. per mile, and if PE, almost 9 ft. per mile. The reduction in length puts the pipe in tension and can have the effect of literally pulling the pipe apart. Usually this results in a leak due to failure of the pipe joint. The NRCS construction specifications call for snaking the pipe in the trench (side to side) to provide some extra length to help to mitigate the effects of temperature. Usually, any snaking that does occur is by accident and is unachievable as pipe sizes increase, particularly in a narrow trench. For this reason, any PVC pipe one and one-half inch diameter and over should have rubber gasketed pipe specified. The rubber gasket joint every 40 feet provides an allowance for minor movement at each joint.

The effect of temperature change on pipelines should be taken into consideration by the designer on any system with the potential for quite drastic temperature changes on the pipe, such as, systems utilizing high temperature wells or systems "plowed in" in extremely hot or cold weather. Allowing adequate time for the pipe to acclimate to soil trench temperature prior to backfilling should be standard procedure on all trenched systems. Other measures which could be considered to reduce expansion/contraction problems include timing installation during favorable temperature ranges, requiring extended warranty if installation methods cannot eliminate extreme pipe temperature differentials, charging the lines prior to backfilling on systems with high temperature wells, or use of specialized pipe fittings allowing differential movement.

5.8.3 Effect of Temperature on PVC and PE Pipe

The pressure rating of plastic pipe is determined at 73.4^0F. Strength of plastic pipe decreases as water temperature becomes warmer. In cases where hot artesian water is used, the effective pressure rating of the pipe must be reduced. Tables 5.2 and 5.3 lists the temperature reduction factors for PVC and PE pipes respectively.

Soil temperatures at normal pipeline burial depths of 5½-6 ft. are fairly constant year round at approximately 50-55^0F. As pipeline distance from the well increases, the soil temperature will have a cooling effect on the water temperature in the pipeline. South Dakota has been using a design temperature reduction of 10^0F per mile for PVC lines carrying hot water. This determination was made based on systems in the Fort Pierre area with hot artesian wells and stock tanks spread along the pipeline which utilizes PE coils and continuous circulation to keep the tanks ice free during winter. The heat loss of 10^0F per mile was not based on actual research data, but rather an estimate based on observation.

Data available from the GEO-HEAT CENTER (GHC) indicates the actual heat loss is much higher than NRCS has been estimating (Appendix B – *WELL PUMPS AND PIPING, GHC BULLETIN Sept. 2001*). The actual heat loss varies depending on the size pipeline, gpm flow, soil texture and moisture conditions. The lowest heat loss occurs with larger pipes, larger flows, and light textured dry soils. Using a 2" PVC line carrying 10 gpm, the calculated heat loss using the GHC figures and the worst case scenario of light textured dry soils, the temperature reduction is 18^0F per 1,000 feet. Therefore, the procedure SD is currently using should result in very conservative designs.

Table 5.2
PVC Plastic Pipe Pressure Rating Reduction Due To Temperature

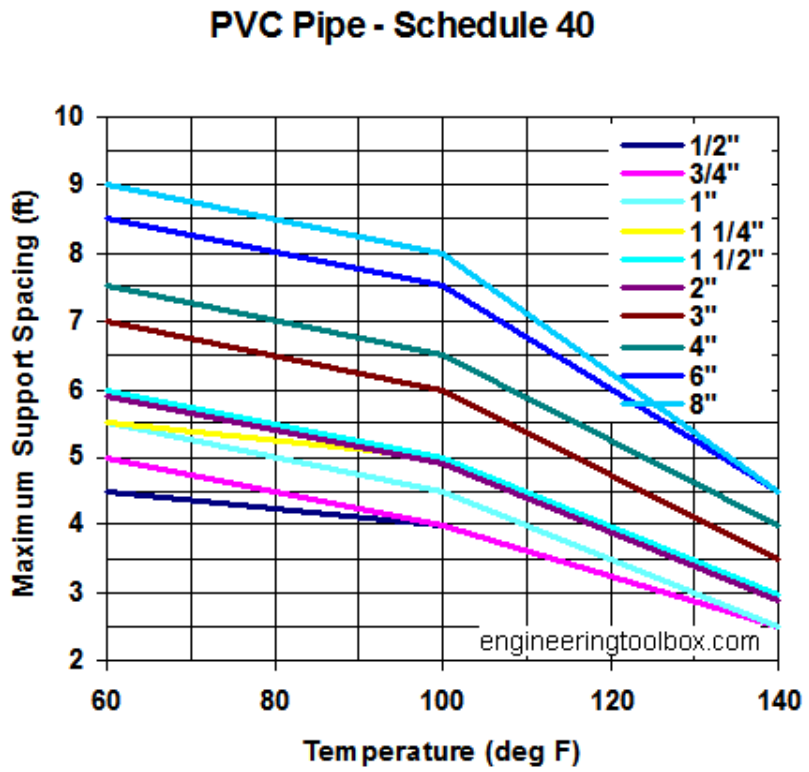
Temperature Degrees F	Multiply Pressure Rating by:
73.4	1.00
80	.88
90	.75
100	.62
110	.50
120	.40
130	.30
140	.22

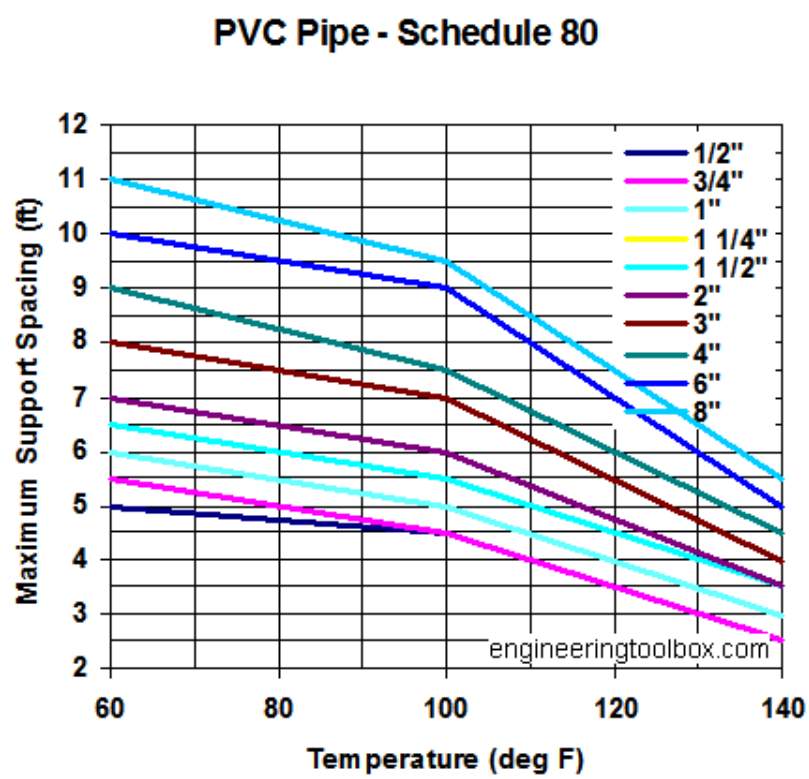
Table 5.3
PE Plastic Pipe Pressure Rating Reduction Due To Temperature

Temperature Degrees F	Multiply Pressure Rating by:
73.4	1.00
80	.92
90	.81
100	.72
110	.63
120	.60
130	.55
140	.50

Increased water temperature also increases support requirements for plastic pipe in plumbing installations such as well pits and other locations without direct soil burial. Plastic pipe without adequate support can deform or bow out of normal alignment which can lead to the pipe bursting. Figure 1 details the maximum support spacing required for various temperatures and pipe diameters.

Figure 5.1
Maximum Support Spacing for Various Temperatures and PVC Diameters





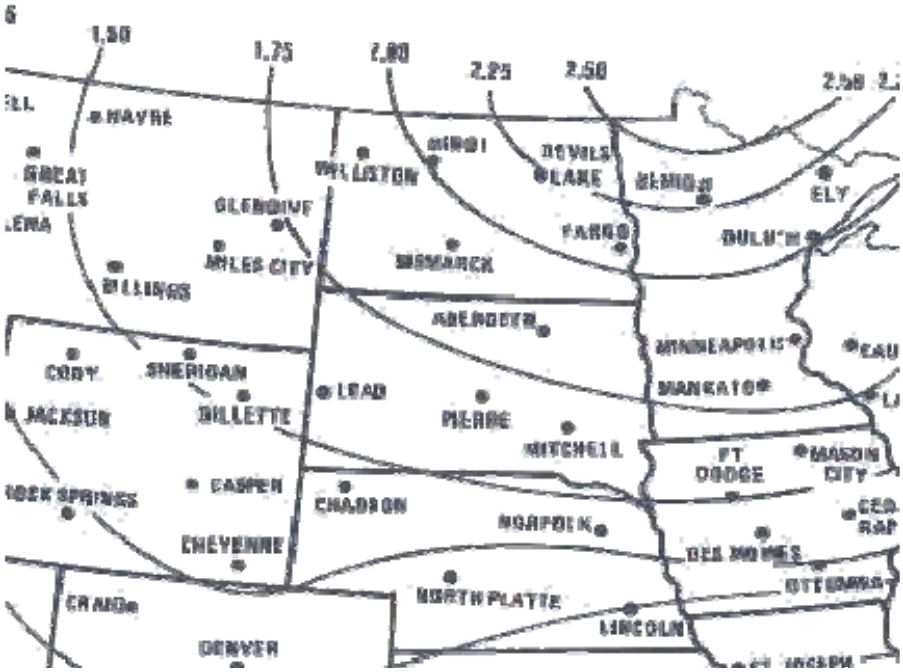
5.8.4 Freezing of Water in Pipe

Plastic pipe containing static (nonflowing) water should be drained when soil temperatures below 32^0F are expected. If the water is moving, freezing is unlikely above 0^0F.

If freezing does occur in the line, the pipe material will influence whether the pipe is damaged. In changing phase from liquid to ice, water expands approximately 10 percent by volume. Some plastic pipe will not survive the required 3.2 percent linear elongation, but most will.

Pipes most likely to be damaged by freezing water are those made of rigid materials including PVC. Pipe most unlikely to be damaged by freezing water include ABS and PE materials. All of these pipes have elongation and recovery properties which should in most cases enable it to expand and recover from occasional freezing without permanent damage. However, no system should be knowingly designed to freeze while full of water. Resistant pipes can be used in areas of severe exposure as an extra safety factor against damage by freezing. An excellent example of this would be shallow bury pipelines where PE pipe would provide an extra level of protection if a section of pipe does not drain properly. Extreme frost depth penetration for SD and surrounding states (*reference* National Oceanic and Atmospheric Administration (NOAA) is provided in Figure 5.2. These depths generally correspond to the minimum burial depths for pipelines the NRCS specifies for SD (see Chapter 2, Part 2.5, shallow bury vs. installation below frost for SD).

Figure 5.2
Extreme Frost Depth Penetration (R*eference* NOAA)



5.8.5 Surge Pressure in PVC Pipe (reference UNI-BELL Handbook of PVC Pipe, UNI-BELL Plastic Pipe Association)

Surge pressures commonly termed "water hammer" are generated in any piping system when flowing liquid changes velocity. Some of the more common causes of surge pressures are 1) the opening and closing of valves; 2) starting and stopping of pumps; 3) changes in reservoir elevation; 4) liquid column separation; and 5) entrapped air.

The intermediate conditions which exist in a system as it moves from one steady state condition to another are best described as *transients*. The closing of a single valve or the starting of a pump are examples of transient surges.

Oscillatory surging is a condition which occurs regularly in time such as with the action of reciprocating pumps. Small oscillatory surges can grow rapidly in magnitude and become extremely damaging if the frequency of surging is at or near the natural resonant frequency of the piping system.

The elastic wave theory of surge analysis has been developed by various investigators over the years, and this technique will yield satisfactory results when correctly applied to *transient* surges. The pipeline designer should be aware that some system conditions (including oscillatory surging) can be extremely complicated and require the use of refined techniques given in various texts. A detailed study of hydraulic surges is a very involved process. Common examples handled by the use of the elastic wave theory are the calculation of the pressure rise occurring in a pipeline due to the rapid closing of a valve, or the starting of a pump. Surge pressures are a function of the following variables: 1) fluid bulk modulus; 2) pipe dimension ratio; 3) modulus of elasticity of the pipe; and 4) maximum velocity change of the fluid.

Table 5.4 provides a design table of pressure surges occurring in PVC pipe of various dimension ratios, per each one foot per second instantaneous flow velocity change **(**reference: UNI-BELL Handbook of PVC Pipe).

Table 5.4
Design Table For PVC Pipe – Pressure Surge Vs. Dimension Ratio
(In Response to 1 ft./sec. Instantaneous Flow Velocity Change)

Dimension Ratio	Pressure Surge (psi)
13.5	20.2
14	19.8
17	17.9
18	17.4
21	16.0
25	14.7
26	14.4
32.5	12.8
41	11.4

Flow velocities in most water distribution systems designed for livestock and potable water, in SD, (exclusive of fire protection) are usually less than 2 ft./sec. The standard design practice currently used by NRCS for providing adequate allowance for surge pressures typically occurring in pipeline systems is to limit the working pressure to 72 percent of the pressure rating of the pipe. This design practice typically then does not require calculation of actual surge

pressures. Depending on the pressure rating of the PVC used, the pressure allowance for surge would range between 45 psi for 160 psi pipe and 88 psi for 315 psi pipe. Some of the nontypical applications may require specific surge calculations to insure pressure ratings of various components are not exceeded. High pressure applications utilizing a timer or float switch (no pressure tank) may be an example of when surge pressure should be taken into consideration.

5.9 PVC Pipe Fittings

Schedule 40 and 80 solvent weld and threaded fittings are covered by the following ASTM standards:

D2624 - Threaded PVC Plastic Pipe Fittings, Schedule 80

D2466 - PVC Plastic Pipe Fittings, Schedule 40

D2467 - Socket-Type PVC Plastic Pipe Fittings, Schedule 80

These standards deal mainly with workmanship, materials, dimensions, tolerances, and testing. There are no pressure rating standards for PVC fittings in the ASTM specifications. The only pressure standards specified are for burst pressure.

One analysis, based on very limited real data, proposes the upper limit working pressures for Schedule 40 and 80 PVC fittings as tabulated in Table 5.5. Use this as a general guide only. Actual allowable working pressures may vary widely with field conditions, particularly the frequency and degree of surge pressures anticipated. On high pressure pipelines, metal or other alternative type fittings may be used.

Table 5.5
Estimated Upper Limit Working Pressures for Schedule 40 and Schedule 80 PVC Fittings
(based on 60 percent of pipe pressure rating)

Nominal Diameter (in)	Outside Diameter (in)	Schedule 40 Pressure Rating Burst (psi)	Schedule 40 Pressure Rating Working (psi)	Schedule 80 Pressure Rating Burst (psi)	Schedule 80 Pressure Rating Working (psi)
1/2	0.840	1910	358	2720	509
3/4	1.050	1540	289	2200	413
1	1.315	1440	270	2020	378
1-1/4	1.660	1180	221	1660	312
1-1/2	1.900	1060	198	1510	282
2	2.375	890	166	1290	243
2-1/2	2.875	970	182	1360	255
3	3.500	840	158	1200	225

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CHAPTER 6

HYDRAULICS

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CHAPTER 6

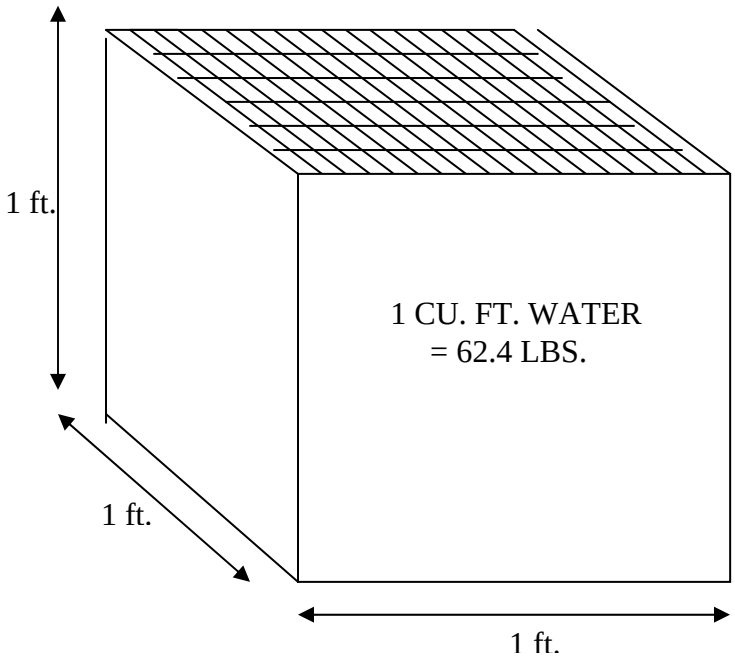
HYDRAULICS

6.1 General

Pipeline design requires an understanding of the basic hydraulic relationships between **head, pressure, flow, friction loss, and pipeline length**. Once these concepts are understood, the basics of pipeline design are easily mastered and the application of these concepts applies to any system regardless of size.

6.2 Relationship between Head and Pressure

Water pressure in a water system or pipeline (defined as head) is measured in feet of water or pounds per square inch (psi), **1 psi = 2.31 feet of water.** This relationship is due to the unit weight of water as shown in the figure below:



The weight of water at 1 ft. depth (1 ft. head) = 62.4 lbs/ft^3 = 62.4 lbs/144 in^2 = .433 lbs/in^2

Therefore, if the water depth were 2.31 ft., the pressure or head would be 1 psi.

$$\frac{2.31 \text{ ft.}}{.433 \text{ psi/ft}} = 1 \text{ psi.}$$

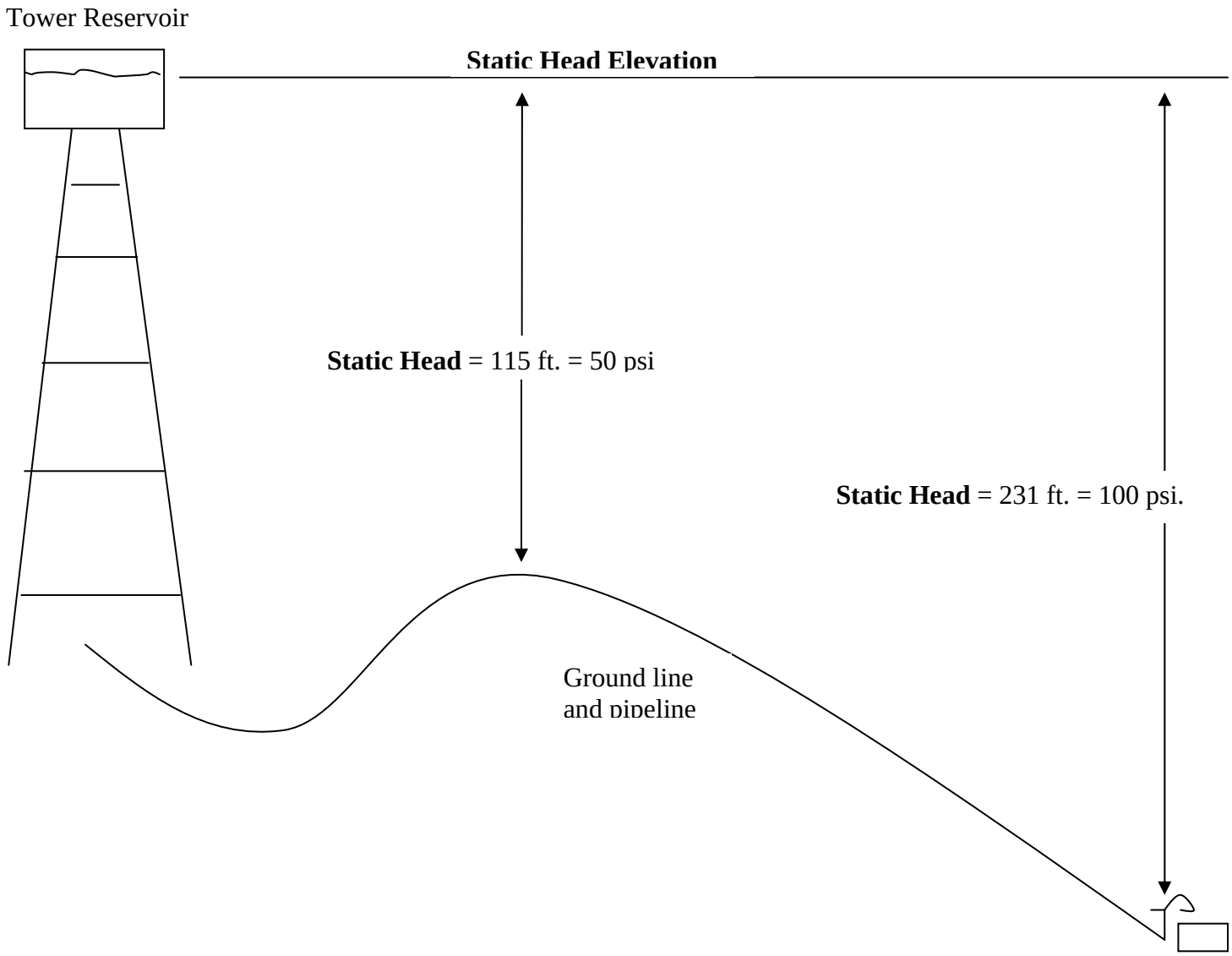
Examples:
(40 psi.) (2.31 ft./psi) = 92.4 ft. head

(200 ft.) / (2.31 ft./psi) = 86.6 psi

(200 ft.) (.433 psi/ft.) = 86.6 psi

Static Head – Represents the vertical distance from a specific point to the water surface when no water is moving (the static condition).

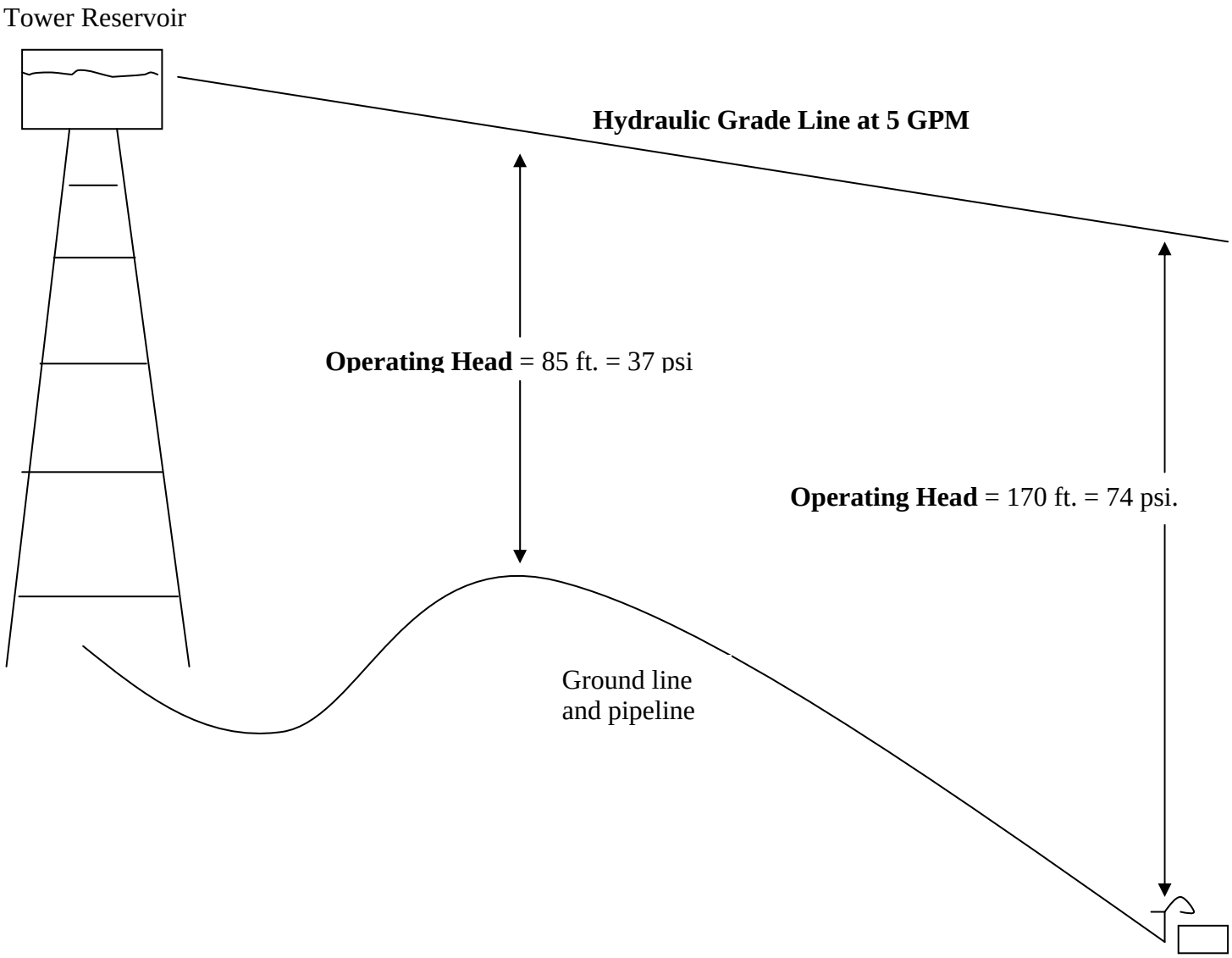
- Static head can be visualized as the elevation to which water could rise with all outlets closed.
- Static head in feet divided by 2.31 = static pressure in psi.



- A pressure gauge at the hydrant would read 100 psi.
- Water in a tube or hose at the hydrant would rise 231 feet to the level of water in the reservoir
- The tower could be replaced with a pump which would supply the necessary elevation head artificially to provide exactly the same condition.

Hydraulic Grade Line – Represents the surface or profile of water flowing in a pipe. The hydraulic grade

- The hydraulic grade line represents the level water would rise in a tube connected to the pipe under design flow condition.
- Operating Head divided by 2.31 = hydraulic pressure in psi.

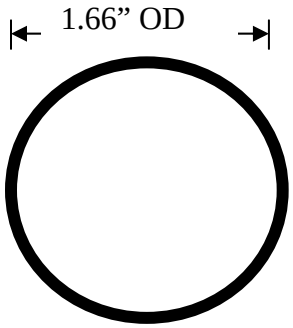


- A pressure gauge at the hydrant would read 74 psi (if flow is limited to 5 gpm).
- A pressure gauge at the hydrant would read near zero if hydrant where wide open (unrestricted).
- The loss of head (the **hydraulic grade line** drops in elevation with increasing distance from the reservoir) is due to friction loss in the pipe.
- The tower could be replaced with a pump which would supply the necessary elevation head artificially to provide exactly the same condition.

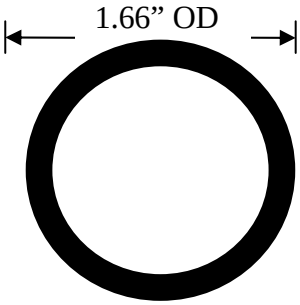
6.3 Relationship between Friction Loss, Pipe Diameter, and Pipe Length

Standard Dimension Ratio (SDR)

The ratio of the specified average outside diameter to the specified minimum wall thickness. This ratio is common to all pipe sizes of a specific standard dimension ratio series.



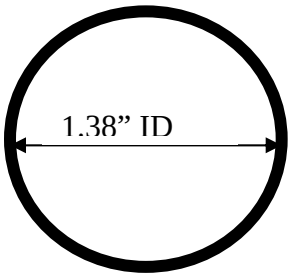
1¼” 160 PSI PVC
OD/Wall Thickness = 1.66/.064 = SDR 26
Friction Loss @ 10 gpm = .8651 ft/100 ft



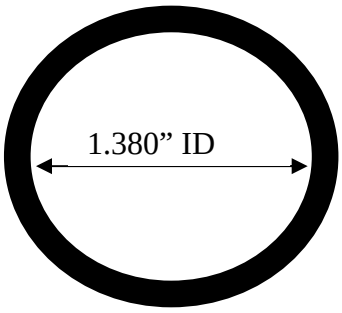
1¼” 315 PSI PVC
OD/Wall Thickness = 1.66/.123 = SDR 13.5
Friction Loss @ 10 GPM = 1.28 ft./100 ft.

For OD controlled Pipes, as pressure rating increases

- OD is constant
- Wall thickness increases
- ID decreases
- Friction loss increases



1¼” 100 PSI PE PIPE
ID/Wall Thickness = 1.38”/.120” = SDR 11.5
Friction Loss @ 10 gpm = 1.53 ft./100 ft.



1¼” 200 PSI PE PIPE
ID/Wall Thickness = 1.38”/.26” = SDR 5.3
Friction Loss @ 10 GPM = 1.53 ft./100 ft.

For ID controlled Pipes, as pressure rating increases

- ID is constant
- Wall thickness increases
- OD increases
- Friction loss is constant

Friction loss is typically expressed in terms of feet of friction loss per 100 feet of pipe (ft/100 ft.). As the flow increases for a particular size line, friction loss increases. If friction loss reduces operating head to an unacceptable level, then pipe size must be increased **or** pressure must be increased at the source. Friction loss tables are included in Appendix B for PVC, PE, and STEEL. There is no set friction loss value at which a pipe size should be increased or decreased but typical friction losses would normally range between .15 ft./100 ft. and 1.0 ft./100 ft. Designs outside this range of friction losses may not be the most economical or the most practical but may still be an acceptable design. The total friction loss on a pipeline is directly proportional to the length and on very long pipelines friction loss is a determining factor in the operating pressures necessary to provide design flows.

The tables in Appendix B are based on friction loss by the Hazen-Williams formula. The form of the equation used is:

$$f = .2083(100/C)^{1.852} \frac{q^{1.852}}{d_i^{4.8655}}$$

C = Hazen-Williams friction loss factor
q = Flow rate in gallons per minute
d_i = Pipe inside diameter (in inches)
f = friction loss, ft./100 ft.

The “C” factor used for PE and PVC plastic pipe is 150. Most research data shows that new PVC or PE has a “C” valve of 150. South Dakota does not account for increasing resistance as the pipe ages. Any losses considered significant such as an above average quantity of couplers, considerable “fall off pressure” for pressure regulators, etc., should be taken into consideration.

It is very important that the correct inside diameter be used. The inside diameter will vary depending on the type of pipe or tubing used. Other forms of the Hazen-Williams Formula are:

Velocity Flow	**Flow**	
$V= 1.318\ CR^{0.63}\ S^{0.54}$	$Q= 16.66\ CR^{2.63}\ S^{0.54}$	$q=7427\ CR^{2.63}\ S^{0.54}$
$V= 0.550\ CD^{0.63}\ S^{0.}$	$Q= 0.432\ CD^{2.63}\ S^{0.54}$	$q=193.9\ CD^{2.63}\ S^{0.54}$
$V= 0.115\ Cd^{0.63}\ S^{0.54}$	$Q=0.000627\ Cd^{2.63}\ S^{0.54}$	$q=0.281\ Cd^{2.63}\ S^{0.54}$

HEAD LOSS

$$HL = 0.2083(100/C)^{1.852}\ \frac{q^{1.852}}{d_i^{4.8655}}\ (L/100)$$

Units

HL = Head Loss in feet
C = Flow Coefficient
R = Hydraulic Radius in feet
S = Slope in feet per foot
D = Inside Diameter in **feet**
d_i = Inside Diameter in **inches**
q = Flow Rate in gallons per minute
Q = Flow Rate in cubic feet per second
f = friction loss, ft/100 ft.
L = length of pipeline

6.4 Hydraulic Design

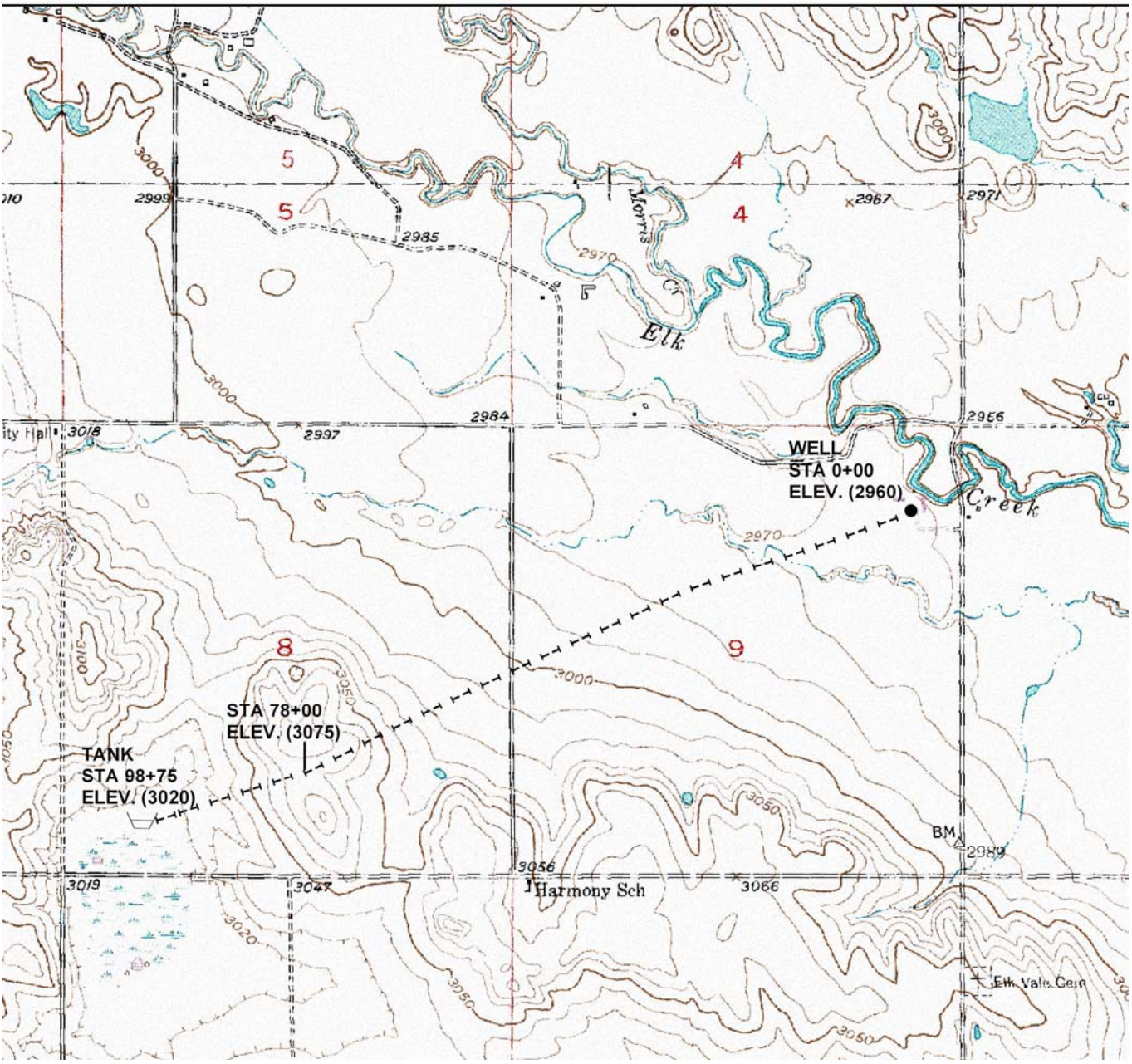
The starting point for any water system design after determining the route and design flow is to size the lines and determine operating pressures (hydraulic design).

A profile of ground elevations along the pipeline route can be a valuable tool for visualizing how the elevation extremes along the line affect the operating pressures and the entire design. Plotting a ground line profile and the associated hydraulic grade lines and static head elevations can be extremely beneficial for inexperienced designers to clearly understand the results of a computer design.

Standard NRCS design procedure for water systems is to utilize USGS 7½ minute quadrangle data for ground elevation and distance (stationing) information. This would include hard copies of USGS maps, digital raster graphs (DRG), digital elevation models (DEM), or commercially available topographic software that utilizes USGS data. Actual survey data obtained in the field is rarely used or needed in water system design except for very small gravity flow systems where relatively minor elevation differences are critical, such as for spring developments.

The design of the system starts with stations and elevations of key points along the pipeline length such as the water source, outlet locations, flow volume changes, undulating highs and lows, pipeline tees, etc. Figure 6.1 illustrates the elevation and station information for a small pressure system.

Figure 6.1
Plan View of Proposed Pipeline Route (Example)



The topographic map and station/elevation data can then be used to determine if any points along the pipeline will be controlling factors (**control points)** which directly affect the pressures required to operate the system. The plan view (figure 6.1) shows the high point on the system at station 78+00 and at elevation 3075. If this is a new system, station 78+00 would be a definite **control point** since the system must have adequate pressure to deliver water over this high point which is 115 feet above the well (equal to 49.8 psi). If the pipeline is connecting to an existing system with pressure switch settings of 100/130 (100 psi. pump on, 130 psi pump off) then the minimum pressure at the well is more than adequate to deliver the design flow with adequate pressure at the high point, and station 78+00 would not be a control point (the controlling factor would actually be the elevations of Static Head and Hydraulic Grade Line developed by the existing pressure switch setting).

Figure 6.2 represents a plot of a profile along the pipeline route with Static Head Elevation and Hydraulic Grade Line @ 8 gpm plotted also. The friction loss and pressures were calculated using the SD Excel spreadsheet developed for pipeline design (Figure 6.3). The actual design procedure for this example assuming a new system is by trial and error, entering a hydraulic pressure at station 0+00 (well) and then checking the calculated hydraulic pressure at sta. 78+00 to determine if the system will have adequate pressure at the high point for a design flow of 8 gpm. In this example, the 9 psi hydraulic pressure is adequate and the pressure setting of 70/100 is selected at the well.

Figure 6.2
Profile Along Centerline of Pipeline (Example)

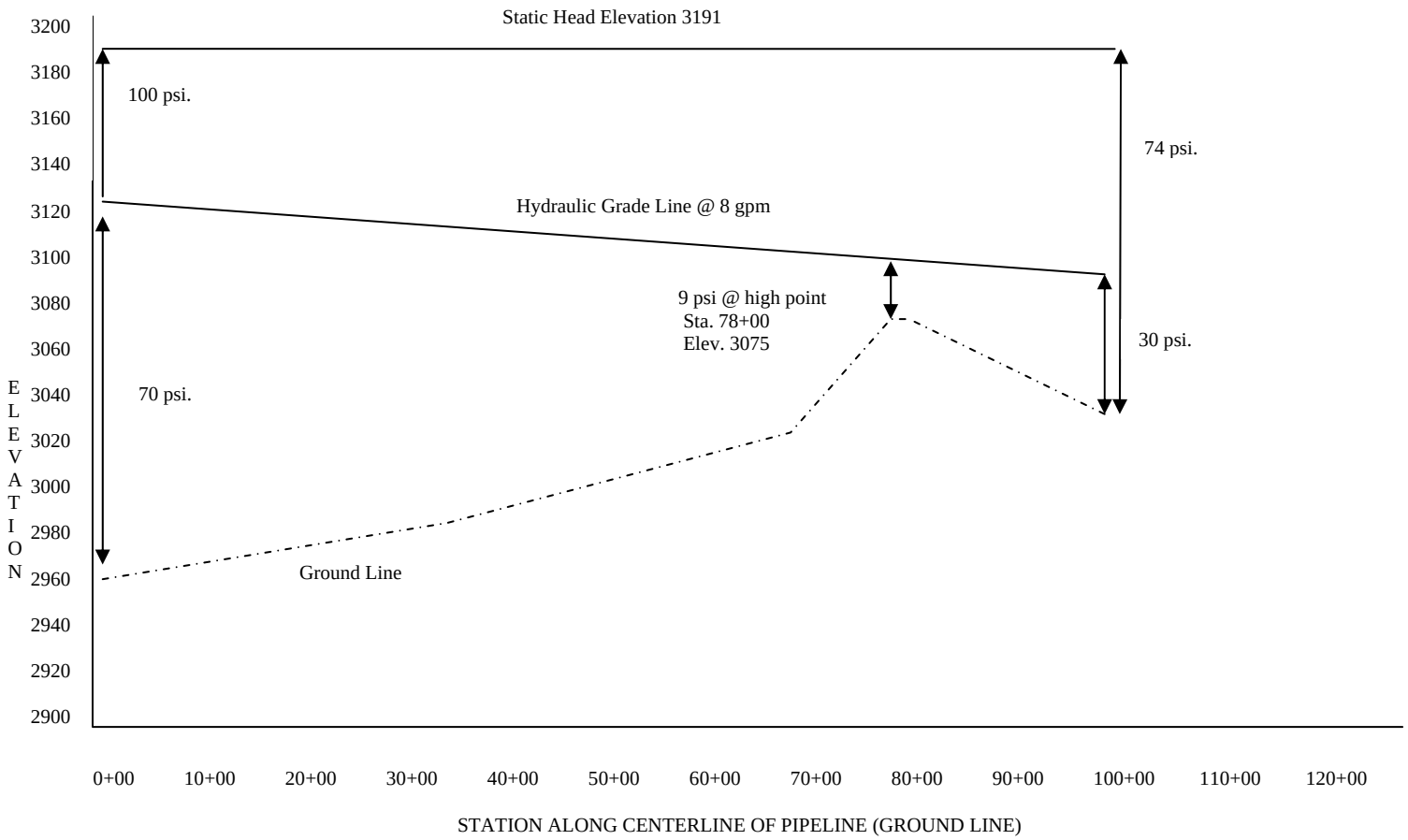


Figure 6.3
Pipeline Design Calculations

Pipeline Design Calculations

Project:		Simple Sample						Sec.	36	T.	00 N	R.	00 E	Any County		County
Designer:		Most Anyone				Date:	1/9/2008	Checker:				Date:			Sheet	1
Line No.	Station	Appurts.	Total AU's	Ground Elev.	Flow gpm	Pipe Size	Material & SDR #	H_F/100 ft	Length	H_F	HGL Elev.	Hydr. Press. psi	SGL Elev.	Static Press. psi	Water Temp (F)	Max Press. Allowed for Pipe (psi)
	0+00	Well	250	2960							3122	70	3191	100	73	144
					8	1 1/2	PVC SDR 21	0.326	7800	25.40						
	78+00	high point		3075							3096	9	3191	50	73	144
					8	1 1/2	PVC SDR 21	0.326	2075	6.76	INCREASE Hydraulic Pressure					
	98+75	Tank		3020							3090	30	3191	74	73	144

- Most water systems have fluctuating pressures at the water source resulting from pumps cycling on and off, from water levels in reservoirs or water towers raising and lowering, or from pressure tanks emptying. In SD, the usual practice is to provide adequate pressure at the source to deliver the design flow at the lowest pressure occurring during normal operation.

  In this example, the design flow of 8 gpm will be possible at the lowest point in the operating pressure range, which is the cut-in pressure of 70 psi when the pump turns on.

- The HGL should clear the ground line by a certain clearance head (the distance the HGL is above natural ground line) of 15 to 25 feet.

  In this example, the clearance head is 21 feet or approximately 9 psi. The spreadsheet will give an "increase hydraulic pressure" warning if this distance is less than 23.1 feet (10 psi.). The system could actually work if the hydraulic grade line is barely above the pipe which is approximately five feet below the ground line. The 10 psi provides a "cushion" or a "margin for error" to account for any discrepancy between the USGS map and the actual ground elevation. The 10 psi clearance head also provides for adequate pressure to overcome minor losses in the plumbing, such as the pump drop pipe (in the well), the valves in the well pit, pressure regulators, tees, hydrants, etc. Usual design practice, in SD, is to not calculate minor losses, but rather to provide adequate clearance head at the control point.

- The pressure differential between the cut-in pressure (pump on) and cut-out pressure (pump off) is normally 20-30 psi. A complete description of pressure differentials and pressure tanks is contained in the chapter on System Appurtenances.

- The greatest pressure at any point along a pipeline occurs when the flow stops in the pipeline and the pump runs the pressure up to cut-out pressure and shuts off. Static pressure everywhere in the pipeline is then computed from cut-out (pump off) pressure.

- In this example the static elevation is 231 feet above the ground elevation at the well. The static elevation is 2,960 + (100 psi x 2.31) = elevation 3191

- The plot of the profile and hydraulic calculations project the minimum operating conditions. In actual operation the pipeline flow will be greater than eight gpm during all operating times except just before the pump turns on. When the pressure at the well is above 70 psi, the hydraulic grade line will be steeper, and; therefore, the flow will be greater. The maximum flow obtainable on this system would be limited by the pump

Figure 6.4 provides additional breakdown of the actual calculations performed by the spreadsheet which would be representative of manual hydraulic calculations for the above example. It is important to understand the methodology involved in any design software results (in this case, the Excel spreadsheet) since blind faith in the software results, without fully considering whether the result seems correct, is a recipe for an eventual design failure. Data can be improperly entered, spreadsheet formulas can be inadvertently altered, and other unforeseen situations can occur (calculated elevations rounded to the nearest foot).

Figure 6.4
Pipeline Design Calculations

Total friction loss between well and high point (7,800)(.326 ft/100 ft)= 25.4 ft

HGL @ 0+00 = El 2960 + 2.31(70 psi) = El 3121.7
HGL @ 78+00 = El 3121.7 - 25.4 = El 3096.3
HGL @ 98+75 = El 3096.3 – 6.76 = El 3089.5

Distance between pipeline stations 7,800 – 0 = 7,800 ft.

Static Head Elevation (also called SGL)
SGL @ 0+00 = El 2960 + 2.31(100 psi) = El 3191
Static Pressures
78+00 = (El 3191 – El 3075)/2.31 = 50.2 psi
98+75 = (El 3191 – El 3020)/2.31 = 74.0 psi

Friction loss (H_f) in ft/100 ft. See friction loss tables in Appendix B pg. B-1

Pipeline Design Calculations

Project:	Simple Sample							Sec	36	T.	00 N	R.	00 E	Any County		County
Designer:		Most Anyone				Date:	1/9/2008	Checker:				Date:			Sheet	1
Line No.	Station	Appurts.	Total AU's	Ground Elev.	Flow gpm	Pipe Size	Material & SDR #	H_F/100 ft	Length	H_F	HGL Elev.	Hydr. Press. psi	SGL Elev.	Static Press psi	Water Temp (F)	Max Press. Allowed for Pipe (psi)
	0+00	Well	250	2960							3122	70	3191	100	73	144
					8	1 1/2	PVC SDR 21	0.326	7800	25.40						
	78+00	high point		3075							3096	9	3191	50	73	144
					8	1 1/2	PVC SDR 21	0.326	2075	6.76	INCREASE Hydraulic Pressure					
	98+75	Tank		3020							3090	30	3191	74	73	144

Manual calculations for this example would use the control point as the basis for calculating the pressure required at the well (as opposed to the trial and error process with use of the spreadsheet). An example using manual calculations for the pipeline design is as follows:

A pipe material and pipe size is selected based on what is commonly available. The pipe diameter and pressure rating may change based on the results of computing the hydraulic grade line and SGL. In this example, 1½" diameter SDR 21 or 200 psi PVC pipe will be used. The inside diameter of 1½" SDR 21 PVC pipe is 1.72 inches. A flow rate of 8 gpm is needed to meet the demands of the livestock. The Hazen-Williams equation is used to determine the friction loss based on a 100 foot section of pipe. Existing tables in Appendix B can also be used to obtain the pipe friction loss.

Hazen-Williams Equation $$f = 0.2083\left(\frac{100}{C}\right)^{1.852}\left(\frac{q^{1.852}}{d_i^{4.8655}}\right)$$

$$f = 0.2083\left(\frac{100}{150}\right)^{1.852}\left(\frac{8^{1.852}}{1.72^{4.8655}}\right) = 0.326\ {}^{ft}\!/_{100\ ft}$$

The source of water is a well with a submersible pump with a pressure tank. The elevation at the water source STA 0+00 is 2,960 feet. The next step is to determine the pressure switch settings needed at the well in order to move water over the control point. In this example, the control point is a hill at STA 78+00 and at an elevation of 3,075 feet. The friction loss at STA 78+00 can be calculated using 0.326 ft. /100 ft.

$$f_{78+00} = \left(0.326\ {}^{ft}\!/_{100\ ft}\right)\left(\frac{7800\ ft}{100\ ft}\right) = 25.45\ ft\ .$$

It is good practice to add 15feet to 25 feet of clearance head above the ground. In this example, 20 feet will be used.

The elevation of the hydraulic grade line (HGL) at STA 0+00 would be:

$$\frac{Elevation\ of\ Control\ Point + f_{control\ point} + Clearence\ Head - Elevation\ of\ Well}{2.31\ {}^{ft}\!/_{psi}} = Kickon\ Setting$$

$$Kickon\ Setting = \frac{3075\ ft + 25.45\ ft + 20\ ft - 2960\ ft}{2.31\ {}^{ft}\!/_{psi}} = 69.4\ psi$$

The pressure switch setting is rounded up and the pressure switch would need to be 70 psi to turn on the pump. A 30 psi differential will be used, so 100 psi kickoff setting would be used to turn the pump off.

$$HGL_{0+00} = EL_{0+00} + Kickon\ Pressure\left(2.31\ {}^{ft}\!/_{psi}\right)$$

$$HGL_{0+00} = 2960\ ft + 70\ psi\left(2.31\ {}^{ft}\!/_{psi}\right) = 3121.7\ ft$$

The static head elevation or SGL uses the kickoff pressure and in this example it would be 100 psi.

$$SGL = EL_{0+00} + Kickoff\ Setting\left(2.31\ {}^{ft}\!/_{psi}\right) \quad SGL = 2960\ ft + 100\ psi\left(2.31\ {}^{ft}\!/_{psi}\right) = 3191\ ft$$

The HGL, the hydraulic pressure, and the static pressure at the high point (STA 78+00) are:

$$HGL_{78+00} = HGL_{0+00} - f_{78+00} = 3121.7\ ft - 25.45\ ft = 3096.3\ ft$$

$$Hydraulic\ Pressure_{78+00} = \frac{HGL_{78+00} - EL_{78+00}}{2.31\ ft/psi} = \frac{3096.3\ ft - 3075\ ft}{2.31\ ft/psi} = 9\ psi$$

$$Static\ Pressure_{78+00} = \frac{SGL - EL_{78+00}}{2.31\ ft/psi} = \frac{3191\ ft - 3075\ ft}{2.31\ ft/psi} = 50\ psi$$

The pressure at the low outlet should be checked to make sure that the pipe pressure rating is not exceeded or there is too much pressure for the hydrant or other valves at the tank. The static pressure is used because static pressure would be the most pressure the hydrant would feel. The pipeline system would feel the static pressure when no water is moving in the system (pump is off, pressure tank fully pressurized, and all valves at the tanks are closed).

The elevation of the low tank at STA 98+75 is 3020 ft.

$$SGL_{98+75} = \frac{SGL - EL_{98+75}}{2.31\ ft/psi} = \frac{3191\ ft - 3020\ ft}{2.31\ ft/psi} = 74\ psi$$

The maximum pressure on the system is 74 psi, which is below 72 percent of the rating of the SDR 21 PVC pipe (200 psi * 72 percent = 144 psi). The only other consideration is the pressure rating of the valves or hydrant at this tank.

The hydraulic pressure at STA 98+75 can also be calculated. This would be the minimum pressure that the tank would have at the design flow rate. There would be 30 psi hydraulic pressure, which would be adequate pressure for a hydrant or tank.

$$f_{98+75} = \left(0.326\ ft/100\ ft\right)\left(\frac{9875\ ft}{100\ ft}\right) = 32.2\ ft$$

$$HGL_{98+75} = HGL_{0+00} - f_{98+75} \qquad HGL_{98+75} = 3121.7\ ft + -32.2\ ft = 3089.5\ ft$$

$$Hydraulic\ Pressure_{98+75} = \frac{HGL_{98+75} - EL_{78+00}}{2.31\ ft/psi} = \frac{3089.5\ ft - 3020\ ft}{2.31\ ft/psi} = 30\ psi$$

CHAPTER 7

SYSTEM COMPONENTS

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SYSTEM COMPONENTS

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CHAPTER 7

SYSTEM COMPONENTS

7.1 General

This chapter provides a description of typical components used in the operation and control of water systems. A general discussion of methods of controlling pumps is contained in Chapter 4 and usually the type of control selected is a decision which must be made early in the design process, and determines system operating pressures and the type of components necessary to complete the water system design.

7.2 Pumps

7.2.1 General

The type of water system generally dictates the type of pump which can be used. Systems utilizing a deep well, in-line booster, solar system, or windmill, for example, have a specific type of pump which must be used. Other systems such as those utilizing shallow wells or cisterns may have a number of different pump options to choose from. The following pump descriptions do not cover all available pump types but rather those pumps commonly used in water systems in SD.

7.2.2 Pump Capacity

Determining the pump capacity for a system will depend on the specific situation and a couple different methods can be used. Each of the following methods is similar yet different:

- Keep in mind any possible future expansion needs.
- The pump should have some excess capacity above the minimum system needs, in other words, **the pump should not have to run for 24 hours to provide the daily needs.**
- A pump which is too large can cause excessive cycling which will shorten pump life.
- Pump capacity should not exceed the flow rate or yield of the water source to limit cycling of the pump due to low flow or no flow caused by low water levels at the source.
- When specifying a pump, be specific concerning gpm and TDH. Simply calling for a three-quarter hp pump is inadequate. There are many different three-quarter hp pumps, some which can pump large quantities of water at very low heads and some which can pump only a small quantity of water at very high heads. You will not get the most efficient pump for your system unless you require exact specifications.

Method #1
Design the pump capacity at approximately **one and one-half times the pipeline capacity**. This method may be more suitable for small systems where the pipeline capacity is based on a practical minimum flow to satisfy normal expectations. Example: system serves 100 cattle, minimum pipeline design capacity would be 2.0 gal./min./100hd. (28.8 gal./hd./day) = 2 gpm. Design pipeline for five gpm which is probably the minimum an operator would expect from a water system. **Specify pump capacity to be (1.5)(5 gpm) = 7.5 gpm**

Method #2
Design the pump capacity to **supply the daily system needs in approximately 12-16 hours**. This method is suitable for most systems and preferred for the larger systems. Example: system serves 500 hd. cattle @ 30 gpd and 2 houses drawing water with a booster pump from a cistern each requiring 360 gal/day. Pipeline design capacity is 11 gpm. Daily water requirements are (500 hd.)(30 gpd) + (2 houses)(360 gpd) = 15,720 gal. **Specify pump capacity to be (15,720 gal.)/(16 hr.)(60 min./hr.) = 16.3 gpm**

Method #3
Design the pump capacity to just **exceed the largest fixture requirement**. This method is suitable on systems were the water requirements for houses on the system overshadow the livestock use. Example: system serves 100 cattle @ 20 gpd and 1 house supplied directly from the well pump. Pipeline design capacity is 12 gpm (10 gpm for house plus 2 gpm for livestock). The house requires 10 gpm to allow for simultaneous uses such as the shower to be used while the washer is operating; however, these uses occur for very short periods and the total daily use for the home is only expected to be 360 gpd. **Specify the pump capacity to be 12 gpm**. The extra capacity available during off peak hours for the household will be available the balance of the day for livestock use and will be more than adequate.

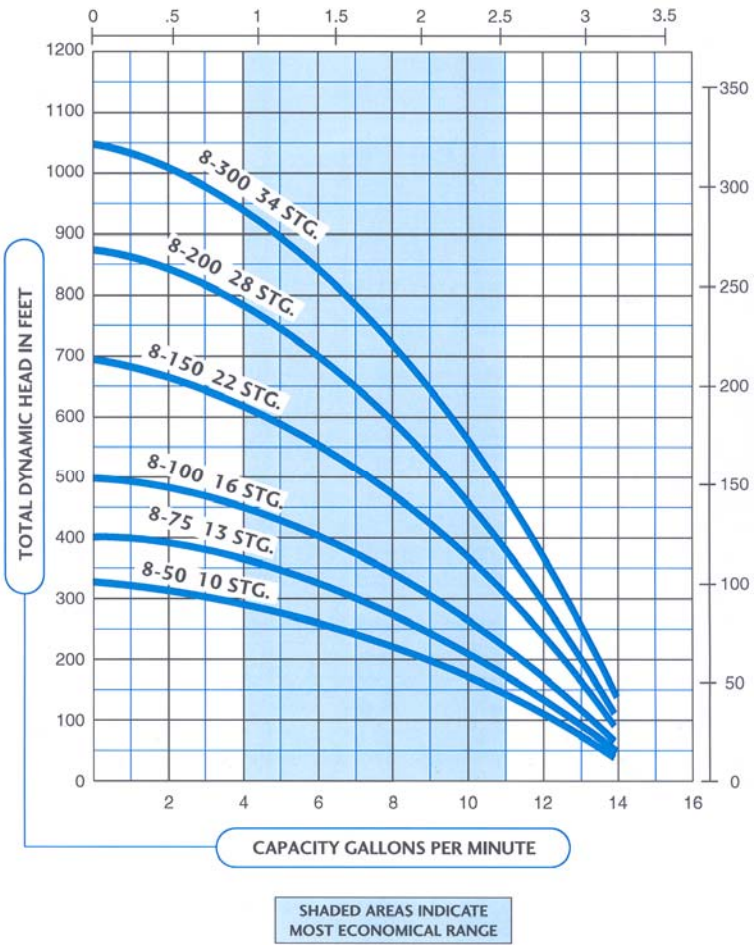
7.2.3 Submersible Pumps

Submersible pumps are one of the most versatile pumps available for general water system use. This versatility is due to the multiple stage (multiple impeller) pump configuration of a submersible pump. An individual impeller is designed to pump a certain volume of fluid (i.e., 10 gpm) at a certain head (i.e., 25 ft.). These impellers can then be stacked atop one another to form a multiple stage pump capable of pumping the design volume (10 gpm) to a higher head (250 ft. for a 10-stage pump). Each subsequent impeller adds to the head delivered by the preceding impeller. This multiple stage configuration allows for submersible pumps to be manufactured in a wide variety of volumes and heads by varying the number of stages, thus providing a range of pumps to fit almost any need.

Submersible pumps can be used in almost any submerged installation where the pump is installed below the water surface. Submersibles are manufactured in nominal diameters of 4”, 6”, 8”, and 10” specifically to fit small diameter well casings of the same nominal diameter. The actual pump diameters are one-eighth inch to one-half inch less than nominal and which allow adequate space around the pump circumference for water flow to the pump inlet. The water flow between the pump motor and casing also provides adequate cooling for the motor.

When selecting a pump, the best resource available is the Web site for the particular manufacturer or brand commonly used by local installers. To find a suitable pump for the nontypical installation or application, the designer may need to investigate pumps available from all domestic manufacturers. The nontypical installation will rarely work satisfactorily with an “off the shelf” pump carried in-stock by a local supplier. For these specialized applications, it is important to convey the required specifications and purpose to the operator to insure the correct pump gets installed. Figure 7.1 is an example of a typical pump curve for a small submersible pump.

Figure 7.1
Typical Submersible Pump Curve

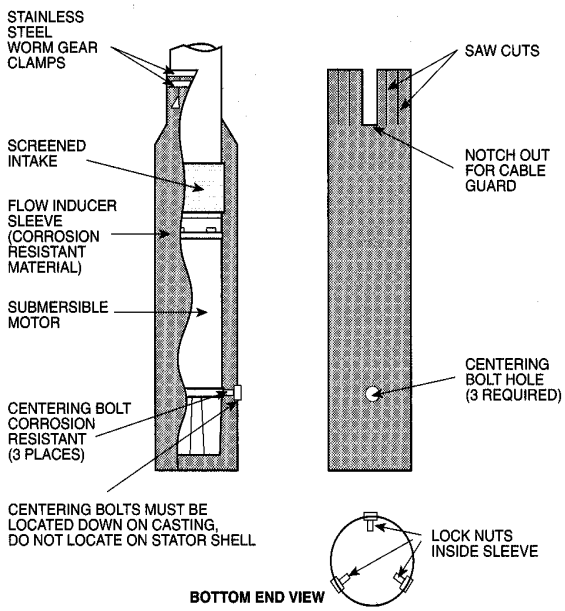


Pumps generally all share a common characteristic relating to TDH and volume (gpm). As the pressure increases (TDH), the volume pumped decreases. Figure 7.1 plots the pump curve for six different pumps rated at eight gpm. The pumps with higher TDH capabilities have a larger number of stages (impellers) and larger horsepower motors. The last digits of a pump model number usually indicate the stages (the 8-200 28 has 28 stages) and other digits may indicate horsepower (200 indicates 2 hp). The manufacturer designates this as an eight gpm pump and eight gpm falls close to the middle of the recommended operating range (shaded area). The operating characteristics of these pumps will fall somewhere along the respective line for each pump (not close to the line, but on the line). **A pump should be selected so the design operating pressures and volumes will correspond with the recommended operating range for the pump**. If the pump is operating outside the recommended range, it will still pump the volume as indicated by the curve, but the pump will not be operating in the most efficient range (power consumed vs. output) and the pump will be less energy efficient. The capacity of all pumps will decrease as TDH increases until reaching the **shut-off head** where the volume is "0." The shut-off head for the 8-200 28 STG for example is 875 ft. TDH.

Assuming a pump specification of 8 gpm @ 450 ft. TDH, enter the pump curve (Figure 7.1) on the left vertical axis at the 450 ft. TDH and read across to the pump curve nearest to the intersection with the 8 gpm rate. The pump selected would be the 8-150 22-stage pump producing 8.5 gpm @ 450 ft. TDH.

Flow Inducer Sleeves are recommended and often required by the manufacturer for pumps installed in an open body of water (i.e., a cistern, large dia. well, or pond), for pumps installed in wells with casings larger than the nominal pump diameter and in hot water applications. Flow sleeves force the incoming water to flow past the motor with velocities adequate to provide the necessary cooling and function as a well casing of the same nominal diameter as the pump. Figure 7.2 shows typical flow inducer sleeve construction. Water temperatures less than 86^0F require flow rates of .25 ft./sec. past the motor, and temperatures over 86^0F require flow rates of 3 ft./sec. Additionally, high water temperatures over 113^0F require a heat factor multiplier to be used in determining motor horsepower requirements, which may increase the horsepower size (usually to the next larger size) for the pump selected. Electric motors generate heat proportional to the load applied; therefore, by increasing the motor horsepower on a pump unit, the motor is under a smaller load, less heat is generated, requiring less cooling. Franklin Electric, a supplier of motors for many of the domestic pump brands, has literature available on hot water applications for submersible pumps**. Flow Inducer Sleeves are required for any submersible pump used in a horizontal application such as laying on the bottom of a cistern or reservoir.**

Figure 7.2
Flow Inducer Sleeve



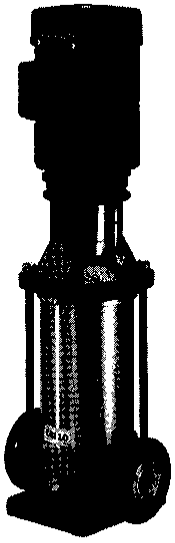
Pump motors of 1 hp or less are usually available only in single phase 115/230V; midrange units 1½ hp to 5 hp, usually are available in either single phase or 3-phase power motors; and 7½ hp and over are usually only available in 3-phase power. If 3-phase power is not available at the site, then a phase converter will be required for units 7½ hp and over.

It is recommended that one or more **check valves** always be used on submersible pump installations. If the pump does not have a built-in check valve, the first check should be installed within 25 feet of the pump and then on deep installations it is recommended a check be installed every 200 feet. Spring loaded (quick closing) check valves should always be used rather than swing type checks which can have some reversal of flow after the pump stops, resulting in water hammer and hydraulic shock. Check valves also prevent excessive thrust bearing wear, motor backspin, impeller upthrust, and damaging hydraulic shock resulting from high velocity water filling a pipe void.

Drop pipes are the connection between a submersible pump installed in a well and the plumbing at the surface. Size is usually determined by the same nominal size as the discharge fitting on the pump. Drop pipe material may be either PE pipe or SCH 40 steel (usually galvanized). If PE pipe is used as safety cable and torque arrestors are recommended. The safety cable provides a means to retrieve the pump if fittings pull apart and the torque arrestor reduces the twisting motion and resulting fatigue on the piping upon pump start-up. Steel pipe is recommended on pumps over one hp.

7.2.4 Variable Speed Constant Pressure Pumps

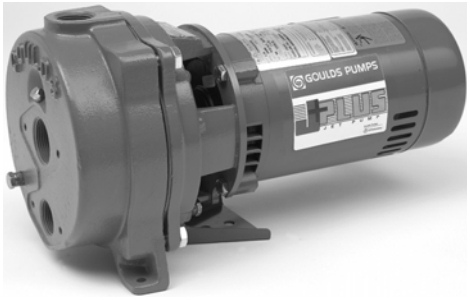
Variable speed constant pressure pumps are available in submersible units for use in wells or as multi-stage centrifugal pumps used as in-line booster pumps. A constant pressure pump uses a variable speed motor and special electronic control (transducer) which functions as pressure monitoring device. The transducer can be set to maintain a constant pressure on the downstream side of the pump in the same location occupied by a pressure switch in a conventional pressure system. The variable speed motor speeds or slows to maintain a constant pressure while delivering the flow necessary to satisfy the demand from the system.



The variable speed pump eliminates the need for large pressure tanks to control pump cycling and provide uniform pressure. Small pressure tanks of approximately two gallons are used to steady pressures monitored by the transducer. These small pressure tanks are available up to 200 psi pressure rating (any variance from the size recommended by the manufacturer should only be with guidance from the manufacturer's technical specialists).

Variable speed pumps, particularly the multi-stage centrifugal, are typically not carried as a stock item by suppliers, and; therefore, a disadvantage of this type pump is the longer down time if replacement is needed. Initial cost for this type system is comparable to a conventional automatic pressure system and may even be less, since if the system is operating at pressures over 125 psi, the expense of large high pressure tanks is eliminated. This type of pump provides an economically feasible means of providing an automatically controlled pressure system for those projects operating at pressures over 125 psi.

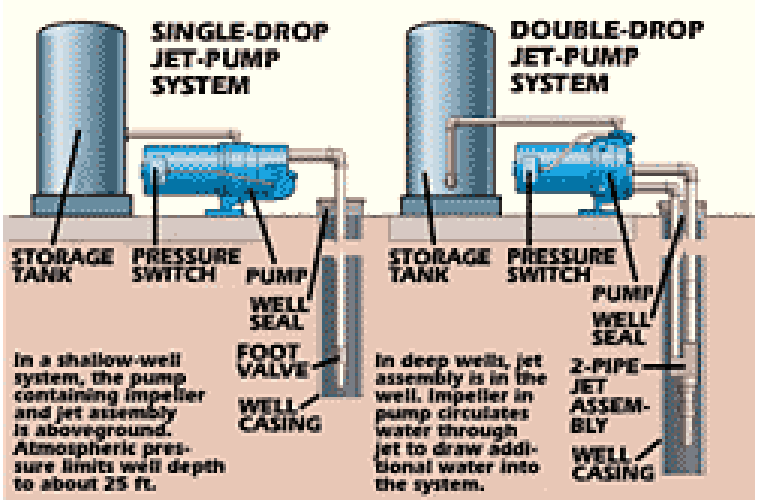
7.2.5 Jet Pumps



Jet pumps are mounted above the well, either in the home or in a well house, and draw the water up from the well through suction. Because suction is involved, atmospheric pressure is what's really doing the work. A vacuum is created and once the vacuum is there, the weight of the air, or atmospheric pressure, pushes the water up from the well. Consequently, the height that you can lift the water with a **shallow-well jet pump** is limited by the atmospheric pressure (weight of the air). While air pressure varies with elevation, it's common to limit the depth of a jet-pump-operated shallow well to about 25 ft.

Jet pumps create suction in a rather novel way. The pump is powered by an electric motor that drives an impeller or centrifugal pump. The impeller moves water, called drive water, from the well through a narrow orifice, or **jet**, mounted in the housing in front of the impeller. This constriction at the jet causes the speed of the moving water to increase, much like the nozzle on a garden hose. As the water leaves the jet, a partial vacuum is created that draws additional water

from the well. Directly behind the jet is a venturi tube that increases in diameter. Its function is to slow down the water and increase the pressure. The pumped water–new water that's drawn from the well by the suction at the jet–then combines with the drive water to discharge into the plumbing system at high pressure. Because shallow-well jet pumps use water to draw water, they generally need to be primed–filled with water–before they'll work. To keep water in the pump and plumbing system from flowing back down into the well, a one-way check valve is installed in the feed line to the pump.



Deep well jet pumps can be used for wells from 25 ft. to about 200 ft. depth. Deep well jets separate the jet from the motor and impeller housing and placing the jet assembly down in the water. In a typical deep well jet-pump configuration, one pipe mounted to the impeller housing drives water down into the jet body that's located about 10 to 20 ft. below the minimum well water level. A second pipe connects the output side of the jet body back to the pump. At the jet, the increase in water velocity creates the partial **vacuum** that draws standing well water into the second pipe and then back into the pump and plumbing system. Deep well jet pumps use both the suction at the jet to bring water into the system and pressure applied by the impeller to lift the water. Like shallow well systems, a jet pump in a deep well system needs to be primed to operate. A foot valve at the bottom of the well piping prevents water from draining from the pipes and pump. Jet pumps that have two or more impellers are called multistage pumps.

Jet pumps are somewhat of a “niche” pump typically used for supplying homes. The use is limited by wells less than 200 feet. Pressure switch settings typically range from 20-50 psi and shut-off pressures for most jets are approximately 65 psi. These pressure constraints limit these pumps to a very narrow range of applications for stockwater use, but jets are a very common pump for household applications.

7.2.6 Horizontal Booster

A multi-stage, in-line horizontal booster is essentially a submersible pump-end manufactured in an integral “casing” intended for horizontal installation in a conventional booster pit. The multi-stage configuration provides versatility similar to a submersible pump for range of capacity and head, except the multi-stage booster is only available in sizes of one-third to approximately three hp.

Total dynamic head for this type of pump is calculated by **subtracting the inlet pressure** delivered to the back side of the pump **from the discharge head**. Therefore, an advantage of this type of “in-line” installation is that there is no loss of head as would be the case if the incoming flows were delivered to a cistern which then supplies a pump, and no cistern is required. To visualize the TDH for this type of in-line installation another way, consider that the inlet pressure (head) delivered to the pump is equivalent to the height of water above a submersible installed in a well (TDH calculated from water surface).

Booster pumps installed in an "in-line" installation should be provided with "run-dry" protection to shut the pump down if flow is not available at the inlet. If the supply line delivering water to the booster pump has outlets which potentially could rob the booster pump inlet of positive pressure, flow control valves should be considered at these outlets or other measures taken to insure a dependable flow to the booster.

7.2.7 Solar Pumps *(reference University of Tennessee Agricultural Extension Service PB 1640)*

Solar power is now a very viable option for replacing traditional pumping systems such as windmills or engine generators for reasons that include less maintenance, lower cost, improved mobility, increased system availability over windmills, less noise, and no fuel transportation.

A solar-powered water pumping system is made up of two basic components. The first component is the power supply consisting of **photovoltaic (PV) panels** (Figure 7.3). The smallest element of a PV panel is the solar cell. Each solar cell has two or more specially prepared layers of semiconductor material that produce direct current (DC) electricity when exposed to light. This DC current is collected by the wiring in the panel. It is then supplied either to a DC pump, which in turn pumps water whenever the sun shines, or stored in batteries for later use by the pump. Manufacturers normally rate voltage (volts) and current (amps) output from PV panels under peak power conditions. Peak power (watts=volts x amps) is the maximum power available from the PV panel at 1,000 W/m2 solar irradiance (amount of sunshine) and a specified temperature, usually 25 C (77^0F). Typical output from a 60-watt PV panel is shown in Table 7.1 The amount of DC current produced by a PV panel is much more sensitive to light intensity striking the panel than is voltage generated. Roughly speaking, if you halve the light intensity, you halve the DC current output, but the voltage output is reduced only slightly.

Figure 7.3 Photovoltaic Panels

Table 7.1 Typical Output from a 60-Watt, 12-Volt Photovoltaic Panel

Maximum Power 60 Watts
Maximum Power Voltage 16.9 Volts
Maximum Power Current 3.55 Amps

Individual PV panels can be wired in series or parallel to obtain the required voltage or current needed to run the pump. The voltage output from panels wired in series is the sum of all the voltages from the panels. For example, the maximum voltage output from two of the 12-volt PV panels shown in Table 1 wired in series is 33.8 volts. Thus, a 24-volt DC pump requires a minimum of two, 12-volt panels wired in series. The current (amps) output from these same panels wired in series is equal to the current (amps) output from an individual panel, 3.55 amps. The voltage and current output from panels wired in parallel is the exact opposite of series-wired panels. For panels wired in parallel, the current (amps) output is the sum of all the currents (amps) from the panels and the voltage is equal to the voltage output from an individual panel.

The other major component of these systems is the pump. **Solar water pumps** are specially designed to use solar power efficiently. Conventional pumps require steady AC current that utility lines or generators supply. Solar pumps use DC current from batteries and/or PV panels. Also, they are designed to work effectively during low-light conditions, at reduced voltage,

without stalling or overheating. Although a wide range of sizes are available, most pumps used in livestock-watering applications are low volume, yielding two to four gallons of water per minute. Low-volume pumping keeps the cost of the system down by using a minimum number of solar panels and using the entire daylight period to pump water or charge batteries. Some solar pumps are fully submersible, while others are not. The use of submersible pumps eliminates potential priming and freezing problems. Most solar water pumps are designed to use solar power most efficiently and operate on 12 to 36 volts DC.

Many solar pumping systems use **positive displacement pumps** that seal water in cavities inside the pump and force it upward. Their design enables them to maintain their lift capacity all through the solar day at the slow, varying speeds that result from varying light conditions. Positive displacement pumps include piston and jack pumps, diaphragm, vane, and screw pumps.

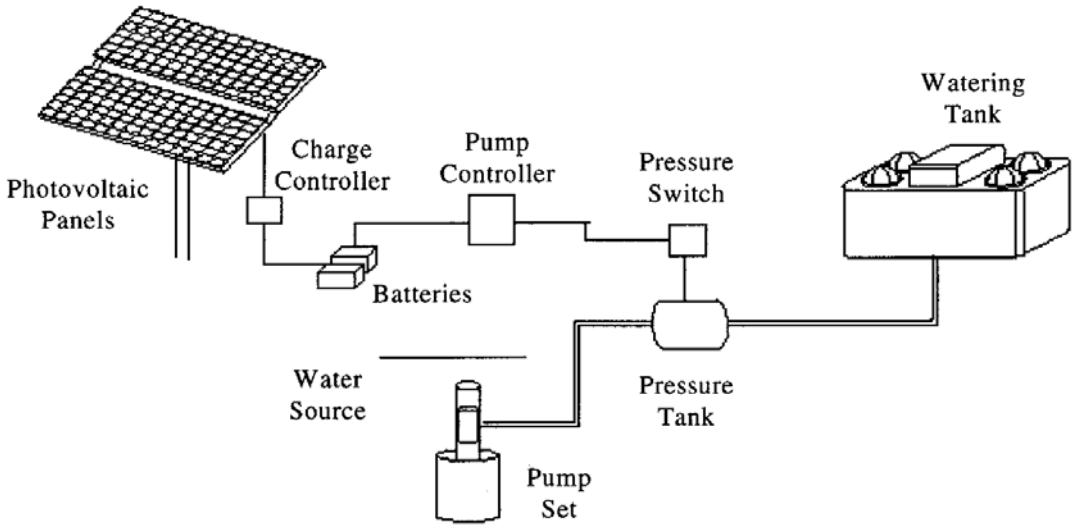
Centrifugal-type pumps that impart energy to the water using a rotating impeller are typically used for low-lift or high-volume systems. Centrifugal pumps start gradually and their flow output increases with the amount of current. For this reason, they can be tied directly to the PV array without including a battery or controls. However, because their output drops off at reduced speeds, a good match between the pump and PV array is necessary to achieve efficient operation.

Pumps, because of their mechanical nature, have certain well-defined **operating properties**. These properties vary between types of pumps, manufacturers, and models. The amount of water that a solar pumping system will deliver over a given period of time (usually measured in gpm or gph) depends upon the pressure against which the pump has to work. The system pressure is largely determined by the total vertical pumping distance (the vertical distance between the water source and the watering tank) referred to simply as elevation head. Simply put, as the vertical pumping distance increases, the amount of water pumped over a given period of time decreases. When system friction losses and discharge pressure requirements (if any) are added to elevation head, the total system head can be determined. Pump manufacturers publish information that describes how each pump will perform under varying operating conditions. The choice of pump depends on water volume needed, efficiency, price, and reliability.

There are two basic types of solar-powered **pumping configurations**, battery-coupled and direct-coupled. A variety of factors must be considered in determining the optimum system for a particular application.

Battery-coupled water pumping systems consist of PV panels, charge control regulator, batteries, pump controller, pressure switch and tank, and DC water pump (Figure 7.4). The electric current produced by PV panels during daylight hours charges the batteries, and the batteries in turn supply power to the pump anytime water is needed. The use of batteries spreads the pumping over a longer period of time by providing a steady operating voltage to the DC motor of the pump. Thus, during the night and low light periods, the system can still deliver a constant source of water for livestock.

Figure 7.4
Battery-Coupled Solar Water Pumping System



The use of batteries has its drawbacks. First, batteries can reduce the efficiency of the overall system because the operating voltage is dictated by the batteries and not the PV panels. Depending on their temperature and how well the batteries are charged, the voltage supplied by the batteries can be one to four volts lower than the voltage produced by the panels during maximum sunlight conditions. This reduced efficiency can be minimized with the use of an appropriate pump controller that boosts the battery voltage supplied to the pump.

The primary **function of a pump controller** in a battery-coupled pumping system is to boost the voltage of the battery bank to match the desired input voltage of the pump. Without a pump controller, the PV panels' operating voltage is dictated by the battery bank and is reduced from levels which are achieved by operating the pump directly off the solar panels. For example, under load, 2 PV panels wired in series produce between 30 to 34 volts, while 2 fully charged batteries wired in series produce just over 26 volts. A pump with an optimum operating voltage of 30 volts would pump more water tied directly to the PV panels than if connected to the batteries. In the case of this particular pump, a pump controller with a 24-volt input would step the voltage up to 30 volts, which would increase the amount of water pumped by the system.

Solar panels that are wired directly to a set of batteries can produce voltage levels sufficient enough to overcharge the batteries. A **charge control regulator** should be installed between the PV panels and the batteries to prevent excessive charging. Charge controllers allow the full current produced by the PV panels to flow into the batteries until they are nearly fully charged. The charge controller then lowers the current, which trickle charges the battery until fully charged. The regulator installed should be rated at the appropriate system voltage (i.e., 12-volt, 24-volt, etc.,) and the maximum number of amperes the solar panels can produce. The regulator should be installed near the batteries, in accordance with the manufacturer's instructions. This usually requires only four connections: the PV panel "POS" and "NEG" terminals and the battery "POS" and "NEG" terminals. In addition to overcharging protection, a **low-voltage or battery state-of-charge control** is required to prevent deep-discharge damage to batteries. The low-voltage relay acts as an automatic switch to disconnect the pump before the battery voltage gets too low. The relay is activated and switches when battery voltage drops to "low-voltage" threshold, and deactivates and switches back when the battery voltage rises to "reconnect"

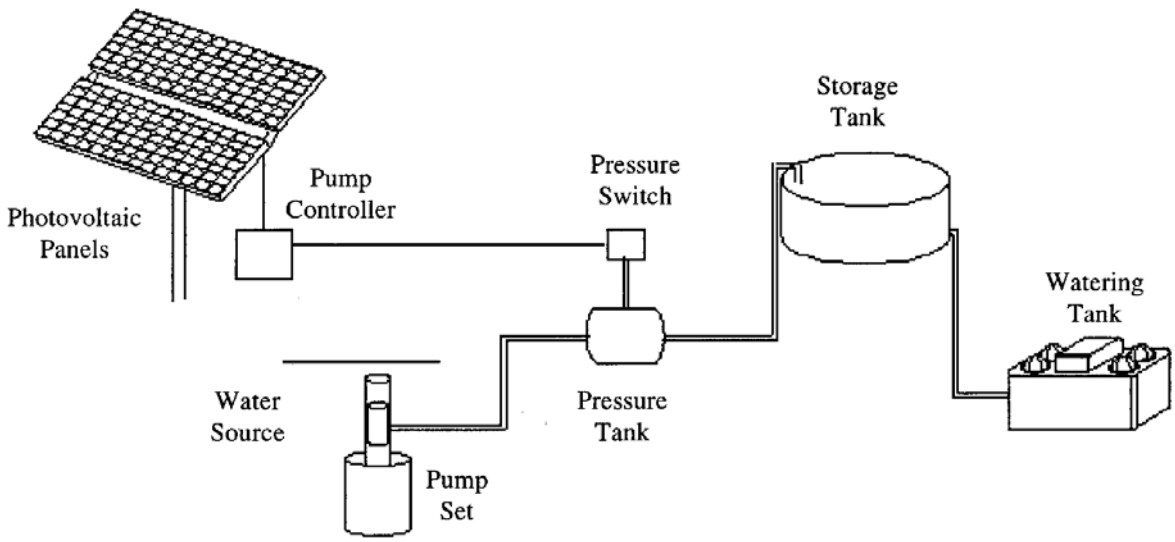
threshold. Most suppliers of PV equipment offer a charge control regulator that combines both overcharge protection and low-voltage disconnect to protect the batteries.

The most common **batteries** used in stand-alone PV systems are lead-acid batteries. The familiar deep-cycle, marine-grade battery is a good example. They are rechargeable, easily maintained, relatively inexpensive, available in a variety of sizes, and most will withstand daily discharges of up to 80 percent of their rated capacity. A new type of lead-acid battery **"gel cell"** uses an additive that turns the electrolyte into a nonspillable gel. These batteries can be mounted sideways or even upside down if needed because they are sealed. Another type of battery using **nickel cadmium (NiCd)** plates can be used in PV systems. Their initial cost is much higher than lead-acid batteries, but for some applications, the life-cycle cost may be lower. Some advantages of NiCd batteries include their long-life expectancy, low maintenance requirements, and their ability to withstand extreme conditions. Also, the NiCd battery is more tolerant to complete discharge. It is important to choose a quality battery rated at a minimum of 100-amp-hour storage capacity. **Shallow-cycle (car batteries)** should not be used for PV applications. These batteries are lighter, less expensive, and are designed to produce a high-current cold-cranking amps for a short period. The battery is then quickly recharged. Generally, shallow-cycle batteries should not be discharged more than 25 percent of the rated battery capacity. Battery banks are often used in PV systems. These banks are set up by connecting individual batteries in series or parallel to get the desired operating voltage or current. The voltage achieved in a series connection is the sum of the voltages of all the batteries, while the current (amps) achieved in series-connected batteries is equal to that of the smallest battery. For example, 2 12-volt batteries connected in series produce the equivalent voltage of a 24-volt battery with the same amount of current (amps) output as a single battery. When wiring batteries in parallel, the current (amps) is the sum of the currents (amps) from all the batteries and the voltage remains the same as that of a single battery. Batteries must be protected from the elements. Batteries should be buried below the frost line in a watertight enclosure or placed in a building where the temperature will remain above freezing. If the batteries are buried, select a well-drained location. Batteries should never be set directly on concrete surfaces, as self discharge will increase, especially if the concrete surface gets damp.

In **direct-coupled pumping systems**, electricity from the PV modules is sent directly to the pump, which in turn pumps water through a pipe to where it is needed (Figure 7.5). This system is designed to pump water only during the day. The amount of water pumped is totally dependent on the amount of sunlight hitting the PV panels and the type of pump. Because the intensity of the sun and the angle at which it strikes the PV panel changes throughout the day, the amount of water pumped by this system also changes throughout the day. For instance, during optimum sunlight periods (late morning to late afternoon on bright sunny days) the pump operates at or near 100 percent efficiency with maximum water flow.

However, during early morning and late afternoon, pump efficiency may drop by as much as 25 percent or more under these low-light conditions. During cloudy days, pump efficiency will drop off even more. To compensate for these variable flow rates, a good match between the pump and PV module(s) is necessary to achieve efficient operation of the system. Direct-coupled pumping systems are sized to store extra water on sunny days so it is available on cloudy days and at night. Water can be stored in a larger-than-needed stock tank or in a separate storage tank.

Figure 7.5
Direct-Coupled Solar Pumping System



Water-storage capacity is important in a direct-coupled pumping system. Three to seven days' storage is recommended in SD, with the larger volumes of storage providing greater dependability. Storing water in tanks has its drawbacks. Considerable evaporation losses can occur if the water is stored in open tanks, while closed tanks big enough to store several days water supply can be expensive. If the system is to be utilized in freezing weather, central storage may be the most practical method of providing the needed storage.

The **efficiency of a direct-coupled water pumping system** is sensitive to the match between the pump and the PV system. PV panels produce a fairly constant voltage as the light intensity changes throughout the day; however, amperage changes dramatically with light intensity. During low-light levels, such as early morning and late evening, the PV array may be producing 30 volts at 1 amp. The pump motor needs current to start; however, it can run on a lower voltage. A pump controller's circuitry trades voltage for current, which allows the pump to start and run at reduced output in weak-sunlight periods. Matching pump motor performance to the available sunlight with a properly sized **power controller** can increase the amount of water pumped in a day by 10 to 15 percent.

Cost is a factor that must be considered when selecting a solar pumping system. Total cost depends on many factors, such as the type of system (direct-coupled or battery-coupled), daily water requirements, pressure the pump must work against to supply the required water flow, and complexity of the water delivery system, etc. For example, low-volume solar pumping systems keep costs down, when compared to higher output solar pumping systems, by using a minimum number of solar panels and by using the entire daylight period to charge batteries or pump water. Cost for a solar pumping system can range from a low of $3,000 or less to over $15,000 depending on the volume and head requirements and the type of system. Many reputable solar equipment dealers provide technical assistance free of charge. The dealer will combine the information provided by the producer about the daily water requirements and TDH requirements with the information on solar energy available for SD, and select the solar pumping system that best fits the livestock needs and budget.

The PV panels should be **mounted facing due south** in a location where they receive maximum sunlight throughout the year. Panels facing 30 degrees away from south will lose approximately 10 to 15 percent of their power output. When choosing a site, it is essential to avoid trees or other obstructions that could cast shadows on the solar panels and reduce their output. This is especially true during the winter when the arc of the sun is lowest over the horizon. Solar panels produce the most power when they are pointed directly at the sun. The tilt angle is the angle between the plane of the solar panel surface and the ground. For maximum energy collection, the panel surface should be perpendicular to the sun. The **desired tilt angle** (angle from horizontal) can be selected using the following general rules for optimum summer or winter use: the ideal pitch of an array for year-round operation is about the same as the number of degrees of local latitude which, for SD, would be about 45^0. If the system is not used throughout the year, a lower array-tilt angle will be advantageous and lead to better system performance. For example, if the summer months have the highest water needs, an array tilt of 15° less than the latitude angle (approximately 30^0 for SD) is recommended.

Summer Use: tilt angle = 30 degrees **Winter Use: tilt angle = 45 degrees**

For installations where the solar panels are permanently mounted, they should be tilted for maximum winter output if the system is used in the winter. As a rule, if the power output is sufficient in the winter, it will be totally satisfactory during the rest of the year. Most manufacturers and distributors sell mounting hardware specifically designed for their panels. This hardware is intended for multiple applications so parameters such as wind loading have been considered in the design. Using this mounting hardware is the simplest and often the most cost effective. Locating the PV modules close to the water source is important to keep voltage loss in the system wiring to a minimum. A fence around the PV modules is required to protect the PV panels from damage due to animals. After installation, the area inside the fence must be maintained. Shading from weeds or a single tree branch can limit power output.

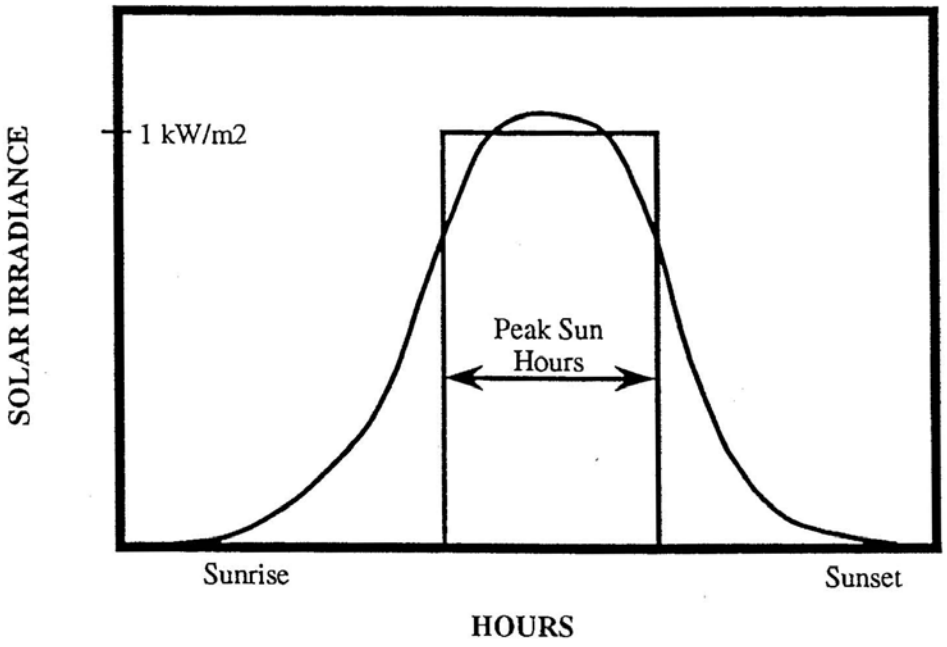
Special devices called **sun trackers** are available which automatically turn the solar panels for maximum exposure to the sun during daylight hours. These units optimize the available solar panel area. Depending on the operating conditions, increasing the number of solar panels may be more economical than a sun tracker mechanism. Also, sun trackers utilize a motorized mechanism that can be susceptible to mechanical problems resulting from dusty, windy conditions. Some of the dealers, in SD, do not recommend trackers for use in this area because of the extra maintenance problems expected in our extreme conditions.

A study done by USDA Agricultural Research Service in 1997 concluded the extra water produced by a tracker system compared to a non-tracking system did not warrant the extra cost. A major hindrance limiting the production was that the tracking system did not always follow the sun. The passive tracking system was unstable in gusty winds and flopped to one side causing it to not maintain an optimum angle with the sun.

Insolation maps of the U.S. contain contours that denote the daily amounts of solar insolation during the seasons of the year. The daily insolation is kWh/m2 is also called peak sun hours. Figure 7.6 below illustrates the definition of **Peak Sun Hours** as "the equivalent number of hours per day when solar irradiance averages 1,000 watts/m^2. For example, six peak sun hours means that the energy received during total daylight hours equals the energy that would have been received had the irradiance been 1,000 watts/m^2 for 6 hours". Or, stated another way, the total energy available from sun up to sun down would be the equivalent of 1,000 watts/m^2 for 6 hours.

Figure 7.6

Peak Sun Hours ***(reference Photovoltaic Power As A Utility Service: Guidelines For Livestock Water Pumping, SAND93-7043, Sandia National Laboratories)***



The **average daily solar insolation,** for SD, in June, ranges from 6.1 hours per day to 5.7 hours depending on the location in the state as illustrated in Figure 7.7, and for December ranges from 3.3 hours per day to 2.1 hours depending on location as illustrated in Figure 7.9. Most manufacturers base their daily water pumping volumes for solar pumps on the solar insolation available in July and; therefore, if the main water use period is for seasons other than summer, adjustments need to be made to the total daily production based on the reduced hours of insolation. The insolation values are averages for the month, taking into account overcast days and cloudy days (note the monthly insolation values for Seattle, known for its clouds; and Phoenix, known for is sun, in comparison to other locations of similar latitude.) A totally cloudless day in June would then produce more solar power than the average and the converse is true for cloudy days. The **average annual daily solar insolation** for Central SD is 4.8 hours per day.

The **design flow for a pipeline** served by a solar system should be based on the peak output from the pump. The peak output can be calculated based on the daily pump output (gallons) delivered during the equivalent peak sun hours available at the site in the June-July period. For example, a pump installed, in SD, and rated at 2,400 gallons per day would base that volume on approximately 6 peak hours per day. The peak output for the pump would then be 6.7 gallons per minute (2,400 gpd/6 hours per day/60 minutes per hour) and; therefore, the pipeline would be designed for at least 7 gpm. During the early morning and early evening the output from the pump would be much less than this, but around noon the peak out put would be approximately seven gpm or slightly more. The average flow for the day could be approximated as 3.6 gpm (2,400 gpd/11 hours per day/60 minutes per hour).

Figure 7.7
Average Daily Solar Insolation – June
(reference Photovoltaic Power As A Utility Service: Guidelines For Livestock Water Pumping, SAND93-7043, Sandia National Laboratories)

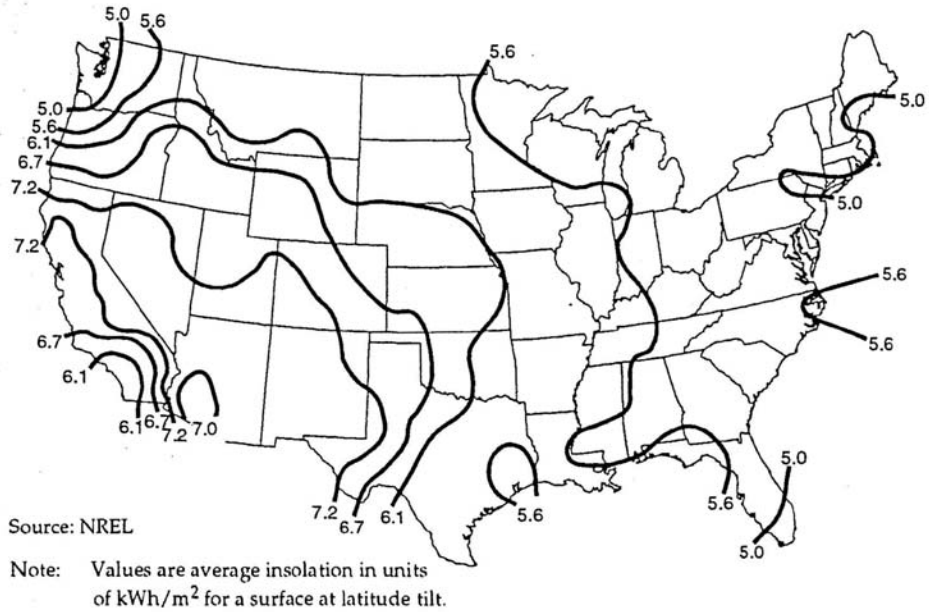


Figure 7.8
Average Daily Solar Insolation – September

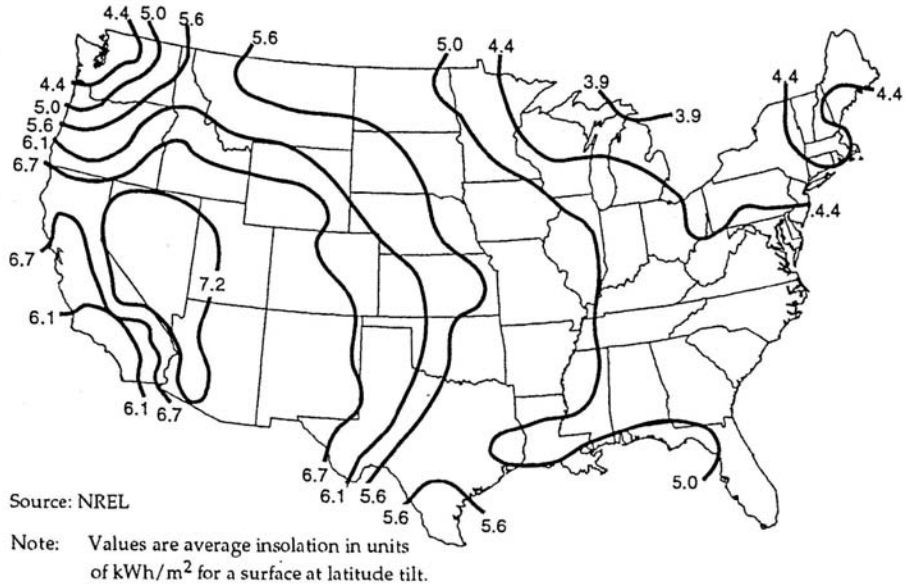


Figure 7.9
Average Daily Solar Insolation – December

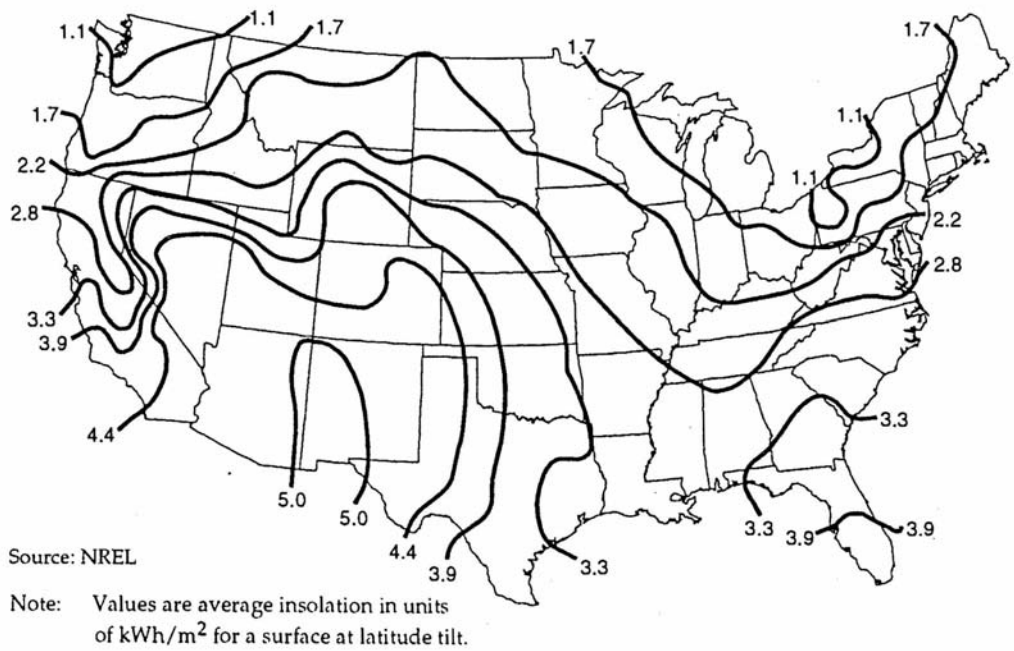
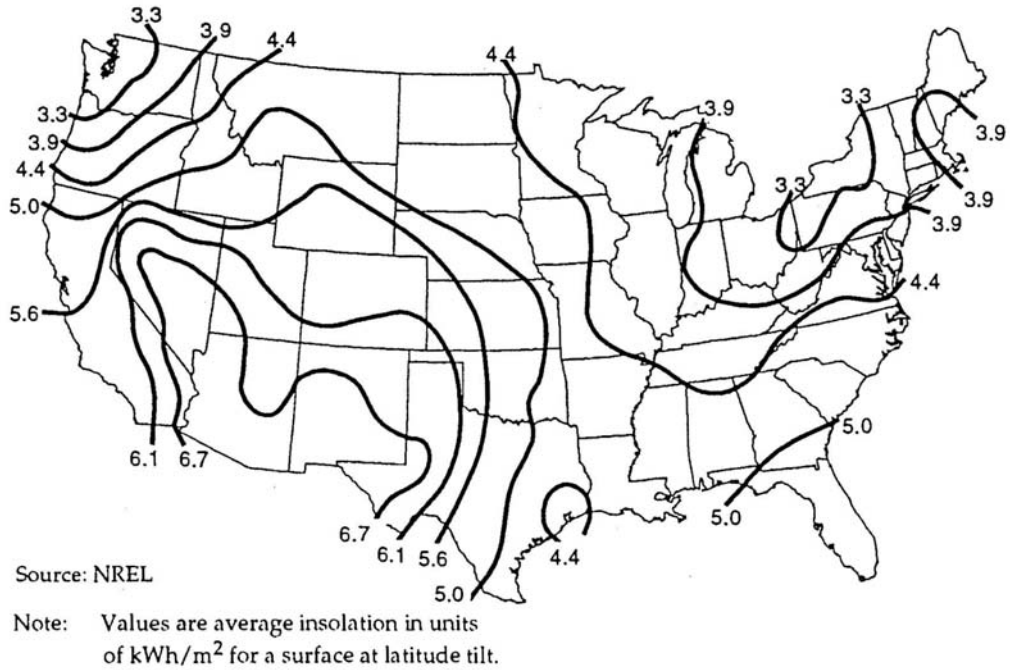


Figure 7.10
Average Daily Solar Insolation – March



Selecting the correct **size and type of wire** when connecting the pump to the batteries or solar panels increases the performance and reliability of the system. If possible, keep the PV panel and pump sets within 100 feet of each other. At this distance, a #12 gauge wire is sufficient to keep the voltage loss in most 24-volt systems to roughly 3 percent. Larger diameter wires will be required at distances greater than 100 feet to keep the voltage loss in the system to a minimum. A voltage drop of only five percent translates to a seven and one-half percent power loss at the pump. The use of direct-burial wire (UF) simplifies installation, since the wire can be

buried under the water pipe in the same trench without conduit. Make all connections in water-tight junction boxes and attach all wires to support structures with wire ties. Use PVC conduit to protect the wires anytime they are above ground.

Solar water pumping systems attract lightning because of the excellent ground they provide. If possible, do not locate the pump system, which includes the PV array, wiring, and pump, on high ground. Ground the PV panel frame and all equipment boxes to metal well casings or to a driven ground rod. You might have to install lightning rods on higher terrain around the pump if lightning is a problem.

The **pump can be operated using either a standard pressure switch** and recharged pressure tank commonly used with home well pumps or an **electronic float switch**. The recharged pressure tank prevents the continuous on/off cycling of the pump when cattle drink from a nearly full watering tank. When the float valve closes in a recharged pressure tank system, the pump continues to run until the pressure tank is charged with water at the preset off-pressure. As the level in a near-full tank fluctuates when animals are drinking and the float valve opens and closes, water is supplied from the charged pressure tank and the pump does not cycle. When animals drink enough to lower the water level and the float valve remains open, the pressure tank water charge is exhausted and the pressure switch then turns on the pump. A check valve placed in line upstream from the pressure switch location prevents the water line from draining when the pump is not operating.

Electronic float switches can be used to turn the pump on and off when the livestock watering and/or storage tank is low or full. Control wires from the livestock watering tank and/or storage to the pump controller must be run to make the system operate. Consider the maximum distance between float switch and pump as being approximately 1,200 feet unless the dealer/supplier permits a longer distance.

The amount of **maintenance** required by solar pumping systems depends on the type and complexity of the system. PV panels generally require very little maintenance; however, pumps, batteries, and other components require periodic routine maintenance. If the PV panels are dirty, operating efficiency of the system can be improved by cleaning the panels. Damage to PV panels caused by hail or other impact sources can destroy individual solar cells, but the PV panel will continue to produce current proportional to the amount of undamaged cells in the panel. The point at which the panel replacement is necessary should be determined by the dealer. A solar system will last a certain time before it needs replacement. The panels should last 20-30 years, whereas, the pump may have to be replaced every 5-10 years.

7.2.8 Conventional Windmills

South Dakota has wind resources consistent with winds suitable for utility-scale production. Good to excellent wind resource areas are located throughout the state. Prominent excellent to outstanding resource areas are located on the hills east of Pierre, the ridges in south-central SD near the Nebraska border, and hills near Rapid City. Ridge crest locations in the Black Hills can also have excellent wind resources. On a smaller scale, wind resources suitable for stock water pumping are available at most locations in the state. A wind resource map produced by the Department of Energy is included in Appendix A and maps the different classes of wind power in SD. In general, at 50 meters, wind power Class 4 or higher can be useful for generating wind power with large turbines. Class 4 and above are considered good resources. Wind resources at a micro level can vary significantly; however, the wind resource map can be used as a general indicator of wind power adequate for stock water windmills.

Windmills are still used to great advantage when power is not available at a site. The most important factor is to provide adequate water storage to carry over during periods of little or no wind. A windmill harnesses the free and renewable power of the wind and uses that energy to lift underground water to the surface. The basic design of a windmill hasn't changed in almost 120 years. A windmill works by converting the rotary motion of the wheel located at the top of the tower to a reciprocating (up/down) motion that powers a cylinder pump in the well. The cylinder pump pushes a column of water from the aquifer to the surface within the drop pipe using a series of check valves which create a one-way flow of water within the drop pipe and constantly ratcheting water upward to the surface (Figure 7.11).

Table 7.2 tabulates approximate windmill capacities (GPH) depending on the cylinder size. Table 7.3 tabulates approximate pumping heads which vary depending on the size of the windmill wheel. As the size of the wheel increases, more power is available to deliver the water at higher head. The tables are based on a windmill operating in a 15-20 mph wind using a long stroke cylinder pump. Short stroke cylinders may also be used to increase pumping head available by one-third but pumping capacity is reduced by about one-quarter. Deep wells use a short stroke; shallower wells a long stroke. Shorter more powerful strokes can lift a deeper heavier column of water than pumps using longer strokes. Naturally, deeper wells will pump less water in a given time than shallower wells.

For 12 mph winds, capacity is reduced about 20 percent and for 10 mph winds, about 38 percent. If prevailing winds are low, use of a cylinder smaller than shown will permit the mill to operate in lower wind velocity.

It is important to use a tower high enough for good wind exposure from every direction. Wind velocities become stronger as the distance above ground level increases. The windmill will pump more often and more efficiently if positioned high enough to catch winds unaffected by obstructions. A windmill should be placed away from nearby trees a minimum distance of 20 times tree height. The bottom of the wheel should be at least 15 ft. above all surrounding obstructions within 400 ft. Manufactured towers are available in sizes from 21 ft. to approximately 60 ft. in 6-7-ft. increments with towers of 30-50 ft. being most common.

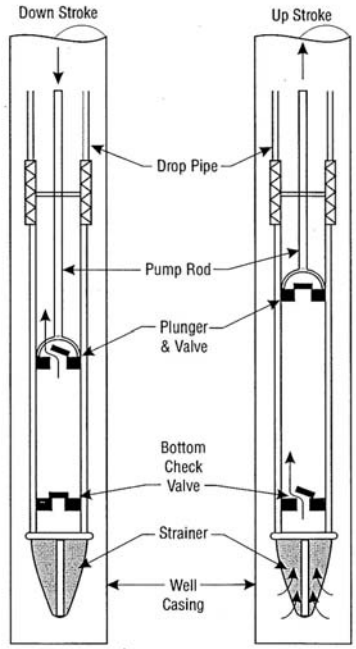
Fasten a windmill down securely to prevent it from being upset by high winds. Tall windmills should be anchored in concrete, while shorter windmills may be anchored to posts or deadmen with guy wires.

Since wind velocities adequate for pumping cannot be relied on every day, even in SD, storage is and important part of any windmill installation. Usually the storage is provided in a large diameter stock tank located at the well site, although an elevated central storage tank could be utilized as well. The most common large diameter stock tanks used at windmills are fabricated from galvanized, corrugated steel rims which are available in sizes up to 39 ft. diameter (or more) and storing 25,000 gallons. The storage should be sized to provide a three to seven days water for the livestock served. Dependability of the installation increases with increased storage volume with the volume being three days.

Table 7.2
Approximate Windmill Capacity
(Gallons Per Hour)

Cylinder Diameter (inches)	Wheel Diameter (feet) 6 feet	8-16 feet
1-7/8	125	180
2	130	190
2-1/4	180	260
2-1/2	225	325
2-3/4	265	385
3	320	470
3-1/2	440	640
3-3/4	500	730
4	570	830
5	900	1300
6	---	1875

Figure 7.11
Cylinder Pump Detail



The cylinder pump commonly used with windmills is a simple device— similar to a bicycle pump. A geared transfer case in the windmill rotor converts rotational motion into the reciprocating (up and down) motion required by the pump. Two one-way valves in the pump direct water through the pump.

Table 7.3
Windmill Pumping Head
(Feet)

Cylinder Diameter (inches)	Wheel Diameter (feet) 6	8	10	12	14	16
1-7/8	120	175	260	390	560	920
2	95	140	215	320	460	750
2-1/4	77	112	170	250	360	590
2-1/2	65	94	140	210	300	490
2-3/4	56	80	120	180	260	425
3	47	68	100	155	220	360
3-1/2	35	50	76	115	160	265
3-3/4	30	44	65	98	143	230
4	27	39	58	86	125	200
5	17	25	37	55	80	130
6	-	17	25	38	55	85

The following procedure is used to size a windmill:

- Calculate the daily water requirement for the livestock to be served.
- Calculate the hourly pumping rate based on the estimated hours per day of adequate wind velocity (four to six hours for SD).
- Select the cylinder size that will provide the necessary volume of water.
- Determine the pumping head based on the drawdown in the well and the discharge elevation. If the stock tank is located at the well, then the head would be the depth to water during pumping. If the stock tank is located some distance from the well then elevation and friction loss would need to be accounted for.
- Determine windmill wheel size based on pumping head.
- Select a tower with sufficient height to position the windmill at least 15 ft. above any surrounding obstructions within 400 ft.

Example:

Daily water requirement - (60 hd.)(30 gpd) = 1,800 gpd
Hourly pumping rate – (1,800 gpd)/(6 hours per day) = 300 gph note: the windmill capacity should not exceed the well yield, 300 gph is 5 gpm
Cylinder size – 2½" with 8-16 ft. wheel (325 gph)
Water level estimated at 120 ft. @ 5 gpm – Pumping head approximately 120 ft.
Wheel size – select 10 ft. wheel capable of 140 ft. pumping head with 2½" cylinder
Tower size – the location selected has no nearby obstructions, a 21 ft. tower was selected
Figure 7.12 illustrates a conventional windmill installation with the tank located at the well.

Figure 7.13 illustrates one type of plumbing configuration for a windmill connected to a pipeline.

Figure 7.12
Windmill/Tank Plumbing

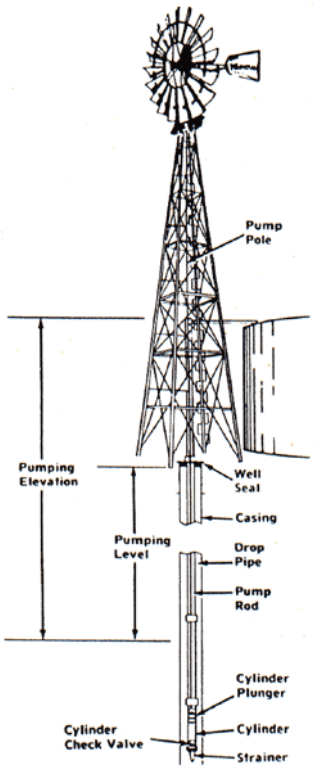
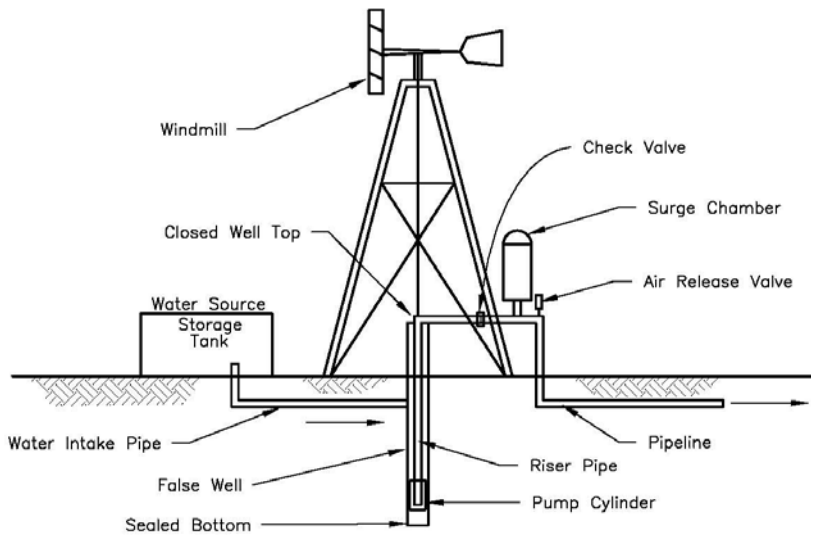


Figure 7.13
Windmill/Pipeline Plumbing



Advantages of windmills include:

- Suitable in remote areas where electricity is not available
- Windmills are difficult to dismantle and steal
- If regularly maintained, windmills are dependable
- Operating costs are low

Disadvantages include:

- Dependent on wind
- Water is pumped at relatively low rates
- Storage must be provided
- Windmills are expensive to purchase and install
- Maintenance must be done high off the ground
- Cylinder parts must be changed every one to five years
- Windmills are targets for vandalism
- Conventional windmills require wind speeds approaching 12 miles per hour to start pumping

7.2.9 Counterbalanced Windmills

In a fully counterbalanced windmill, water is pumped on both the up-stroke and the down-stroke. A non-counterbalanced windmill pumps only on the up-stroke. A counterbalanced windmill allows the windmill to start pumping at lower wind speeds of as little as 5 mph, versus the 12 mph wind needed to start a non-counterbalanced windmill. At wind speeds below 10 mph, tests show a counterbalanced windmill will pump 3 times more water than a conventional windmill and at wind speeds above 10 mph approximately $^{1}/_{3}$ more. These counterbalanced pumps are capable of pumping water from as deep as 1,200 ft.

These windmills use a rotary counterbalanced crank shaft, and industrially designed gear box to account for the higher performance, as compared to other windmills. The rotary counter balance jack pump improves pumping power by lightening the weight of the load of water being lifted from the well, resulting in the ability to pump much higher volumes of water from deeper depths in lower winds than traditional windmills. A high strength sealed gear box, with industrial quality anti-friction bearings and heavy duty gears, provides reliable performance.

Examples of pump performance are shown in Figures 7.14 and 7.15 respectively for a counterbalanced long stroke pump set in a 25 ft. deep well, and a short stroke pump set in a 1,000 ft. deep well.

Figure 7.14
Counterbalanced Windmill Pump Performance (Long Stroke)

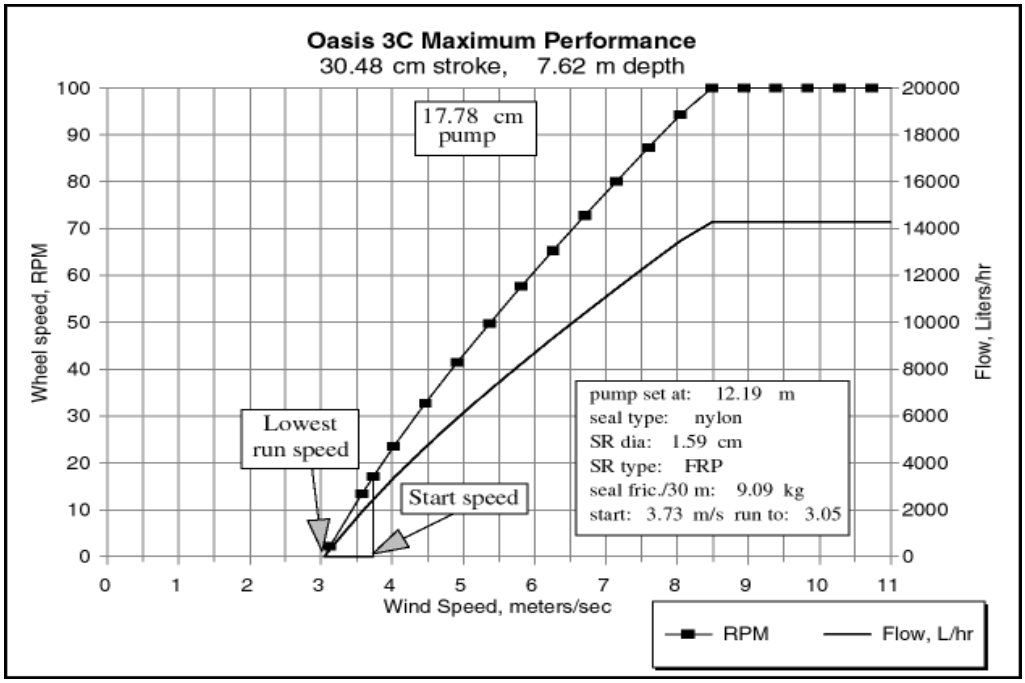
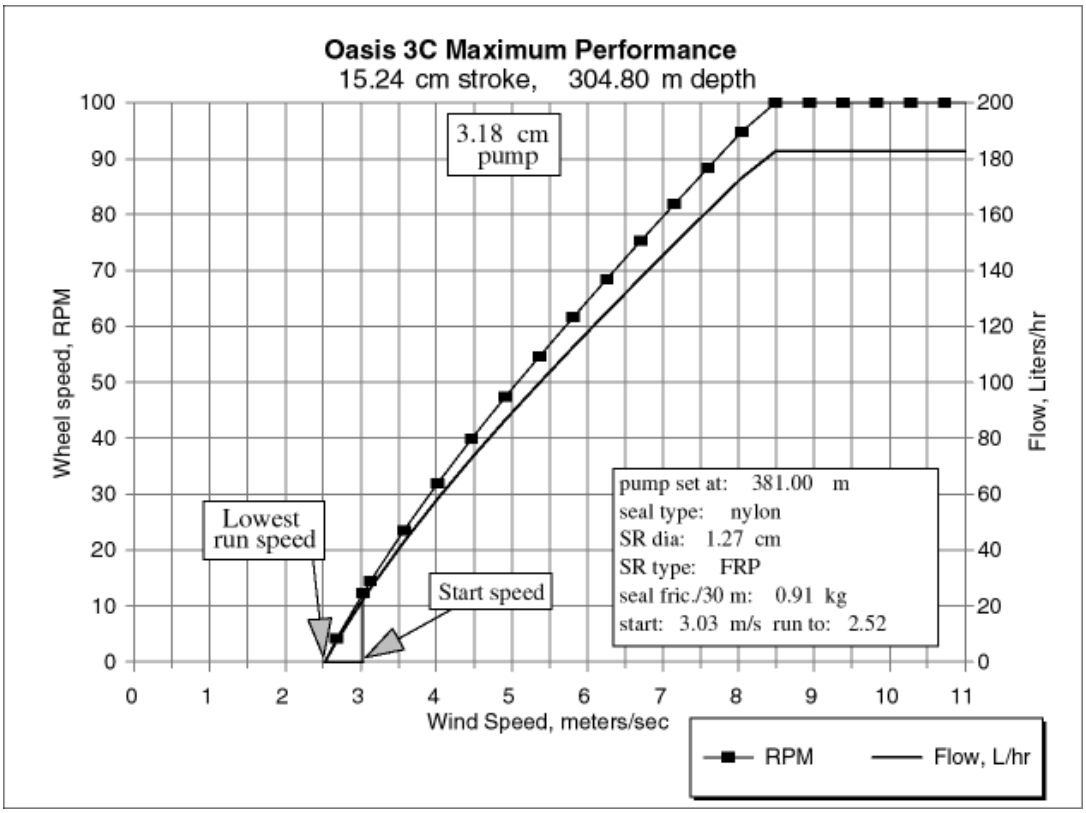


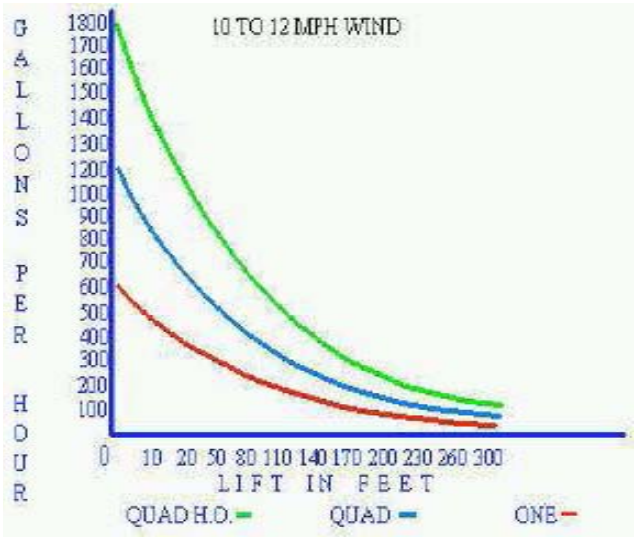
Figure 7.15
Counterbalanced Windmill Pump Performance (Short Stroke)



7.2.10 Windmill-driven Air Pump

Unlike other windmills that pump water, an airlift windmill water pump does not have to stand over the water well or other water source. It can be located up to a quarter mile away or wherever the wind achieves maximum velocity such as on a nearby hill. A one-half inch air hose connects the compressor on the windmill and the air lift pump located below the water surface in the well and attached to a drop pipe. The pump is actually a perforated foot piece attached at the end of the drop pipe. As air is pumped into the foot piece, the water column becomes less dense and is forced up by the more dense water on the outside of the drop pipe. Capacity of an airlift windmill can range from 30 gpm for shallow lifts of 10 ft. or less to 3 gpm for lifts up to 315 ft. (Figure 7.16). It can accommodate well casings as small as two inches. Multiple wells can be serviced by the same windmill by simply attaching more air lines. Air pump windmills pump well water by the use of an air injection pump. The air injection pump measures a bubble of air created by the windmill that floats water to the surface in a continuous cycle. All moving parts in the air pump system are above ground. There are no cylinders, leathers, or plunger type assemblies as in other conventional windmill cylinders. The air pump can run dry, accepting sand and sludge without harm. The air pumps require a minimum of maintenance. The air pump windmills can be installed by a single person in less than a day. Towers are available as a standard three-way trussed tower or three-way folding trussed towers of 17-22' height. Air pump windmills can also be used to aerate stock tanks to reduce freeze-up in winter. Cost for an air pump system will usually be less than a complete conventional windmill system.

Figure 7.16
Air Pump Capacity



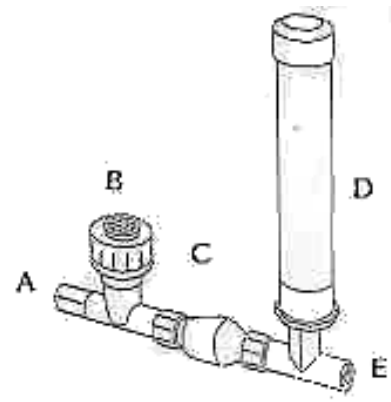
7.2.11 Highbred Systems

There are numerous renewable energy variations of pumps combining wind, solar, or batteries to run pumps designed for variable amperage DC current. They exhibit similar characteristics to the single source pumps described in previous sections. Combining wind and solar you get the best of both worlds with higher output from solar in the summer and wind in the winter. Thus,

giving more consistent water production year around if that is desired. There would be very few days when a highbred system would not pump in SD. Most systems draw power from both sources simultaneously so there is no switching required to get the maximum production on sunny windy days. The operator must weigh the economics of these higher cost systems to decide if the added cost will be offset by the increased production and dependability.

7.2.12 Hydraulic Ram Pump

Figure 7.17
Hydraulic Ram Pump



A **hydraulic ram** pump is a simple device for pumping water that requires no energy source other than the elevation head obtained from the water. It uses the energy of flowing water to lift water from a stream, pond, spring, or artesian well to an elevated storage tank or other discharge point. It is suitable for use where small quantities of water are required and power supplies are limited or not available. A hydraulic ram is feasible where a constant flow of water is available, the usable fall from the water source to the ram location is at least three feet, and the volume at the source is adequate waste the majority of the water and still have enough volume to supply the need at the point of delivery.

Components of a hydraulic ram pump are illustrated in Figure 7.17. Its operation is based on converting the velocity energy in flowing water into elevation lift. Water flows from the source through the drive pipe (A) and escapes through the waste valve (B) until it builds enough pressure to suddenly close the waste valve. Water then surges through the interior discharge valve (C) into the air chamber (D), compressing air trapped in the chamber. When the pressurized water reaches equilibrium with the trapped air, it rebounds, causing the discharge valve (C) to close. Pressurized water then escapes from the air chamber through a check valve and up the delivery pipe (E) to its destination. The closing of the discharge valve (C) causes a slight vacuum, allowing the waste valve (B) to open again, initiating a new cycle. The cycle repeats between 20 and 100 times per minute, depending upon the flow rate. If properly installed, a hydraulic ram will operate continuously with a minimum of attention as long as the flowing water supply is continuous and excess water is drained away from the pump.

Hydraulic rams can offer a lower cost alternative to solar power or other alternative power systems. The main limitation is that rarely is a flow of water of sufficient volume (10-20 gpm) and at sufficient elevation available to power the ram, although there are a few hydraulic rams installed around the state. A ram will multiply the elevation head by a factor of 10 or more. For example, if the ram is 10 ft. below the water supply, the water can be pumped up to 100 ft. above the pump while wasting approximately 90 percent of the water supplied to the ram. You can see that the one big disadvantage of a ram pump is that it **wastes a lot of water**. Design information is available on the internet. Hydraulic rams may be purchased from suppliers or instructions are available on the Internet for fabricating a ram pump.

7.2.13 Nose Pump

Typical Nose Pump

Nose pumps are simple diaphragm pumps that provide water when operated by livestock. When an animal pushes the pump arm or paddle with its nose, about one to two pints of water is pumped into a small drinking bowl by the animal's action. Nose pumps provide water to one animal at a time at a low flow rate, so their use is limited to small numbers of animals.

Nose pumps are suitable for large animals such as cows, horses, and calves weighting at least 400 lbs. Smaller calves can use this system if a small shallow tank is placed under the pump to collect overrun water. This overrun water can then be used by a calf, smaller that 400 lbs. The overrun water comes when the cow pumps the nose pump and extra water that can not be held in the nose pump reservoir runs over the reservoir into the small shallow tank. Sheep won't use a nose pump as they prefer to butt with their heads rather than push with their nose. These units must be set reasonably close to the water's surface in terms of elevation.

These pumps are simple, economical options which can be used in remote locations since no power is required. The pumps are easily moved from one water source to another in rotational grazing systems. Manufacturers and producers report that most animals learn to use the pumps very quickly. Animals unable to learn how to use nose pumps will need other accommodations or a substitute watering system. Young calves may not have the strength to operate the pumps, depending on the lift and distance the pumps have to move the water. The livestock need a few days to learn to use the pump before hot weather sets in and other water sources are removed. Dairy cows have proven to be very adept at using the nose pump. No water storage or stock tanks are required for these systems. Manufacturers suggest that the units be protected from freezing, which limits their use to warm months.

One nose pump is adequate for about 25-35 cow/calf pairs. They can lift water up to 28 ft. and can pull water up to 3,000 ft. at sea level; however, as the distance from the source increases, the water has to travel further, the amount of lift possible decreases. In SD, it is probably realistic to not expect lifts over 20 ft. if the pump is set adjacent to the stream or pond and lifts of 15 ft. or less if the nose pump is any distance away from the source. The paddles on the pump are easier to push at reduced lifts.

The pumps need to be mounted so that cattle pushing the paddle or fighting over the water don't move the pump. The mounting is usually done on railroad ties pinned down with re-bar or other stakes. The suction hose with foot valve needs to be mounted in the creek or pond and must be of noncollapsible pipe or hose. Where more than one pump is used, you can use one supply line and manifold the other from the main line. Pumps usually will come with a check valve and strainer; both of which are needed. Cost of these systems is usually less than $400 and is of great benefit to water quality as a result of restricting livestock access to streams.

7.3 Pressure Tanks

7.3.1 Purpose and Operation

Stand Models

A pressure tank is used to control the cycling of the pump. Proper sizing of the pressure tank is necessary to control cycle time and insure the maximum life of the pumping system. Excessive pump cycling (kicking on, shutting off, kicking on, shutting off) affects the life of submersible pump control components such as pressure switches, starters, relays and capacitors, pump splines, and bearings. Excessive cycling also can cause overheating of the motor and windings and can drastically shorten the life of the pump motor. Submersible pumps usually do not fail because of wear proportional to running time, but rather from causes related to overheating, rapid cycling, lightning, or from pumping sand. Over sizing a pressure tank is desirable because the cycle time is lengthened, with the only concern being the cost of the pressure tanks. Under sizing the pressure tank can cause rapid cycling and shorter pump life. Generally, operators and suppliers dealing with pressure systems understand the need for a pressure tank, but few understand the actual purpose or the relationships which determine the size required. One pump manufacturer recommends the maximum number of pump starts per 24-hour period as less than 300 for motors up to ¾ hp, 100 for 1-5 hp, and 50 starts or less per 24 hrs. for motors 7½ hp and over. The NRCS, in SD, uses a design procedure based on six cycles per hour, which based the on preceding recommendation would offer a conservative design for the small hp units but should be based on approximately four cycles per hour for the one to five hp units and two cycles per hour for those motors of seven and one-half hp and over.

The operation of a pressure tank depends on the compressibility of air, which causes air in the tank to act like a huge spring as the pressure fluctuates within the system. As water is used in the system, the air expands to push a small amount of stored water out of the tank, the air volume increases as the tank pressure drops. When the pressure drops to equal the low setting on the pressure switch, the pump kicks on. Some of the pump flow then is delivered to the point of usage on the system and the balance of the flow begins to refill the pressure tank. As the tank fills, the air is compressed and the pressure rises. When the pressure equals the high setting on the pressure switch, the pump shuts off. The total time to empty the tank and then refill and stop the pump is called a cycle. **The recommended design is to limit pump operation to 6 cycles per hour or less (cycle times of 10 minutes or more).**

7.3.2 Efficiency

Only a small percentage of the total tank volume is available for useable water storage or **drawdown**. The tank efficiency refers that portion of the total pressure tank volume actually available for drawdown. Drawdown of the tank is equal to the water volume that is stored between cut-in pressure and cut-out pressure. Cut-in pressure is that pressure at which the pump is automatically turned on. Cut-out is the pressure at which the pump is turned off.

Pressure tank manufacturers usually state the volume of drawdown for a given tank and although there is some variation among manufacturers the drawdown can be estimated for any operating range by the following equations:

$$\text{Tank Efficiency} = \frac{\left(1 - \dfrac{\text{Pump Cut-In} + 14.7}{\text{Pump Cut-Out} + 14.7}\right)}{1.1}$$

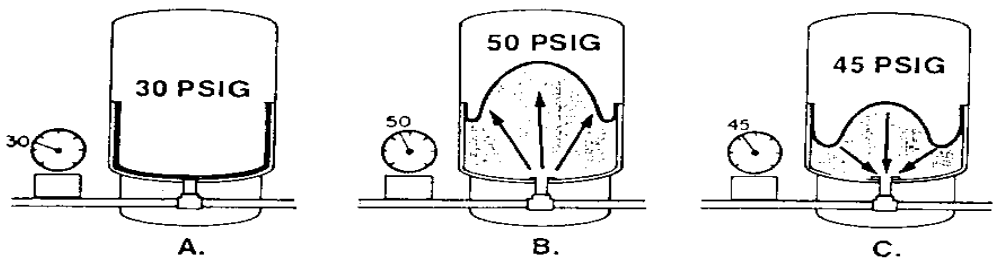
Drawdown (gal.) = Tank Efficiency x Tank Volume

For an 80 gallon pressure tank operating at a 70/100 psi setting the drawdown would be 23.8 gallons.

Figure 7.18 illustrates the operation of a pressure tank with a 30 psi "on" 50 psi "off" cycle. A pressure tank is 28 percent efficient at a 30-50 pressure setting. Therefore, if the pressure tank has a 40 gallon capacity, when the pump shuts off as the pressure rises to 50 psi, (Figure B), the water occupies 28 percent of the tank volume (11.2 gallons), and as the pressure decreases as water is being used in the system, the tank is empty at 30 psi when the pump starts.

Figure 7.18

HOW A PRESSURE TANK WORKS



A. Factory installed precharged air cushion. Pump off.
B. When pump starts, water enters the reservoir. At 50 psig, system is filled. Pump shuts off.
C. When water is demanded, pressure in the air chamber forces water into the system. Pump stays off.

Tanks operating at higher pressures (i.e., 60-80 psi) are less efficient (have less drawdown) than tanks operating at lower pressures (i.e. 20-40 psi). This is due to the physics of compressed air, but an everyday example of this would be adding air to a tire. A truck tire at 5 psi needs quite a volume of air added to raise the pressure an additional 10 psi, but the volume of air necessary to raise a tire at 50 psi an additional 10 psi is considerably less.

7.3.3 Pressure Differential

The difference between the Cut-in pressure and Cut-out pressure is defined as the **pressure differential**. Tanks operating with a kick-off pressure less than 80 psi usually have a 20 psi pressure differential between kick-on and kick-off (i.e., 40-60 psi). Tanks operating over 80 psi usually have a 30 psi differential pressure (i.e., 90-120 psi). The larger pressure differential provides more drawdown volume at these higher pressures. As tank pressures increase, the efficiency and resulting drawdown decreases, but by increasing the differential to 30 psi or more, the loss of drawdown caused by the increased pressures can be offset. It is perfectly acceptable to use pressure differentials of 25 or 30 psi on the lower pressure systems, as long as the higher kick-off pressure is below the maximum pressure rating of the tank and the higher static pressure can be accommodated by the pipe rating and other pipeline appurtenances.

7.3.4 Air Charge

Tanks are available with or without rubber bladders which are used to separate the air from the water and keep the tank fully charged with air. Without a bladder, tanks will absorb the air in the pressure tank over time and become waterlogged. When the tank becomes waterlogged, the pump cycles rapidly just as if the pressure tank were too small (the drawdown volume is eliminated). The higher the operating pressure, the faster a tank will absorb or “eat” the air. Tanks with operating pressures over about 70 psi should have bladders or a means to regularly replace the air. If a tank with a bladder is “cycling rapidly,” that is a good indication the bladder is ruptured. Most tanks currently on the market are of the bladder type. Tanks with bladders cost appreciably more than those without, primarily because if the tanks carry a good warranty, there is a good chance the bladder will rupture and the tank will be replaced by the company before the warranty runs out. Consideration should be given to specifying only tank models with replaceable bladders for the larger, higher pressure, higher cost tanks; however, some replacement bladders cost almost as much as a new tank. Bladder rupture is a common occurrence and bladder replacement is much less costly than continual tank replacement. Tanks without bladders need air added periodically, with the frequency more often as the operating pressure increases. Tanks operating over 100 psi may need air 3-4 times per year or more.

Tanks must be pre-charged with air prior to being put into service. The amount of pre-charge should be approximately equal to the cut-in pressure. For example, a tank to be used for system with a 70/100 pressure switch setting should be pre-charged to 70 psi. Tanks may carry a standard pre-charge from the factory of approximately 30 psi, and will; therefore, need additional air added for pressure settings higher than the pre-charge amount. If a tank is not properly pre-charged, the bladder may be ruptured when placed in operation.

7.3.5 Pressure Rating

Common pressure tanks are rated for maximum operating pressures between 75 psi and 150 psi. The upper design limit for cut-out pressure is; therefore, about 150 psi unless a specialized American Society of Mechanical Engineers (ASME) rated tank is used. The ASME tanks are available up to 250 psi rating but are very expensive and are rarely used. For systems with pressures above 150 psi, some other type of pump control should be used such as a timer or a probe or a alternative type pump which does not require a pressure tank could be used (variable speed constant pressure).

It is very dangerous to use a tank at higher than its rated pressure. A tank used beyond its rating could explode and cause death or serious injury to anyone working near the tank. For that reason, **a pressure tank should never be used beyond its rated pressure**. Occasionally, owners want to use "used" tanks such as old propane tanks as water pressure tanks. These tanks are not designed for water use and could soon corrode and weaken, and the high operating pressure would necessitate an air compressor plumbed into the system to automatically re-charge the tank with air to maintain drawdown capacity. **Pressure tanks not manufactured for water containment should not be used.**

7.3.6 Sizing and Design

In any high pressure automatic pressure system, additional storage can be added by installing multiple pressure tanks out on the pipeline at a location higher in elevation where pressures are relatively low. The lower pressure location would provide for tanks operating at a higher efficiency and possibly using a lower cost model. In such a system, it is desirable to have a primary high pressure tank located at the pump site. This tank takes the initial surge of flow and

allows flow and pressures to equalize in the pipeline and serves as a surge tank to eliminate pressure spikes that could cause a pressure switch to rapidly bounce between cut-in and cut-out. If all of the pressure tanks are located at a remote location away from the well, the pressure switch should be located at the remote location and the pump relay controlled with small gauge wire connecting the remote location with the well site. This configuration will prevent a rapidly cycling pressure switch caused by spikes in surge pressure but may limit the distance between the remote location and the well pump.

Pressure tanks are designed based on a relationship between the pump discharge volume (pump capacity and the average daily use (gpm). Because of this relationship, the pressure tanks can not be sized until the pump is designed. The procedure for sizing a pressure tank is as follows: (Note: this sizing procedure is not applicable for variable speed constant pressure pumps).

1. Determine **Average Daily Use –**

   - This is the average flow in gpm being delivered by the pipeline system.
   - Calculate the total gallons per day used by the system during the peak season (this is typically summer grazing).
   - Figure the average gpm over the **normal daily use period**. Many of our systems have extra capacity and the normal daily use period during the peak summer season would be the time which the cattle would be drinking, - early morning (6 a.m.) to dark (10 p.m.) or **about 16 hours**. On other systems where the pipeline capacity is close to the minimum design capacity, the normal daily use period may be **close to 24 hours**, and even though the cattle are only drinking during the daylight hours, it takes close to 24 hours to refill the tanks. If some systems have only a couple horses and most of the use occurs in the house, then the average daily use period may be the time of water use in the house 7 a.m. to 7 p.m., or about **12 hours**. **Consider what is likely to happen on the system and pick a normal daily use period accordingly.**

Example:

Total gallons per day - 300 hd. cattle @ 20 gpd = 6,000 gal.
1 house @ 360 gpd = 360 gal.
Total daily use = 6,360 gal.

Normal daily use period – 16 hours.

Average Daily Use – $\frac{6{,}360 \text{ gal.}}{(16 \text{ hrs.})(60 \text{ min/hr.})}$ = **6.6 gpm**

2. **Go to the Drawdown Chart (Figure 7.19)** – with the pump capacity and average daily use, find the minimum drawdown volume required for a cycle time of 10 minutes per cycle (6 cycles per hour).

3. Example:

   Pump Capacity – 9 gpm
   Average Daily Use – 6.6 gpm
   Minimum Drawdown Required – approx. 17.2 gal.

Normally, you will have to interpolate between chart values, or you can figure the cycle time mathematically as in the examples on the previous pages.

4. **Calculate minimum pressure tank size –**

Example:

Minimum drawdown required – 17.2 gal.
Pressure switch setting – 40-60 psi.
Tank efficiency (Figure 7.20) – 24 percent
Minimum pressure tank size – 17.2 gal./.24 = 71.7 gallons

There are many different sizes of pressure tanks depending on the brand. Most companies have tank sizes of approximately 42 gal., 80 gal., and 120 gal. There may be sizes in between and also larger sizes, and if you have a brand popular in your area and know those sizes, you can be more specific. In this example, we would specify a minimum tank size of 80 gallons with a minimum pressure rating of 100 psi. Manufacturers have a maximum recommended operating pressure specified in their literature and stamped on the tank specification tag. Common pressure tank maximum operating pressures are 100, 125, and 150 psi. The higher the pressure rating; the higher the cost. A pressure tank with a rating of less than 100 psi is rarely specified. Two or more smaller tanks can be installed side by side on a manifold in place of one large tank.

Figure 7.19
Minimum Pressure Tank Drawdown Required
(10 minutes per cycle) (1-(U/P))U = Drawdown

Average Daily Use (GPM)	1	2	3	4	5	6	8	10	12	15	20	25	30	35	40	50
40																80.00
35															43.75	105.00
30														42.86	75.00	120.00
25													41.67	71.43	93.75	125.00
20												40.00	66.67	85.71	100.00	120.00
18											18.00	50.40	72.00	87.43	99.00	115.20
16											32.00	57.60	74.67	86.86	96.00	108.80
14										9.33	42.00	61.60	74.67	84.00	91.00	100.80
12										24.00	48.00	62.40	72.00	78.86	84.00	91.20
10									16.67	33.33	50.00	60.00	66.67	71.43	75.00	80.00
9								9.00	22.50	36.00	49.50	57.60	63.00	66.86	69.75	73.80
8								16.00	26.67	37.33	48.00	54.40	58.67	61.71	64.00	67.20
7							8.75	21.00	29.17	37.33	45.50	50.40	53.67	56.00	57.75	60.20
6							15.00	24.00	30.00	36.00	42.00	45.60	48.00	49.71	51.00	52.80
5						8.33	18.75	25.00	29.17	33.33	37.50	40.00	41.67	42.86	43.75	45.00
4					8.00	13.33	20.00	24.00	26.67	29.33	32.00	33.60	34.67	35.43	36.00	36.80
3.5				4.38	10.50	14.58	19.69	22.75	24.79	26.83	28.88	30.10	30.92	31.50	31.94	32.55
3				7.50	12.00	15.00	18.75	21.00	22.50	24.00	25.50	26.40	27.00	27.43	27.75	28.20
2.5			4.17	9.38	12.50	14.58	17.19	18.75	19.79	20.83	21.88	22.50	22.92	23.21	23.44	23.75
2			6.67	10.00	12.00	13.33	15.00	16.00	16.67	17.33	18.00	18.40	18.67	18.86	19.00	19.20
1.5		3.75	7.50	9.38	10.50	11.25	12.19	12.75	13.13	13.50	13.88	14.10	14.25	14.36	14.44	14.55
1		5.00	6.67	7.50	8.00	8.33	8.75	9.00	9.17	9.33	9.50	9.60	9.67	9.71	9.75	9.80
0.5	2.50	3.75	4.17	4.38	4.50	4.58	4.69	4.75	4.79	4.83	4.88	4.90	4.92	4.93	4.94	4.95
0.2	1.60	1.80	1.87	1.90	1.92	1.93	1.95	1.96	1.97	1.97	1.98	1.98	1.99	1.99	1.99	1.99

P = Pump Capacity (GPM)

U= Average Daily Use P= Pump Capacity

Figure 7.20
Pressure Tank Efficiency

Operating Pressure
20 PSI Differential

PSI	Efficiency
20-40	.33
30-50	.28
40-60	.24
50-70	.21
60-80	.19
70-90	.17
80-100	.16
90-110	.15
100-120	.13
110-130	.13
120-140	.12
130-150	.11

Operating Pressure
30 PSI Differential

PSI	Efficiency
20-50	.42
30-60	.37
40-70	.32
50-80	.29
60-90	.26
70-100	.24
80-110	.22
90-120	.20
100-130	.19
110-140	.18
120-150	.17
130-160	.16

7.3.7 Design Example

The worst case scenario for rapid cycling occurs when a system runs for long periods of time with the water use approximately one-half of the pump capacity, and with a small pressure tank. An example would be a stockwater pipeline during summer operation running for long periods at 5 gpm and with a 10 gpm pump. A typical pressure tank would be a 42 gallon (these are inexpensive and common) operating at 50-70 psi setting. The tank efficiency at this pressure setting is 21 percent; therefore, the useable storage is (.21)(42 gal) = 8.8 gal. The pump operating cycle is shown below with the tank full and the pump shut off:

Off Cycle - 8.8 gallons = **1.8 minutes** (8.8 gal. storage being used at a rate of 5 gpm)
5 gal/minute

On Cycle - 8.8 gallons = **1.8 minutes** (8.8 gal storage being refilled at a rate of 5 gpm which is the 10 gpm pump rate less 5 gpm being used on the system)
5 gal/minute

Total Cycle Time = **3.6 minutes** (16.7 cycles per hour)

This is a poorly designed system which can be greatly improved with minor changes and little added expense. The cost of having a pump installer change out a burned out pump on a regular basis is much greater than a small increased cost in a larger pressure tank, or having a pump properly matched to the system which costs nothing or may even cost less. This is the pump cycle time with a larger 120 gallon pressure tank installed (useable storage (.21)(120 gal) = 25.2 gal) :

Off Cycle - 25.2 gallons = **5 minutes** (25.2 gal. storage being used at a rate of 5 gpm)
5 gal/minute

On Cycle - 25.2 gallons = **5 minutes** (25.2 gal storage being refilled at a rate of 5 gpm which is the 10 gpm pump rate less 5 gpm being used on the system)
5 gal/minute

Total Cycle Time = **10 minutes** (6 cycles per hour)

This would be a good design, but it could be improved even further if the pump was matched more closely to the system. If the livestock use of five gpm was the only load on the system, a pump of seven and one-half gpm would have been a better choice. The pump cycle time with a 7.5 gpm pump and a 120-gallon pressure tank would be as follows:

Off Cycle - 25.2 gallons = **5 minutes** (25.2 gal. Storage being used at a rate of 5 gpm)
5 gal/minute

On Cycle - 25.2 gallons = **10.1 minutes** (25.2 gal storage being refilled at a rate of 2.5 gpm which is the 7.5 gpm pump rate less 5 gpm being used on the system)
2.5 gal/minute

Total Cycle Time = **15.1 minutes** (4 cycles per hour)

This would be a very good design; and the cost of the system could even be reduced slightly by using a smaller pressure tank, but the use of the 120-gallon tank would provide the longest pump life.

7.3.8 Direct Bury Pressure Tanks

Most of the companies manufacturing pressure tanks market models specifically designed for direct bury installations. The typical installation would have the pressure tank buried in-line near the well and located below frost. There are also pressure tanks available which combine a tank with a pitless adaptor and are made to be installed on a four- to five-inch diameter well casing. The only part of the installation protruding above ground is the casing extension and well cap.

These installations are popular with some installers. The main advantages to these types of installations are that the total cost is usually less than a conventional system with a well house or well pit, and the plumbing is fairly simple with all of the components installed in the well casing or direct buried. The disadvantages are that any pressure tank maintenance requires digging, and any alteration, modification, or additions to the plumbing and controls located in the well casing may be difficult if not impossible to accomplish. Currently, there are no state statutes preventing buried pressure tanks nor are there any restrictions in the SDTG Standards for Pumping Plants; however, these installations should be given very careful consideration due to the maintenance disadvantages associated with these tanks.

7.3.9 Surge Control

Surge (water hammer) can be a serious problem in long stockwater pipelines. Consider what happens when a two mile long pipeline is suddenly shut off. The entire mass of water in the pipe is moving in the direction of flow. When the water is suddenly shut off, considerable force is required to stop the momentum of the large water mass, similar to the force necessary to stop a moving freight train. Surge occurs both on when water is suddenly shut off, and when water flow suddenly starts such as when a pump starts.

Actual pressure build up depends on the total volume of water in the pipe, velocity at which the water is moving, and how fast the velocity changes. Surge pressures can be much greater than operating pressure, and can even be greater than static pressure in the pipeline.

In low pressure pipelines, surge is usually not a significant consideration. The pipe and appurtenances have high enough safety factors to withstand minor surges. Surge is almost always a factor that must be addressed in long, high pressure pipelines where water flow can be suddenly stopped for any reason.

A frequent surge problem is encountered on pumped systems. When the pump shuts off, the water starts to reverse in the line. A check valve closes, setting up a pressure wave and cyclic pressure surges. If the pump system contains an automatic pressure switch, the pump can rapidly cycle on and off causing damage to the pump, pipeline, and valves.

Another frequent cause of surges is rapidly turning off a hydrant. Frost free hydrants can be shut off very rapidly by slamming down the handle. This is sure to cause surges in the pipeline. .

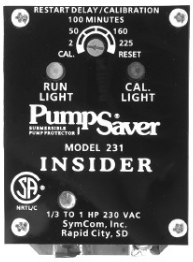
For automatic pressure systems, a pressure tank acts as a surge chamber. The air volume in the pressure tank acts as a cushion for water surges as they occur. On high pressure systems, utilizing a timer or probes to control pump operation rather than a pressure switch should be considered. In addition, surge tank may need to be installed to control dangerous surges. In

these situations, it may be necessary to install a high pressure rated diaphragm-type pressure tank, or a specially designed surge chamber. These are expensive but may be needed in high pressure automatic systems.

See Chapter 5, Pipe Design, **Section 5.8.5, Surge Pressure in PVC Pipe** for actual surge pressure calculation information.

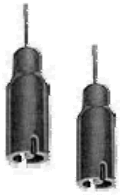
7.4 Electrical Pump Control Equipment

Most pump installations require some type of mechanism to shut the pump off in the event the water source is inadequate to supply the needs of the pump. These mechanisms are referred to by terms such as "run-dry protection, low water shut-off, pump saver, low water probe, low flow switch," etc., and are utilized as a safety measure to prevent damage to the pump or motor from running dry. This can occur in wells where the water level drops below the pump setting, on booster pump installations where the storage reservoir is empty, or if a booster pump is installed in an in-line installation and the main pump fails to maintain adequate pressure to the booster pump inlet. The **shut-off protection** is usually incorporated with a time delay switch to prevent the pump from re-starting immediately and beginning rapid on/off cycling.



(a)

Electronic shut-off protection (a) is quite commonly used on submersible pumps, particularly on small diameter well installations. The control is installed with the other electrical equipment without the need for additional wires or probes to be installed to monitor the water level in the well. The electronic controller monitors the amperage draw of the pump and shuts the pump off if the amperage drops below a specific set point. If the amperage draw of a pump approaches zero, it is an indication the flow volume of the pump is also approaching zero, such as would occur if the water level in the well dropped below the pump. (The electrical current used by a pump is proportional to horsepower (TDH x gpm/3960), as the water level in the well drops and pump flow approaches zero, horsepower approaches zero, as does amperage)



(b)

Electric probes (b) can be used in a variety of ways to control pump operation and are commonly used in reservoir applications to monitor water levels. Probes can be used to prevent booster pump operation at low water levels, or can be used to control water levels in a reservoir by controlling pump on/off cycles.

(c)

Mechanical (paddle type) **flow switches** (c) are installed in the plumbing at a threaded tee with the "paddle" extending into the flow path of the water. The force of the water on the paddle is necessary for pump operation to occur. This type of switch must be used in conjunction with a time delay allowing the pump to start, but then stopping the pump if flow is not maintained. An important feature of this type of switch is that it is adjustable to trip at various flow rates, and; therefore, could have applications for in-line booster pump installations.

Pressure switches (d) are used in all applications where pump operation is controlled by sensing system hydraulic pressure. Every pressure switch has two operating points; one on rising pressure and one of falling pressure. The operating point on rising pressure is referred to as the **trip point** or cut out and the operating point on falling pressure is referred to as the **reset point** or cut in. These operating points are called the **settings** of the switch. The differential is the difference in pressure between the trip point (cut-out) and the reset point (cut-in). The differential can be adjustable or non-adjustable. Pressure switches are manufactured in numerous models to fit a wide range of applications. Most off-the-shelf switches will be rated at operating pressures less than 80 psi with a standard 20 psi nonadjustable differential, or an adjustable differential of 15-30 psi. Other models are available with operating pressures between 60-200 psi and adjustable pressure differentials of 20-40 psi or 30-50 psi.

(d)

7.5 Pitless Adaptors

A pitless adaptor is a fitting which attaches to the side of a well casing approximately five to six feet below ground line. The purpose is to provide a connection below frost line between the submersible pump drop pipe and the buried pipeline, which can be easily disconnected if the pump needs to be serviced or replaced. The pitless adaptor shown attaches to the casing by way of a two piece threaded fitting which attaches to the casing wall through a hole cut through the casing. Pitless adaptors use two machined surfaces which are "wedged" together by the hanging weight of the submersible pump. The surfaces are sealed with and integral "O" ring. The pump hangs from the drop pipe which is threaded into the bottom of the adaptor and a short length of pipe five to six feet in length attaches to the top of the fitting and runs to the surface and terminates just under the well cap. When the pump needs to be pulled, it is just a matter of grabbing the exposed pipe and lifting the pump off the pitless wedge and pulling the pump out of the well casing. Pitless adaptors are made to attach to casings in a variety of ways including welded, clamped, or compression. On a system used in freezing weather, the alternative to a pitless adaptor is to terminate the well in a pit below frost. The pipeline then joints to the pump drop pipe with a conventional union at the top of the casing and to pull the pump the union is disconnected and the pump pulled out of the manhole opening. **Wells terminating in a pit are not allowed according to SD State Well Standards** for water quality reasons due to the potential for aquifer/well contamination if the pit floods.

7.6 Well Caps and Well Seals

(a)

Standard well caps (a) usually have bolts around the side of the cap that loosely hold the cap onto the top of the casing. The small airspace between the well cap and the casing can allow for insects, small mammals, or surface water to enter the well.

(b)

A sanitary well cap (b), sometimes referred to as a "vermin-proof" well cap, looks similar to a standard well cap but usually has bolts on the top of the well cap around the perimeter. Most sanitary well caps include an airtight rubber gasket seal, compressed with the bolts, to prevent insects, small mammals, or surface water from entering the well and a small, screened vent to allow for air exchange. South Dakota well standards require well casings to "be capped with a cover having a downward flange which shall be securely fastened to the pitless unit or casing and shall fit sufficiently snug to the unit or casing to be vermin proof." A sanitary well cap meets those requirements. Well caps are the standard application for all small diameter wells utilizing a pitless adaptor.

(c)

Sanitary well seals (c) are a compression type seal used at the top of the well casing manufactured in different configurations depending on the type of pump being used (submersible, jet, windmill). They do not meet the state well standard unless used with a cap or cover having a downward flange. Well seals were fairly common for wells terminating in a well pit **(well standards no longer allow a well terminating in a pit for water quality reasons)** since on these installations the piping from the pump exited the top of the casing. Well seals are used on installations not used for winter use and may be utilized for windmills.

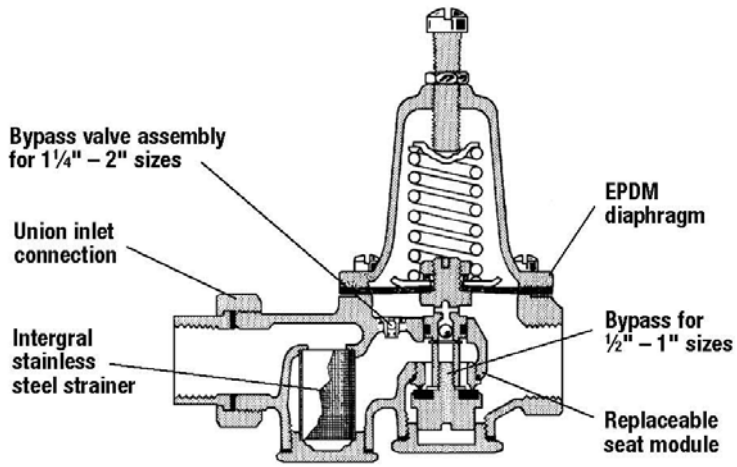
7.7 Pressure Regulator Valve (PRV)

Pressure regulators are used to control excessive pressures on a water system. They are a standard feature in meter pits for rural water systems and are very common on water systems

with elevation extremes to protect pipelines from pressures in excess of the pipe pressure rating and to control damaging pressures at outlets to protect hydrant seals, floats, and other appurtenances.

Regulators typically have **reduced pressure settings** between 25 and 75 psi. The reduced pressure setting is the maximum pressure desired downstream of the valve and is adjusted by a screw or dial on top of the valve. The adjusting screw regulates the tension on the spring that controls the downstream pressure. High pressure and low pressure models are also available from most manufacturers which have optional springs installed allowing higher or lower reduced pressure settings. Regulators typically come preset from the factory with a 50 psi setting. The regulator shown requires the use of a pressure gauge to determine the setting; however, regulators are available which can be set to a specific pressure by means of a dial on top of the valve. **Figure 7.21** shows a cutaway view of the regular pictured.

Figure 7.21
Pressure Regulator Cut-away



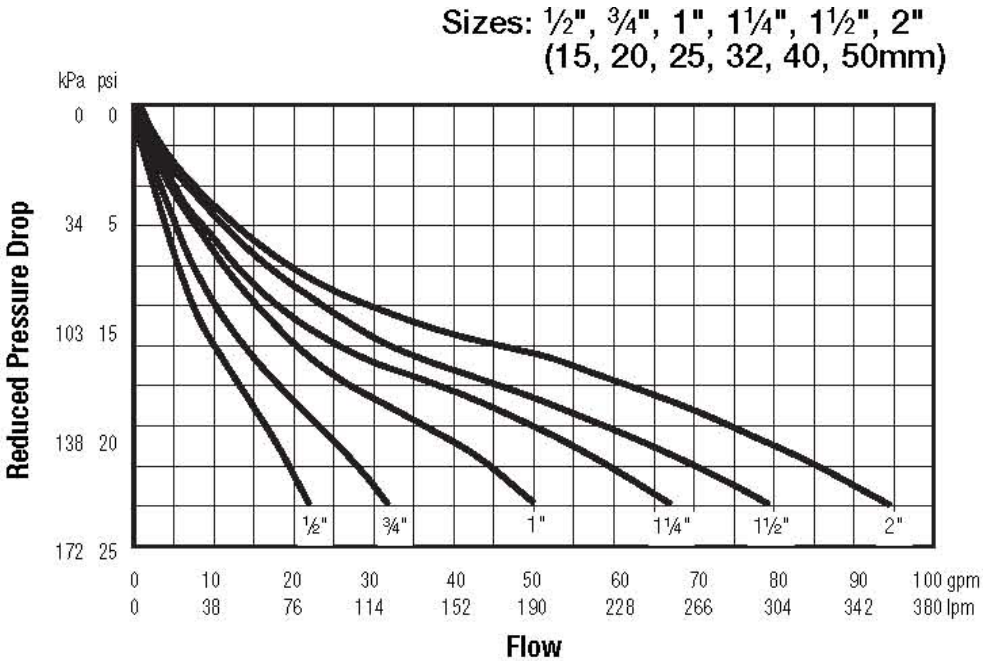
Regulators must be installed in a pit or manhole to facilitate servicing and adjustment. The valve may need adjustment periodically or the strainer may need cleaning if downstream flows are not satisfactory. Some regulators have integral strainers and others must have a separate strainer valve install immediately upstream of the regulator. The strainer is extremely important on an livestock pipeline since grass, debris, and gravel entering the system from leak repairs can get caught in the valve and affect operation.

Sizing of regulators is determined by the allowable **reduced pressure falloff.** Reduced pressure falloff represents friction loss through the valve. If a regulator is set to 50 psi, the pressure immediately downstream of the valve will be 50 psi **only** when there is no flow (static condition). With increasing flow, the downstream hydraulic pressure will be less than 50 psi by the amount of reduced pressure falloff (the higher the flow the greater the pressure falloff). Figure 7.7 represents the reduced pressure falloff for a typical **standard capacity valve**.

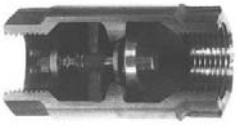
The reduced pressure falloff will not be of particular concern for water systems with fairly moderate elevation differences, since the problem is too much pressure rather than not enough. On systems with large elevation differences; however, the regulator setting required to protect the pipe or lower outlets at static conditions, may have just marginal hydraulic pressure to supply the higher outlets. In these situations, the pressure falloff must be considered. Pressure regulators are fairly economical in sizes of one inch and less, but rise in price quite dramatically for sizes of one and one-quarter-inch and larger. For the standard capacity valve illustrated in F**igure 7.22**, a 1” valve flowing at 15 gpm would have a pressure drop of approximately 12-13 psi and have a hydraulic pressure immediately downstream of the valve of approximately 37 psi. If this is more pressure loss than can be tolerated, a **high capacity** model equal to a Watts 223S can be used which will have a pressure drop of about half the standard capacity valve and will be lower in cost than a 1¼” standard capacity valve.

When pressure regulators are used in conjunction with other valves in a manhole or pit, consideration should be given to the sizing all of the other valves the same nominal size as the PRV. If friction loss is of concern on the valves other than the PRV they can be placed upstream of the PRV. Fittings to reduce or increase pipe sizes are not only expensive but take up very limited space in a manhole or pit.

Figure 7.22
Pressure Regulator Reduce Pressure Drop



7.8 Check Valves



The purpose of a check valve is to prevent backflow in a water system by restricting flow to one direction. They are commonly used on the discharge side of pumps to prevent backflow and emptying of pressurized lines. Check valves also used on potable water systems to prevent backflow for sanitary purposes.

Spring loaded poppet type check valves (upper right) have a spring loaded valve providing some resistance to flow, but insuring instant closure when flow stops. This is very important in most applications in reducing water hammer, particularly on pumped systems. They also provide positive closure which is important in sanitary applications. South Dakota state statutes and NRCS standards require two spring loaded check valves to isolate lines used for human consumption (potable water) from other outlets and branch lines.

Swing check valves (lower right) have a swinging flap which closes against a seat by gravity. They offer less flow resistance and friction loss but do not close instantly with flow reduction or provide positive closure for sanitary purposes. One application where swing checks are used is on overflow outlets for storage tanks and cisterns.

7.9 Gate Valves, Curb Stops, and Ball Valves

(1)

Shut-off valves used on private water systems and small group systems are typically one of the styles pictured. Generally, sizing for shut-offs can be at least two sizes smaller than the nominal pipeline size. Lines of one and one-quarter inch would use three-quarter inch valves; one and one-half inch lines would use one inch valves; and four inch lines would use two and one-half inch valves. Friction loss on these types of valves with nearly a full nominal flow area is negligible and using valves of equal size to the pipeline is not justifiable cost wise.

(2)

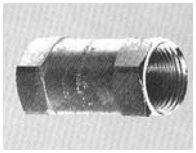
Gate valves (1) operate via a hand wheel and rising gate. They have the advantage of replaceable seat components should the valve need maintenance. Gate valves are not suitable for direct burial due to the need for periodic adjustment of the packing nut around the stem, and they may be more susceptible to "freeze-up" if not operated on a regular basis.

Ball valves (2 & 3) are a one-quarter turn valve utilizing a ball secured between "O" (3) rings to regulate flow. They are available in brass and CPVC plastic versions and provide positive shut-off, easy operation, and are relatively low cost. They are commonly used in well pit plumbing and manholes but are not suitable for direct burial, primarily due to the type of handle and the construction is somewhat less "substantial" than the curb stop shown below (4) which is specifically made for direct burial.

(4)

Curb stops (4) are so named because this is the type of valve used in city residential areas to shut the water off at the curb. Curb stops are a one-quarter turn "O" ring seal valve specifically intended for direct burial. They are available with threaded pattern surrounding the shut-off stem to facilitate attaching a threaded riser pipe which would extend to the ground surface and provide access for the valve key. Curb stop style valves are also available with a weep or drain hole in the valve body (shown). The style with the drain hole is called a "stop and drain" or "stop and waste" valve and is used at stock tank locations. When this type of valve is closed, the drain allows the water line downstream from the valve (leading to the tank and above frost line) to drain and prevent freezing. Valve keys (seven feet long) which fit over the valve handle and are used to operate the valve can be purchased or fabricated.

7.10 Flow Control Valves



Flow control valves are used to restrict flow when a specific volume is not to be exceeded. They consist of a metallic cylinder containing a flexible rubber disk with an orifice. As pressure increases the disk flexes resulting in decreased orifice diameter, resulting in a somewhat constant flow even a pressure varies. Flow control valves can be used on group systems to prevent a neighbor at a low elevation from "robbing" flow from a downstream neighbor higher in elevation. Flow control valves can also be used to "throttle" a pump, for example, to limit capacity and prevent over-pumping the supply. Flow control valves should never be direct buried since the small orifice is susceptible to plugging from grit and debris, and; therefore, may require regular maintenance. If these valves are used on group systems, they should be installed immediately preceding the float valve at tank installations. Installing the valve in these locations requires some degree of cooperation from neighbors, but is the only practical means of insuring they will not be removed and discarded because of owner frustration. Flow control valves are available in a full range of flow volumes from less than 1 gpm up to more than 50 gpm.

7.11 Air-Release and Air-Vacuum Valves

There are three general types of air valves commonly used on stock water pipelines:

1. Air relief/vacuum relief valve (relieve vacuum and expel large volumes of air during filling).
2. Air release valve (release small volumes of air under pressure).
3. Combination air/vacuum relief, air release (combines all functions in one valve).

The smallest valves available are usually adequate. Valves are rated according to maximum pressure that they can operate under, as well as, by orifice size. Only appropriate pressure rated valves should be used.

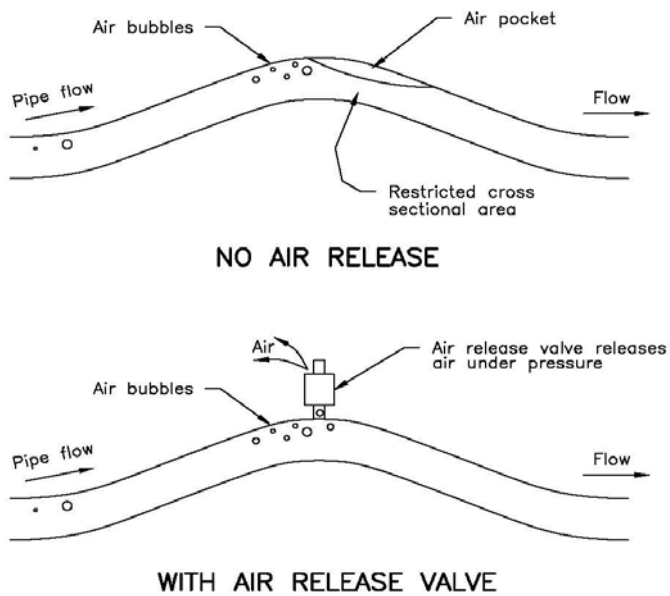
Air trapped in a livestock watering pipeline can reduce or even completely stop the flow of water in the line. This is a particularly critical problem in pipelines that operate under very low heads or pipelines of long lengths.

Air or gas gets into a pipeline in several ways including:

- When a pipeline is drained, air enters the line through hydrants or other openings.
- There are various forms of gases in well waters. These gases can come out of solution during pipeline operation. Deep artesian wells are particularly prone to air coming out of solution once the water previously under high pressure in the artesian aquifer, reaches the surface in a pipeline system under much lower hydraulic pressure.
- If the water level in a well or other source falls below the pump intake, air is drawn into the pipeline by the pump.
- In gravity systems, air can be drawn into the pipeline when water surface falls below the pipeline entrance.
- Air enters the system during operations to repair leaks, to perform other maintenance, and is initially present during start up of a new system.

Figure 7.23 illustrates what happens when air is trapped at a high point in a pipeline. A bubble is formed at the high point. The effect is to reduce the cross-sectional area of the pipeline and thus restrict flow. This has the same effect as inserting a short length of small diameter pipe in the pipeline. Velocity accelerates through the smaller section of pipe and friction loss is increased. Since friction loss is a function of the square of velocity, friction loss can increase drastically when a large bubble is present. If the bubble is big enough or there are many of them, flow can be cut off completely. In addition to the flow restriction they cause, air pockets can react in a way that aggravate water hammer problems. As velocity increases, the air pocket tends to be pushed down the pipe in some sort of elongated bubble. There may be several separate bubbles formed. If velocities are high enough and elevation difference to the next low point is not too great, the bubble may be pushed through to the next high point or outlet.

Figure 7.23
Air Release Valve Operation



Air locks are a frequent problem in very **low flow, low pressure pipelines**. An example of this type of system is a spring fed installation or on other gravity flow systems fed by a reservoir. In some cases, the velocity of water can be very low. Air bubbles do not get pushed out, even if the summit in the line is only one pipe diameter above the rest of the line.

The solution for **air lock problems in low pressure pipelines** can be one of the following:

- Install open air vents or air-vacuum valves, at all summits in the line.
- Install the pipe so there are no summits in the line. Carefully lay out the pipe so it is on either a constantly increasing or decreasing grade.
- Install hydrants at all summits in the line so the air can be vented manually.

For very low pressure pipelines, experience indicates that minimum pipe diameter should be:

- One and one-quarter-inch nominal diameter for grades over 1.0 percent.
- One and one-half-inch nominal diameter for grades from 0.5 to 1.0 percent.
- Two-inch nominal diameter for grades from 0.2 to 0.5 percent.

The solution for **air problems in high pressure pipelines** can be one of the following:

- Install continuous acting air valves or manual valves (frost-free hydrants) at summits to control the exhausting of air bubbles as air accumulates. The valves should be installed at the first major summit and any additional high points along the line which would collect air from long sections of pipeline. Stock tanks can also be strategically placed to provide air exhaust locations.
- Install air-vacuum valves at summits, as appropriate, for lines which must be drained.

There are three types of **functions that air valves perform**:

1. When a pipeline is emptied, air must enter the line some place. If provisions are not made for entry of air, a vacuum can be created in the pipeline. This can lead to collapse of the pipe or at least breaking of the water column, which creates gas or water vapor pockets in the pipeline. Although it is unlikely that the small diameter pipe in stockwater lines will collapse due to vacuum, it is a bad design practice to allow significant vacuum to develop in the pipeline and will likely prevent complete draining of the pipeline. It is;

therefore, important to have a **vacuum relief mechanism** at significant high points in the line.

Figure 7.24
Air Vacuum Valve

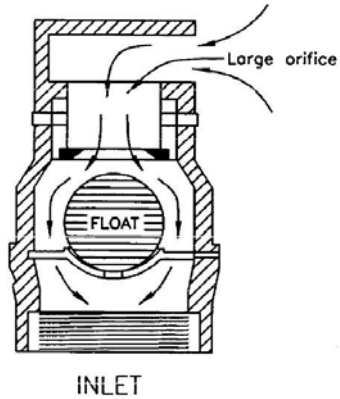


Figure 7.24 illustrates how a typical air-vacuum valve takes care of this function. Since there is no water in the valve chamber, the float drops on to a cage and allows air to enter the large orifice.

2. When an empty pipe is filled with water, air in the line must be released in large volumes. This can be done by leaving the outlets open. If the outlets are closed, air pressure will build up in the pipeline. When the outlets are eventually opened, high pressure air will escape causing water hammer which could be a problem on high pressure systems. Air-vacuum valves take care of this function, as well as, vacuum relief. **Figures 7.25** and **7.26** illustrate how a typical air valve functions. Since water has not yet entered the valve chamber, the float stays down on a cage. Large volumes of air escape through the large orifice. When the pipe fills, the float floats to the top of the valve and closes the large orifice. The valve then remains closed until the pipeline is again empty. The float will not drop unless pressure drops to zero, since pressure keeps it jammed against the orifice. This is the case even if an air pocket builds up in the valve chamber during operation, since the air pocket which is under pressure will keep the float from dropping.

Figure 7.25
Air Vacuum Valve Operation

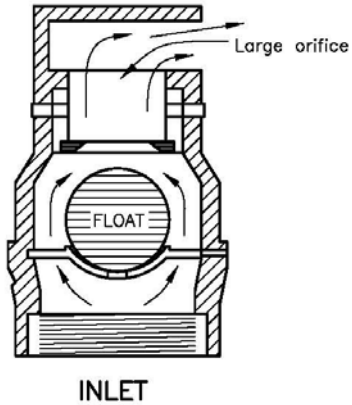
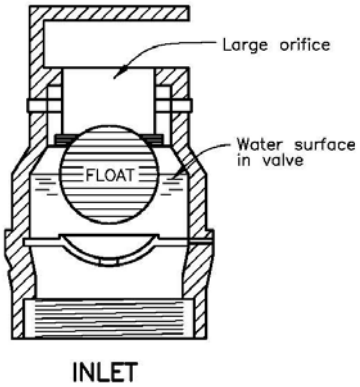


Figure 7.26
Air Vacuum Valve Operation



3. During operation of the pipeline, air bubbles and other gases come out of solution and build up as gas bubbles at summits in the line. There are usually also remnants of the large volumes of air present immediately after filling. If the summit is high enough, this

air will never push on through the line. Gases may eventually buildup to the point where the flow rate is seriously reduced or flow may even stop. It is not possible to predict how serious a problem this may be when designing a pipeline.

Figure 7.27 illustrates how a typical air release valve works. A heavy float and a small orifice allow the float to drop and open the orifice even when the system is under pressure. So when air bubbles gravitate to the air chamber, and the float drops, high pressure air is expelled from the valve.

Figure 7.27
Air Release Valves Operation

AIR RELEASE VALVE
FOR RELEASING AIR WHILE PIPE IS UNDER PRESSURE

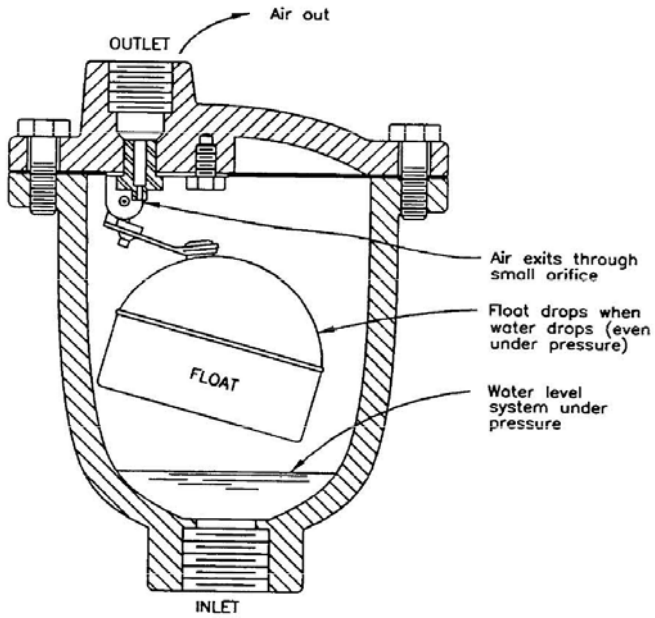
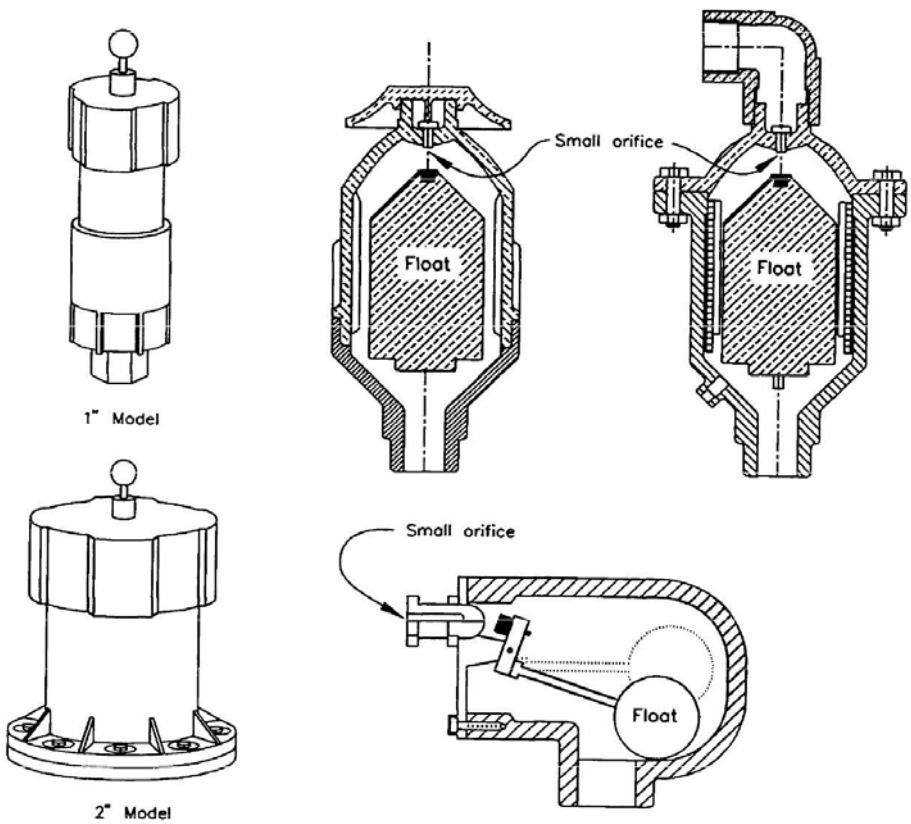


Figure 7.28 illustrates cutaway views of typical air valves used in stockwater pipelines. Different manufacturers have different ways of doing the same job. Some valves are made of plastic. These generally are adequate for low pressure operation. The cast iron models are for high pressure operation.

It is sometimes claimed that the air release (small orifice) valve will also serve the purpose as vacuum relief valve. The small orifice is not adequate to prevent high vacuum from occurring if there is a sudden break in flow or during emptying of the pipeline. The proper kind of valves should be used where they are needed.

A combination (three-way) valve should be installed at all significant summits needing air release, vacuum relief, and large volume air exhausting.

Figure 7.28
Typical Air Release Valves



In SD, policy and general practice has changed over the years from requiring air release mechanisms at all significant summits to a practice of installing an air release mechanism at the first summit only and then adding additional air release as needed. This valve at the first summit would catch and release most air introduced at the pump or gas coming out of solution on artesian wells.

Most systems operate satisfactorily with the minimum of venting locations. Air problems can also be lessened by strategic locating of stock tanks and hydrants which can function as manual air release valves.

In the typical, moderate to high pressure, moderate flow systems, there are frequently many small undulations in the ground surface and a few large humps. Trial and error on typical pipelines, in SD, has led to the conclusion that we can usually get away with not installing air vents or valves on these numerous summits. So far, the risk involved in using this rule of thumb has proved acceptable. The exceptions to this rule are the very low pressure gravity systems and the deep artesian wells containing gas. Air release valves should not be spared on these systems, many of which have had additional valves added years after the initial installation due to continuing problems with flow.

Valves for controlling air should not be added to a system without due consideration because they not only cost money but also can be a maintenance problem and many times are removed later by the operators. However, if they are needed, it is important they be planned and installed.

The **size of the valve** for small diameter stock water pipelines is generally not critical, but rather the issue is whether a valve is needed.

The typical situation requiring **vacuum relief valves** are shallow bury lines which must be drained. Small diameter pipelines (six-inch or less) may be prone to separation of the water column in a vacuum situation, but rarely if ever would the line be at risk of collapse, and; therefore, the size of the opening to the atmosphere is not important. As long as a vacuum valve is installed at the high points, the line will eventually drain. A valve with a larger opening to the atmosphere may drain the line somewhat faster, but without any real benefit.

Air valves which exhaust **large volumes of air on filling** are usually not needed as long as outlets along the pipeline route are opened to provide locations for the air to be exhausted.

Continuous acting air release valves which use small orifices to expel air bubbles which collect in pressurized lines increase in venting capacity with increased pressure. The volume of air actually vented through the orifice continues to increase indefinitely as the pressure increases. Since air is compressible, the volume is expressed in cubic feet free air at atmospheric pressure. **Figures 7.29** and **7.30** give venting capacities for various sized orifices. The standard orifice size for air release valves is typically a 3/32” or 1/8” opening which will exhaust up to 20 standard cubic feet free air per minute (SCFM) depending on orifice size and line pressure. To put this in perspective, a 4” diameter line flowing full of water at 75 gpm equals a flow of 10 cubic feet per minute. Since only a small percentage of the total volume of flow is entrained air (most likely less than 2 percent for shallow wells and possibly as high as 10 percent for a gaseous artesian), the volume of air collecting at the high point would be approximately 1 cubic foot per minute, even in the worst of conditions. This volume of air could be handled by a 3/32” orifice with a minimal pressure of approximately 4 psi. **Therefore, the size of the air release orifice for most stock water lines is irrelevant** and the most important feature of the installation would be to install the air release valve on a tee of equivalent size to the pipeline (s x s x s) to provide the maximum area for collection of air and subsequent venting.

Figure 7.29
Discharge of Air Through Air Release Small Orifice

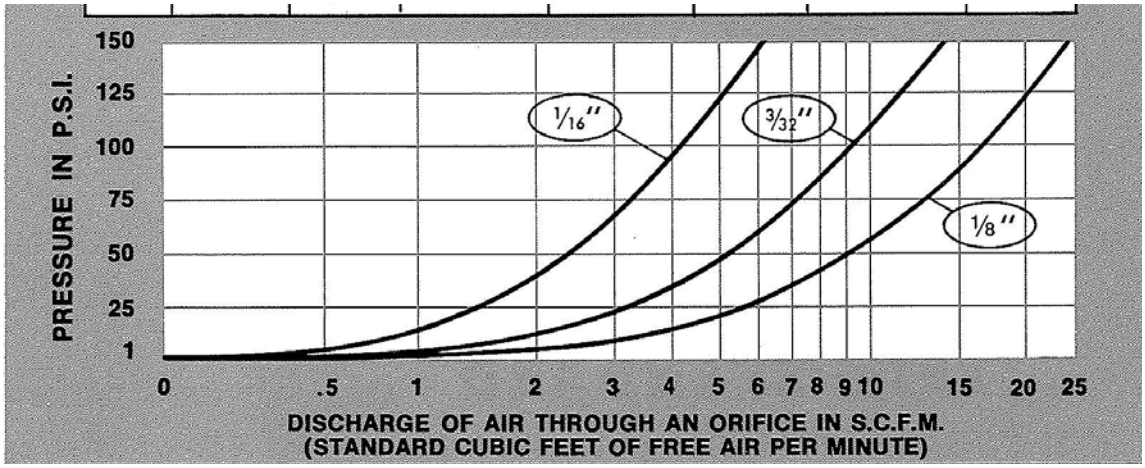
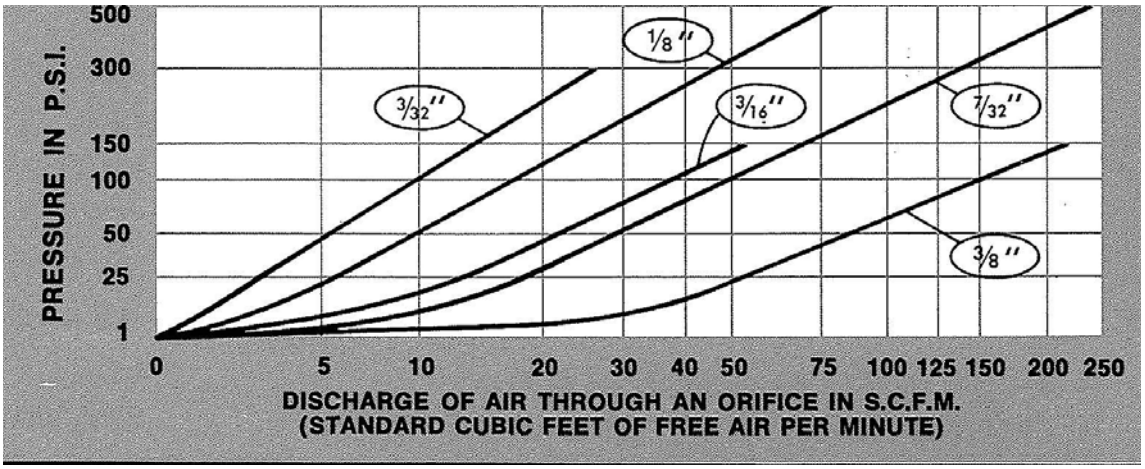


Figure 7.30
Discharge of Air Through Air Release Large Orifice



7.12 Frost-Free Hydrants

Frost-free hydrants are suitable for use at any outlet location or tank where the hydrant will not be continuously open (handle up) in below freezing weather. The typical application at a tank would be to attach a float valve to the hydrant with a short hose, and then leave the handle up (open) to automatically fill the tank. This is an ideal application for spring, summer and fall grazing but is susceptible to freeze-up in winter applications. **For winter applications use a stop and drain valve** and enter through the tank bottom.

A hydrant is frost-free due to the shut-off valve being located at the base of the hydrant. The handle is connected to a rod inside the hydrant which operates the valve at the base. The hydrant drains completely when closed through a drain hole in the shut-off valve. The hydrants should be installed with a gravel pack around the drain valve to insure proper functioning. Frost-free hydrants are available for various bury depths from one to eight feet and are commonly stocked in five and six feet bury models.

Frost-free hydrants should not be used for potable water supplies as the buried stop and waste valve does not provide any protection against contamination.

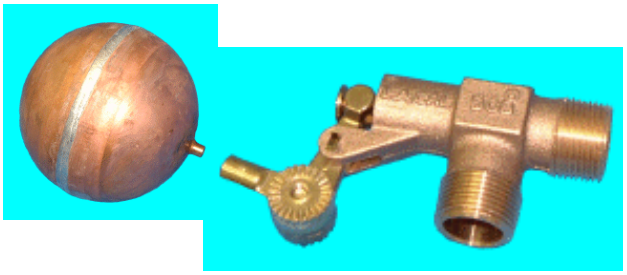
Frost-free hydrants are typically rated up to 125 psi; however, the seals incorporated in the hydrant shut-off may have reduced life with long-term operating pressures over 100 psi.

7.13 Float Valves

Common float valves for stock tank use are typically one of two types; either side mounted at water level which is typical for the float shown in **Figure 7.31** when used with a frost-free hydrant or of a type mounted on the tank bottom and fully submerged such as is typical of the "toilet tank" type float shown in **Figure 7.32**. These floats typically carry a rated maximum operating pressure of 100-125 psi. Regardless of the stated operating pressure of these valves, maximum design static pressures at pipeline outlets should be kept below 100 psi (ideally 80 psi or less) if at all possible. Water systems with operating pressures over 100 psi at the outlets have above average frequency of maintenance issues with leaking or inoperable floats and overflowing tanks.

Figure 7.31
Side Mount Float Valve

Figure 7.32
Toilet Tank Type Float Valve



CHAPTER 8

CENTRAL STORAGE AND STOCK TANKS

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CHAPTER 8

CENTRAL STORAGE AND STOCK TANKS

8.1 Central Storage Considerations

Utilizing a reservoir for central storage in a water system may be done for a variety of reasons to insure a reliable, uninterrupted water supply. Central storage reservoirs are commonly used 1) to provide for peak demand flows which cannot be met by a low producing well or supply source; 2) as a regulating/supply reservoir for a booster pump; and 3) as a "water tower" when placed at a high point in the water system that holds one or more days of water supply to insure dependability, as well as, various other uses. A general discussion of considerations involved in planning a central storage tank is provided in Chapter 2 (Section 2.4, Central Storage).

Determining the type of tank to use for a specific installation depends on factors such as 1) season of use; 2) storage volume required; 3) if the storage will provide potable water; 4) skills required for construction and ease of installation; 5) local availability; 6) susceptibility to vandalism; 7) projected life of installation; and 8) cost.

Central storage tanks used in individual and small group systems for year round use are usually completely buried or installed with just the top of the tank lid exposed. The ground heat and heat from incoming water normally keeps the tanks ice free.

8.2 Above Ground Central Storage

Installations for non-winter use can be installed above ground. Above ground towers and tanks are common for year round use for municipalities and rural water systems, however these systems remain functional in winter due to the latent heat from circulating water, insulation, agitation and even adding heated water. For the typical stock water system though, an above ground tank for winter use is just not practical.

An above ground installation 1) is subject to UV degradation, 2) may need anchoring if tank is lightweight and will be unstable in high wind when empty 3) may be susceptible to vandalism in some locations 4) will most likely be susceptible to more algae and bacterial growth due to temperature and degree of tank opaqueness.

Among the tank types which may be considered for above ground installations are heavy walled polyethylene tanks and steel tanks. Figure 8.1 illustrates one type of vertical polyethylene tank. There can be quite significant differences between tank manufacturers in wall thickness, UV inhibitors, and overall tank quality which will significantly affect tank lifespan and durability. Only the most durable of these tanks should be considered for permanent use in water systems. Steel tanks should be evaluated on wall thickness and Coating of interior and exterior surfaces, which will ultimately determine the tank lifespan. Prefabricated tanks manufactured for above ground use are not suitable for burial, since the tanks are not designed to resist external earth loads.

Figure 8.1
PE Tank
(Above Ground)

Plumbing for these tanks should include an overflow to prevent damage from overfilling, adequate venting to equalize air pressure on filling and emptying, some mechanism to control water levels, and provisions for draining the tank. Installations for above ground tanks should exclude livestock.

8.3 Buried Central Storage

Buried tanks are most commonly poured-in-place concrete, pre-cast concrete, fiberglass, or PE. Buried tanks need overflow, venting, water level control, and draining provisions. Tile drains around the tank perimeter are common on most sites to prevent an empty tank from becoming buoyant if high ground water conditions exist. High water table conditions are possible even on well drained sites should line breaks or tank leaks saturate the site. Mounding around the tank to provide at least of portion of the earth cover will increase the likelihood of an outlet to the tile drain vs. tank installed positioned entirely in an excavation. Manholes to provide access for the tanks must be sized with consideration for any equipment needed for tank maintenance or replacement with a minimum 20” diameter used for access used exclusively as a manway. Livestock exclusion is recommended for all buried tanks.

8.3.1 Poured-in-Place Concrete

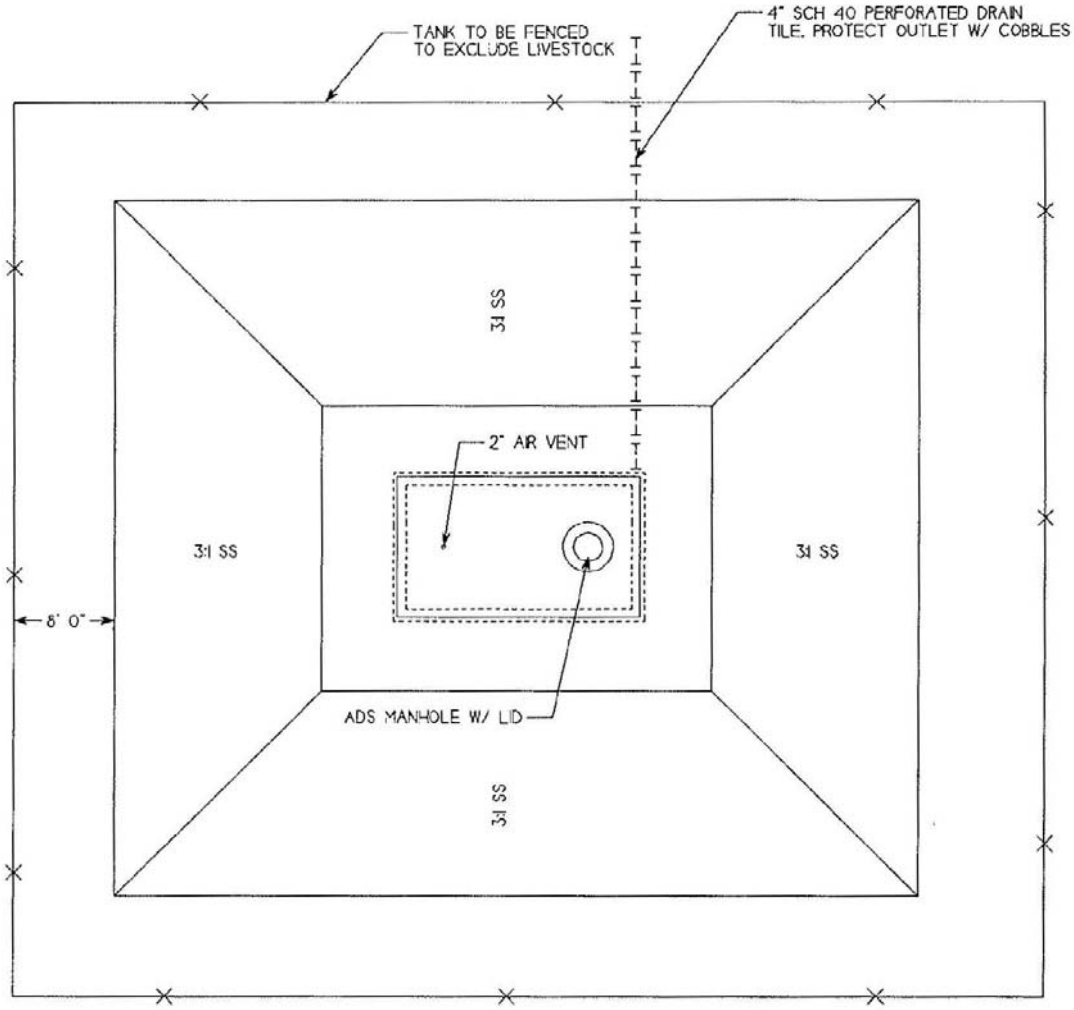
The poured-in-place concrete tank offers the advantage of a design which can be tailored to the specific project needs. Designs based on Midwest Plan Service standard plans have been used for most poured-in-place tanks. These designs typically use 8” thick walls, 8 ft. interior wall height, interior widths of 10-12 ft. (20-24 ft. with interior center wall support) and length determined by volume requirements. The concrete lid is normally left exposed without any earth cover. It is important that those individuals involved with the tank construction understand no earth cover will be allowed over the structure (unless specifically taken into account in the reinforcing steel design). Concrete tanks may be used for potable water and in potable applications the interior surfaces of the tank are usually sealed with a National Sanitation Foundation (NSF) approved product. Also, for potable tanks, the access opening must have a tight sealing cover or lid which will provide a sanitary seal. Costs for this type of tank are probably comparable to other tanks on a per gallon basis, as long as skilled labor is available locally to set the concrete forms and install steel reinforcement.

Figures 8.2 and 8.3 provide site details for a typical 10,000 gallon poured-in-place concrete tank.

Figures 8.4 and 8.5 provide typical reinforcing steel details.

Figures 8.6 and 8.7 show details of a concrete tank with an integral well pit poured at one end to provide for all plumbing and equipment.

Figure 8.2
Site Details 10,000-Gallon Poured-in-Place Concrete



PLAN VIEW
SCALE 1" = 10'

Figure 8.3
Site Details 10,000-Gallon Poured-in-Place Concrete

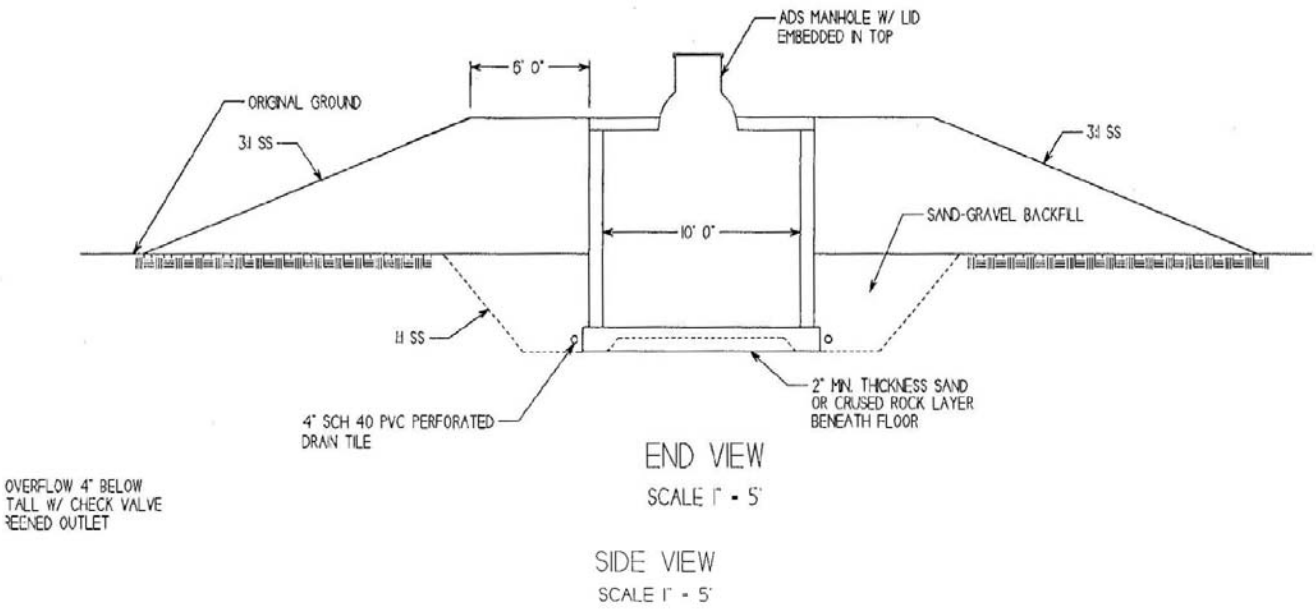
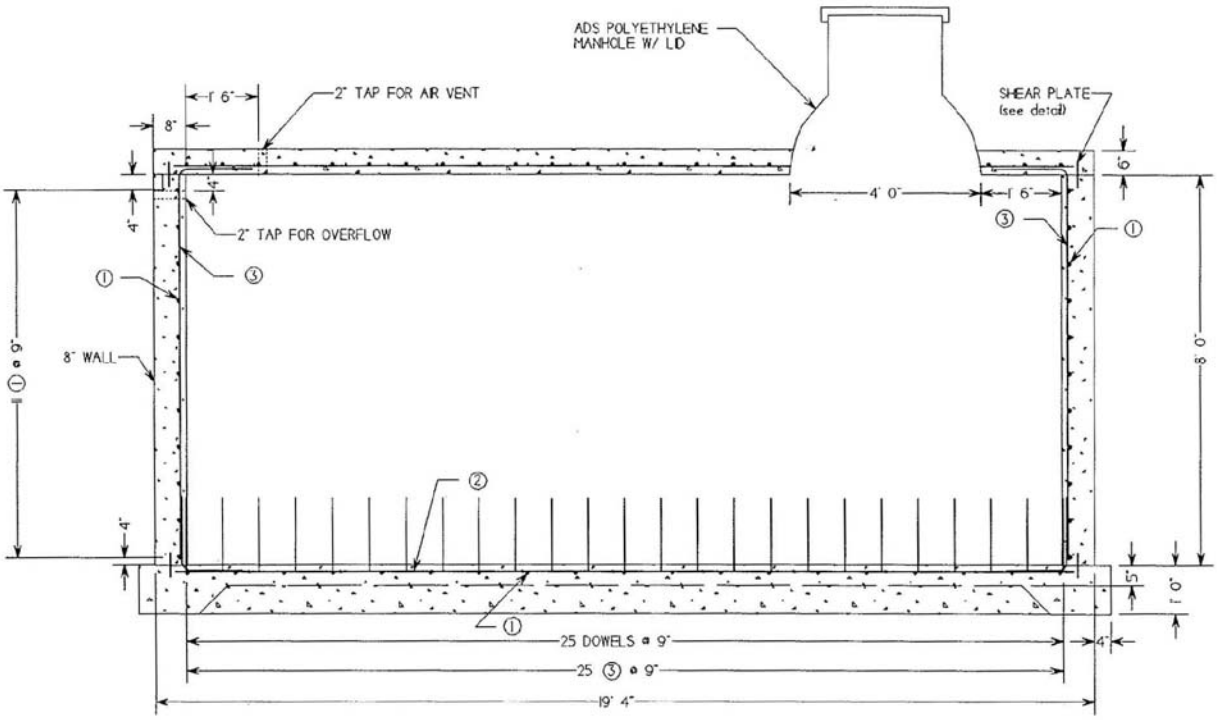
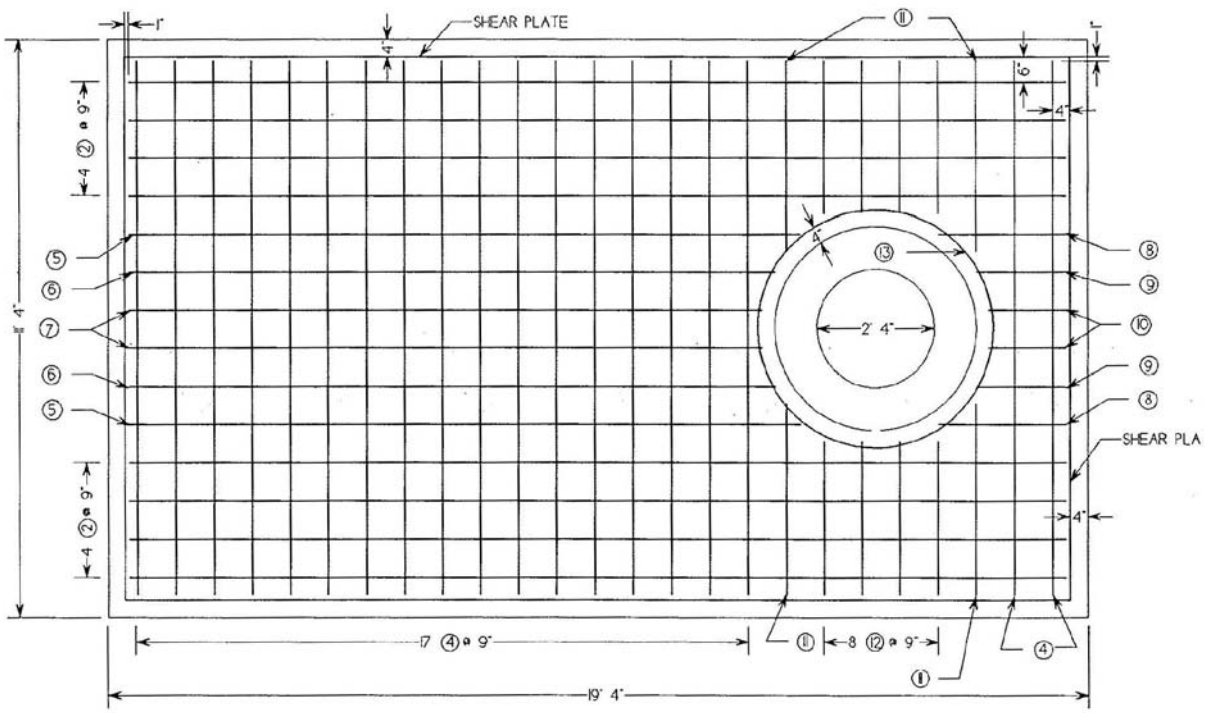


Figure 8.4
Steel Details 10,000-Gallon Concrete Tank

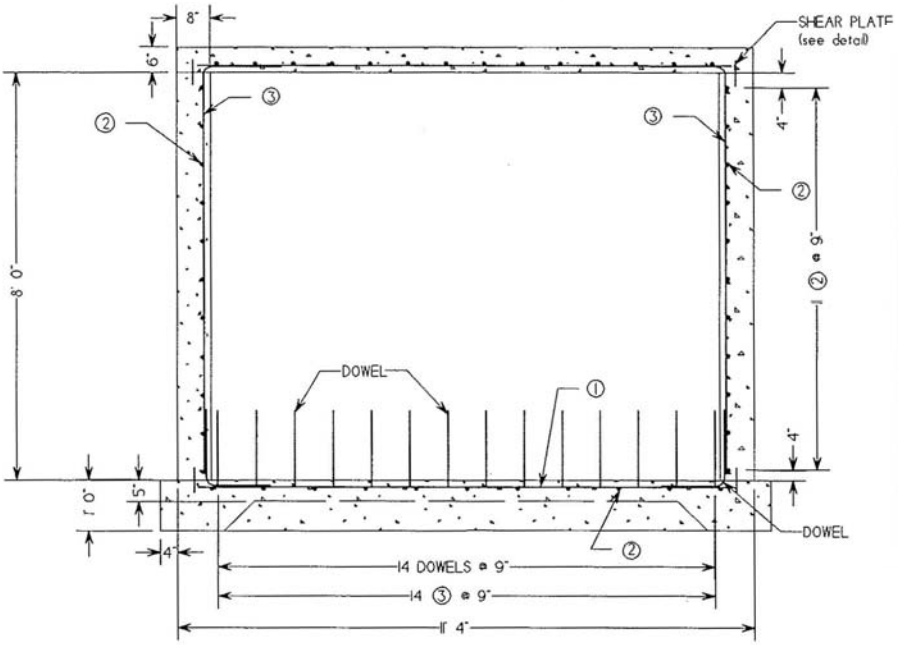


SIDE VIEW



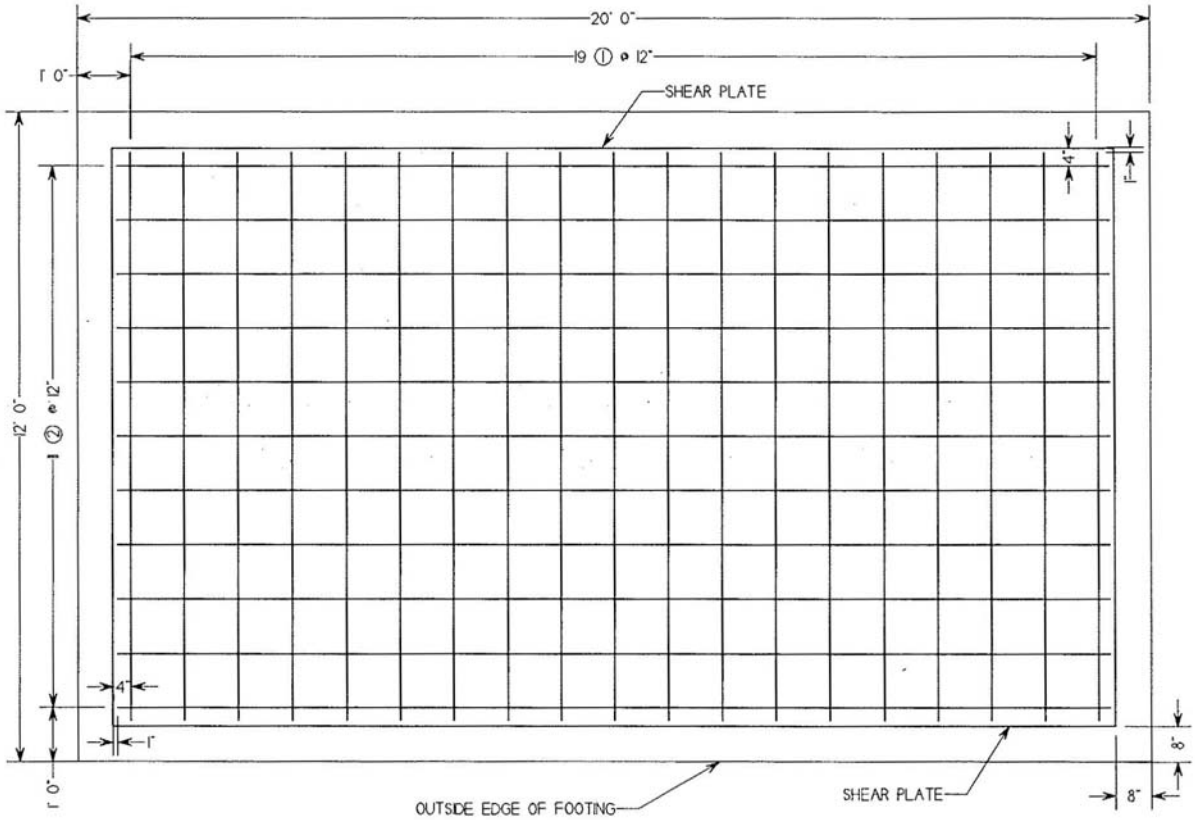
TOP OF TANK

Figure 8.5
Steel Details 10,000-Gallon Concrete Tank



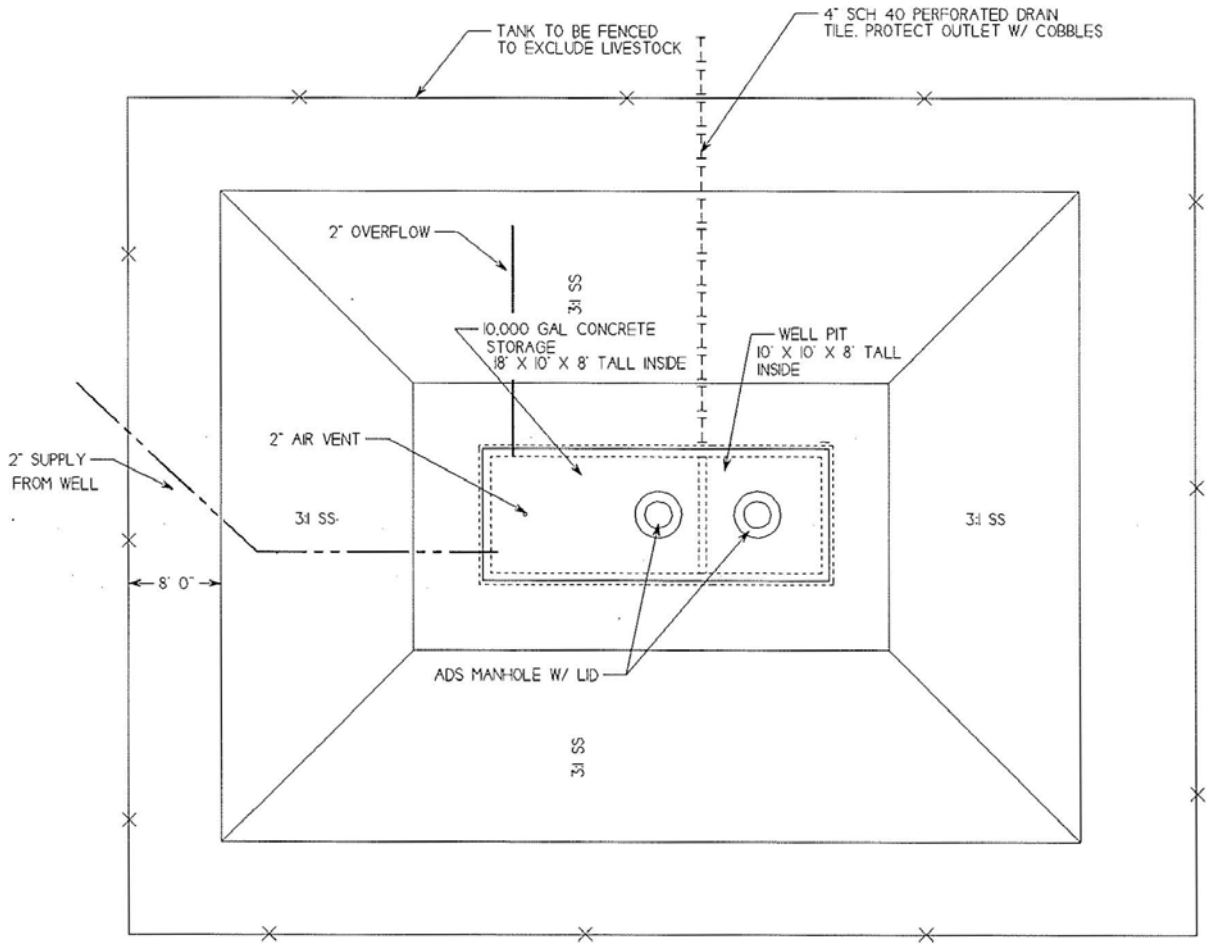
END VIEW

BAR TYPES								
TYPE STR.				C TYPE 21 B		TYPE 19		
STEEL SCHEDULE								
LOCATION	MARK	SIZE	QUANTITY	LENGTH	TOTAL LE	TYPE	B	C
FLOOR	1	4	19	10'-6"	199'-6"	STR.		
	2	4	11	18'-6"	203'-6"	STR.		
	DOWEL	4	78	2'-9"	214'-6"	21	1'-3"	1'-6"
WALLS	2	4	22	18'-6"	407'-0"	STR.		
	3	5	50	9'-6"	475'-0"	21	1'-6"	8'-0"
ENDS	1	4	22	10'-6"	231'-0"	STR.		
	3	5	28	9'-6"	266'-0"	21	1'-6"	8'-0"
TOP	2	4	8	18'-6"	148'-0"	STR.		
	4	5	19	10'-6"	199'-6"	STR.		
	5	4	2	13'-3"	26'-6"	STR.		
	6	4	2	12'-9"	25'-6"	STR.		
	7	4	2	12'-6"	25'-0"	STR.		
	8	4	2	2'-6"	5'-0"	STR.		
	9	4	2	1'-9"	3'-6"	STR.		
	10	4	2	1'-6"	3'-0"	STR.		
	11	5	4	3'-9"	15'-0"	STR.		
	12	5	8	3'-0"	24'-0"	STR.		
	13	4	1	14'-8"	14'-8"	19		



FLOOR W/ FOOTING

Figure 8.6
Concrete Tank w/Well Pit – Plan View and Side View



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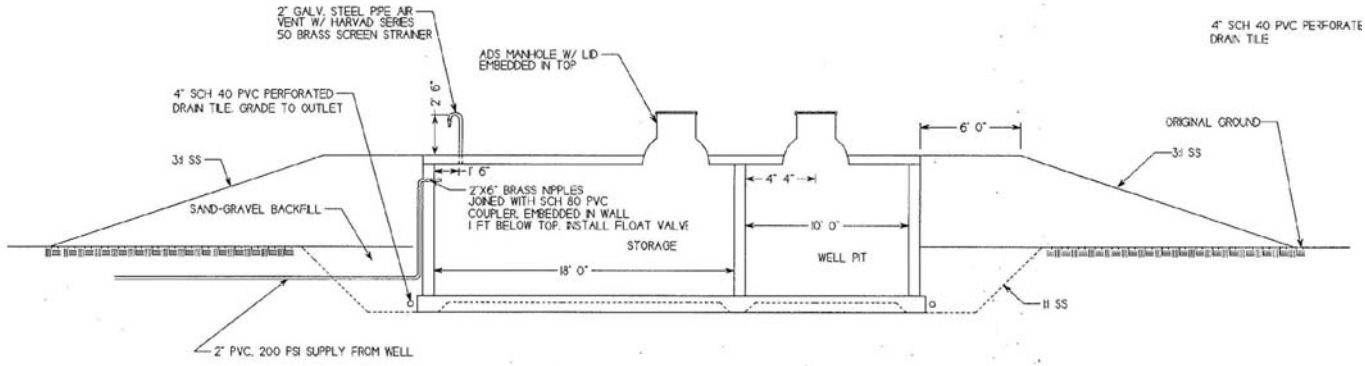
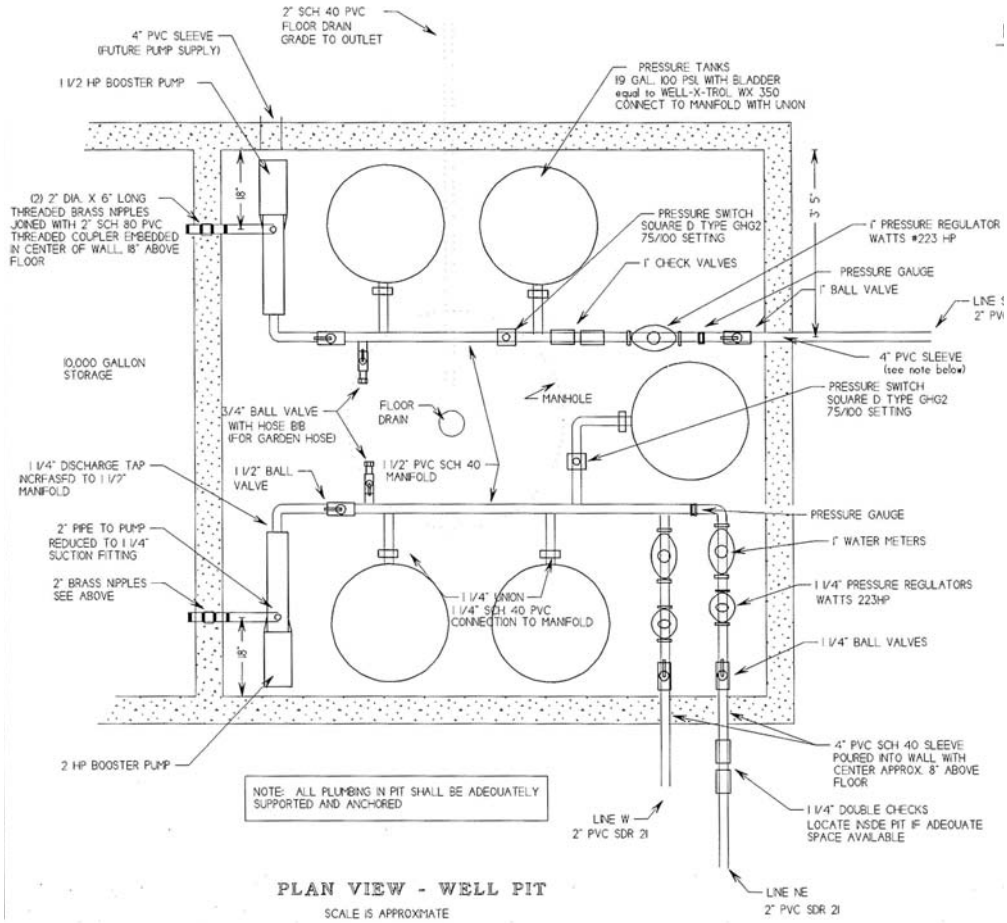


SIDE VIEW

Figure 8.7
Well Pit Plumbing Details



8.3.2 Fiberglass Tanks

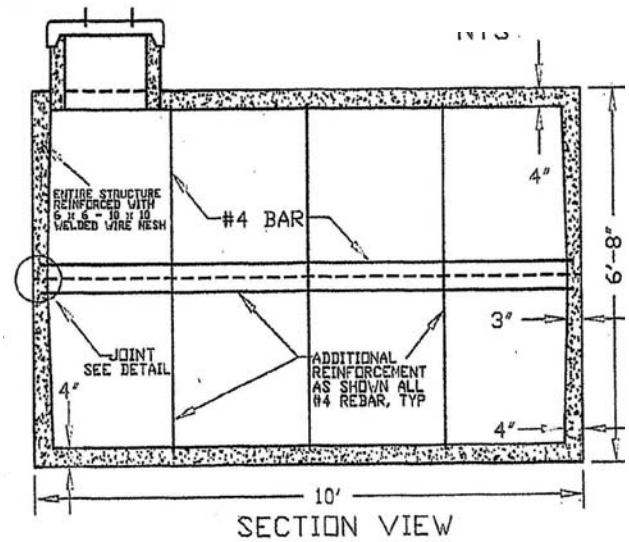
Fiberglass tanks designed for direct burial are manufactured by a number of companies and are available with a variety of options depending on the specific need. The tanks are cylindrical ribbed fiberglass in sizes ranging from approximately 600 gallons to 50,000 gallons. Tanks most commonly used for central storage are 8-, 10-, or 12-ft. diameter with the length determined by storage volume required. All of these tanks are designed to be installed using granular backfill which insures a uniform, controlled loading on the tank. These tanks require either concrete deadmen anchors or tile drains installed below the tanks. Models are available for both potable and non-potable water applications. These tanks are strong, corrosion resistant, watertight, and easily installed and make excellent tanks for potable applications because of the ease of constructing and maintaining a sanitary installation.

These tanks can be installed by anyone with a general construction knowledge. The fiberglass tanks are typically not available locally and would require some lead time for special order and delivery. Costs are comparable to other tanks on a per gallon basis and in 2008 the cost of one of these tanks delivered to a South Dakota distributor would be approximately $0.80 - $1.00 per gallon depending on size, including freight. The total cost of the tank to would need to include the actual charges to install including delivery to site, excavation and granular backfill.

8.3.3 Pre-Cast Concrete Tanks

Pre-cast concrete tanks are produced by a number of plants located around the state manufacturing concrete products, and; therefore, availability is one of the big advantages of a pre-cast tank. Sizes typically range from 1,200 gallons up to 5,000 gallons. All tanks are manufactured in two halves and joined in the field using some type of joint seal. Tanks less than 2,500 gallon can usually be unloaded and set in place with a contractor's front-end loader, whereas, larger sizes may require a crane. Wall thickness and steel reinforcement on these tanks is usually the minimum needed to support the expected loads since dimensions are limited by weight and standardization of forms and; therefore, the tank designs do not meet NRCS concrete standards based on ACI 318 code for working stress. Use of these tanks may be approved for use in specific applications by the engineer with approval authority. These tanks are typically not manufactured for use with potable water. Costs per gallon for the pre-cast tanks are less than either the poured-in-place concrete or the fiberglass. Figure 8.7 details a sectional view of a typical 2,500 gallon tank.

Figure 8.8
Pre-Cast Concrete Tank



8.3.4 PE Tanks

PE tanks, Figure 8.8, designed for use as cisterns for potable water applications (NSF approved) are manufactured by a number of companies. Sizes range from approximately 600 up to 1,700 gallons with the larger sizes being appropriate for cisterns for residential applications. These tanks require granular backfill to insure a uniform, controlled loading, and a well drained site. Maximum cover over the top of the tank is approximately two feet. These tanks are light weight, corrosion resistant, water tight, and very easy to install. A variety of fittings (i.e., B) are available for installing in the tank bulkhead to allow for piping connections. The tanks are available locally and are easily transported to the project site without the use of special equipment.

Figure 8.9
PE Tank (Buried)

8.4 STOCK TANKS

8.4.1 General

Stockwater tanks come in an almost infinite number of shapes and sizes and are made from many different materials. In 2005, NRCS, in SD, implemented policy which sets minimum stock tank storage and perimeter requirements for cattle. This policy is contained in Engineering Technical Note 2005-1, Watering Facility Design Criteria for Cattle. The minimum tank size is a function of the number of cattle, the pipeline design flow, distance traveled to water, and stocking densities.

It takes some consideration to select a stock tank that will serve its function, be cost effective and last for at least a reasonable length of time. A stock tank must withstand a very hostile environment. Water used by livestock is often corrosive; ice and frost heave tend to damage the tank and foundations; animals step in tanks and rub up against them; people shoot at them; and animals tromp away the soil around a tank. All of these factors working together can make a tank short lived if proper precautions are not taken. The NRCS suggested lifespan for the Conservation Practice Standard (CPS) Trough or Tank (614) is 10 years, although quality tank installations, properly maintained, will last 30 years or more.

8.4.2 Tank Materials

The type of tank should be chosen not only for economic reasons, but for durability and functionality.

Used heavy equipment tires have become very popular in recent years and should continue to be popular as long as the tires are available in adequate supply. Condition of the used tire does usually not detract from the lifespan or proper functioning of the tank except in rare circumstances where the tire casing is completely worn out and extremely thin walled and prone to leaks. These tanks offer the advantage of being extremely durable and almost indestructible. The tanks will not be harmed by freezing of the tank (tank plumbing may be vulnerable depending on configuration) and do not require a granular fill or concrete base. The tanks are structurally stiff enough that a well leveled earthen base is adequate; however, if the tank is not set on concrete, then a regular maintenance item will be replacing earth fill around the perimeter. These tanks are prone to leaking from the bead area at the center of the tire if not properly installed. They must be drained in the fall to drop the water level below any plumbing install in through the tank bottom at the center bead. Sizes typically range from 8-12 ft., although a supply of the larger sizes can be hard to find. Figure 8.10 shows a plan detail for a tire tank and Figure 8.11 is a photo of an installed tire tank.

Fiberglass tanks are very resistant to deterioration by corrosion or chemical attack. They are readily available, light weight, and easy to install. A disadvantage is that fiberglass tanks can be susceptible to mechanical damage. The tank bottom can be damaged if large animals get into the tank and the subgrade beneath the tank does not provide adequate support. Also, the light weight tank can be shoved around or even moved by wind if not secured or anchored. The extremely smooth surface can also be difficult for any animal getting into the tank to get out. For these reasons, fiberglass tanks are usually installed with a two or three post arrangement joined by structural lumber which not only secures the tank but can prevent livestock entry. Fiberglass tanks should be installed on a granular fill or concrete base.

Thickness of fiberglass will determine how resistant the tank is to mechanical damage. It is possible to repair damaged fiberglass, which is one advantage of using this material.

Tank size is limited to what can be transported to the site. Sometimes this limitation is overcome by combining tanks built-up from two or more component parts. Sizes of 8-12 ft. are common in round styles and sizes up to 8ft. x 21ft. are available in rectangular or oblong shapes. Several tanks can also be put together in series to get the total gallons required.

Figure 8.10
Used Heavy Equipment Tire Plan Detail

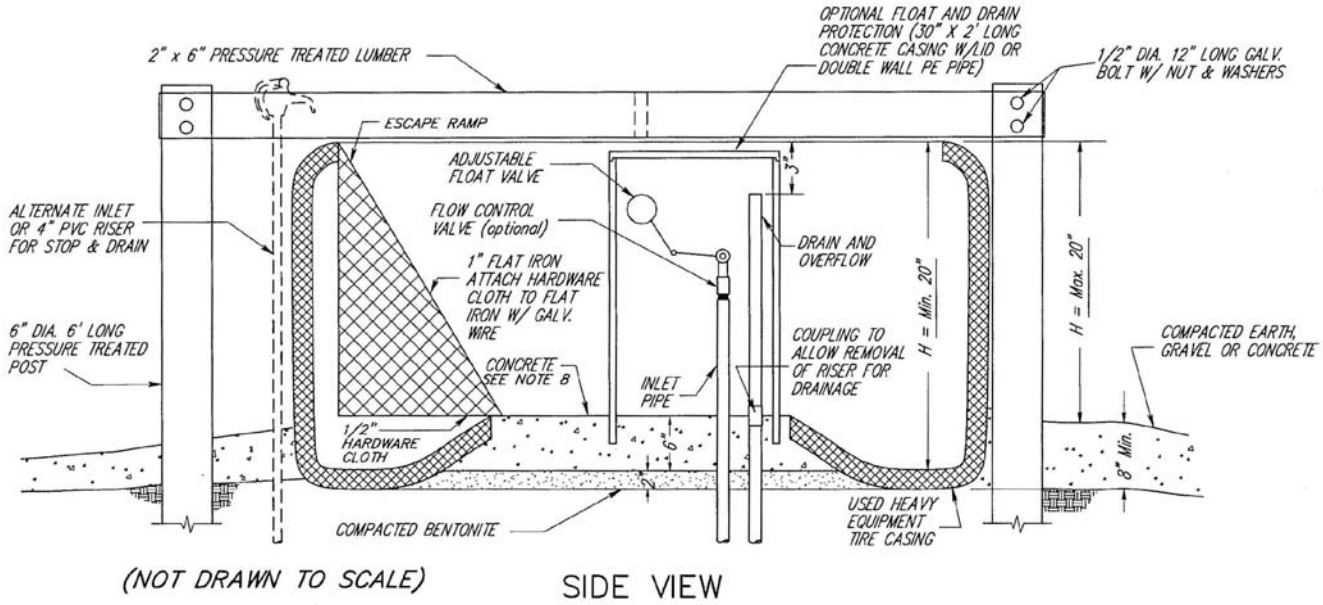


Figure 8.11
Used Heavy Equipment Tire Installation

Galvanized steel tanks are generally of two kinds: (1) those assembled at the site from standard heavy gauge corrugated steel segments; and, (2) prefabricated light weight manufactured tanks of smooth light weight galvanized steel.

Stock tanks made from corrugated steel segments form large diameter stock tanks made up of curved corrugated galvanized steel sheets which are bolted together. These are commonly called bottomless tanks. Mastic is used in the joints. The steel and galvanizing are usually heavy. The bottom of the tank can be made of reinforced concrete or a heavy plastic liner underlain with bentonite clay. The concrete bottom is the most durable, most desirable, and longest lasting tank, but also the most expensive. Properly installed and cared for, a corrugated steel tank with a concrete bottom will last 25 years or more. The real advantage to these tanks is the large diameters available, which can provide a large storage volume and extensive drinking perimeter with the capability to provide multiple days of storage for large herds. Sizes are available up to 39 ft. diameter or more in corrugated sheets of 25½" typically used for concrete bottoms or 33¾" heights typically used with flexible membrane bottoms. Storage volume will vary depending on the type of bottom and embedment used but the larger sizes will hold 17,000 gallons or more.

Manufactured steel stock tanks are typically smaller diameters made of light gauge steel with a minimum of galvanizing. The thickness of steel and galvanizing vary widely in manufactured steel tanks. In SD, these tanks are not considered suitable for a permanent installation due to the relatively short lifespan expected from the lightweight steel. The corrosive nature of the heavy clay soils and/or artesian waters provides a very harsh environment for these tanks. Also, the structural stability of the tank's walls may be lacking on the larger diameter tanks and be subject to being pushed in by the cattle. The manufactured steel tanks are primarily used as a portable or temporary tank.

Figure 8.12
Steel Rim Tank With Concrete Bottom (with calf creep tank)

Concrete tanks, when properly constructed, can provide an extremely durable tank.

Pre-cast concrete tanks are typically relatively small thin walled tanks manufactured by plants specializing in septic tanks and other concrete products. Sizes are limited by total weight and the capability of nonspecialized equipment to handle and transport.

Cast-in-place concrete tanks have been rarely used since the 1950's except for projects such as frost-free winter tanks utilizing earth cover for insulation.

The two environmental factors that can rapidly deteriorate concrete are freeze-thaw action and deterioration of the concrete from sulfates in the soil or water. Stock tanks are in an ideal environment for damage due to freezing and thawing. Pores in the concrete fill with water, freeze, and as a result, the concrete will spall. High sulfate concentrations are present in water from some of the artesian aquifers, in SD, and the sulfates of sodium, magnesium, and calcium (salts known as white alkali) are frequently encountered in soils and ground water of western SD. There are practical things that should be done to make quality concrete that will resist these elements:

1. Use a low water cement ratio. Use the minimum amount of water in the concrete that is possible consistent with being able to place the concrete. Use a minimum of six bags of cement per cubic yard of concrete. This will produce a concrete less porous to water.
2. Use Type II cement which is sulfate resistant or use Type V in the most severe environments subject to sulfate attack.
3. Place the concrete within one and one-half hours after adding water to the cement. This is sometimes a challenge when using ready mix concrete at remote sites. If travel time between batch plant and the site is a problem, add the cement and water at the site. Adding water to make concrete more workable is a leading cause of poor concrete due to a higher water/cement ratio which results in lower compressive strengths and more shrinkage cracks.
4. Use air entrained concrete with air content within NRCS specification range. Air entrainment can be obtained by using cement with built-in air entrainment additives, or by adding admixtures at the concrete batch plant. Cement with air additives built-in is cement type IIA. The entrained air will create small air bubbles in the concrete which improve durability.

Foundation frost heave can also be a problem, particularly if the foundation is wet when the ground freezes. The solution is to build the tank so there will be good drainage away from the tank, provide proper overflow drains for the tanks, and provide a well drained granular base material under the tank.

These tanks all require some skill to construct. If multiple copies of the same tank are to be constructed, costs can be reduced and quality increased by constructing reusable concrete forms.

PE tanks are being manufactured in various configurations by a number of companies. They are very light weight, tough, corrosion resistant, and fairly economical. These tanks are structurally very flexible and require a uniform base fully supporting the entire tank, as the tank will easily conform to any minor irregularities once filled with water. As with the manufactured galvanized steel tanks, PE tanks are considered primarily for use as portable or temporary tanks.

8.4.3 Design Considerations

Tanks are installed in an almost infinite range of configurations depending on the type of tank, the watering needs, season of use, and the ingenuity of the operator. Determining what is acceptable for a specific installation is a function of satisfying the following requirements:

- **Tank foundation and subgrade** – the alternatives for the type of base used beneath a tank are typically of three types: undisturbed earth, gravel or crushed rock, or concrete. Tire tanks may be set directly on leveled, undisturbed earth, and any of the other tank materials require a prepared base of granular fill or concrete. Concrete provides the most permanent, structurally sound base but is also the most expensive.

- **Tank apron** – the apron area, which would generally be the area around the tank perimeter extending out eight ft. or more, requires regular maintenance unless concrete is used. Aprons of gravel or compacted earth may be acceptable, depending on the type of tank, but will be continually worked away by the constant hoof action of the cattle and will require regular maintenance. For tanks set on concrete, the base is usually extended a minimum of two ft. beyond the tank to provide enough concrete for the front feet of the livestock, and ideally would extend eight ft. beyond the tank perimeter. If the apron area is not maintained to provide positive drainage away from the tank, standing water and hoof action quickly deteriorate the apron conditions.

- **Protection and anchoring** – the protection and anchoring requirements for stock tanks depend on 1) susceptibility of the tank to movement or shifting from livestock or wind if empty; 2) need to prevent livestock getting into tank and damaging tank bottom; and 3) the need to protect the tank plumbing. The individual responsible for determining the requirements of a specific installation needs only to satisfy the above conditions to decide if a tank meets NRCS specifications.

  Lightweight tanks requiring anchoring, such as fiberglass, typically use a two-post or three-post arrangement connected by dimension lumber for anchoring as well as for protecting the tank plumbing. If the tank is set on a concrete base, the bottom should not be damaged by cattle getting into the tank and a two-post anchor arrangement would be adequate. For lightweight tanks set on a gravel base, cattle entry should be prevented using a three-post arrangement which can also be configured to protect the float and any plumbing. Bottomless tanks using flexible membrane liners should have protection to keep livestock out of the tank particularly if the operator intends to mound up earth fill against to tank side to make the tank more accessible for calves.

  Tanks structurally strong enough to be unaffected by entry of livestock such as tire tanks, concrete tanks, and steel rim tanks with concrete bottoms need only protection adequate to protect the plumbing, including the float, drain, and stop and drain valve or hydrant. Plumbing protection can be provided using numerous methods including posts and lumber, two ft. sections of concrete casing or large diameter PE pipe with covers or welded steel.

- **Seasonal maintenance** – tank overflows are required when there is no control such as a float on the inlet. They are also highly recommended even when a float valve is used. Float valves occasionally do not close properly and an overflow is insurance against damage caused by the tank running over. A combination overflow and drain is usually incorporated into the tank bottom if either an overflow or drain is needed by way of installing a PVC coupling flush with the bottom of the tank. A length of two- or three-inch diameter PVC is inserted into the coupling to control the water level for the overflow, and the PVC pipe is simply pulled out of the coupling if the tank needs to be drained. The purpose of an overflow is to carry excess water away from the tank an adequate distance so water does not make a bog around the tank. The overflow drain needs to extend at a minimum the distance needed to "daylight" the outlet and far enough to be away from the area the cattle are concentrating to a suitable outlet. Prefabricated tanks such as fiberglass or pre-cast concrete typically utilize a drain plug in the tank side draining directly onto the tank apron. Tanks which are not installed with any provisions for draining (i.e., other than a siphon hose), typically do not get drained. Many of these tanks are left to freeze solid over winter regardless of the stated intentions of the operator.

- **Winter use** – tanks used for winter use are of three distinct types: commercially manufactured specifically for winter use, conventional summer tanks modified for winter use, or tanks constructed on-site specifically for winter use. All of these tank share common characteristics which lend the tank to being "frost-free." The typical tank used for winter grazing is located at a remote site without electricity. The capability of the tank to remain frost-free is due to a combination of insulation, limiting the size of the drinking area, isolating the interior of the tank from exposure to the elements, and regular recharge of relatively warm water.

The type of insulation varies depending on the style of tank but is usually styrofoam, earth, or a combination of the two.

Commercial tanks usually have minimal drinking access for one or two head and the drinking area uses a lid over the drinker that must be depressed by the livestock. Conventional summer tanks which are modified for winter use and tanks constructed onsite specifically for winter use typically provide drinking access for two to four animals and utilize a baffle around the perimeter of the drinking areas which extends below the water level to isolate the interior of the tank form the outside air.

All nonelectric winter tanks rely on a regular recharge of water to maintain their frost-free condition. The temperature of the ground at the 5-6 foot level maintains a constant 50-550 temperature year round which is approximately the temperature of incoming water from most pipelines. Incoming water even at 500 contains enough latent heat to maintain an insulated tank in a frost-free condition provided enough animals are using the tank. The number of head required will vary depending on the installation and the air temperature, but 75 head of cattle will drink enough during the winter to recharge 1,000 gallons each 24 hrs. which should keep most installations relatively ice free.

Figures 8.13 and 8.14 show a cast-in-place concrete “frost-free” tank which utilizes a minimum of 3 ft. earth cover over 2” of styrofoam for insulation over the rear portion of the tank. The tank shown in the photo has been in service since 1982 and is still in nearly an as-constructed condition. A redwood baffle attached to the headwall extends below the water surface in the drinking space to isolate the interior of the tank from the outside air. The float is attached to the baffle for easy maintenance and service. Tanks such as this will maintain a frost-free condition down to zero or below, and subzero temps will form only a thin ice layer as long as cattle are using the tank. The tank shown has an interior dimension of 6’ x 19’ holding 1,450 gallons and would serve up to 300 head with as little as 2.5 gpm supply flow.

Fabricated tanks should provide at least 1 drinking space for each 100 hd. of cattle and 2 gpm per drinking space unless a combination of storage and flow is used to meet the daily water needs.

Figure 8.13
Cast-In-Place Concrete Frost-Free Tank (Schematic)

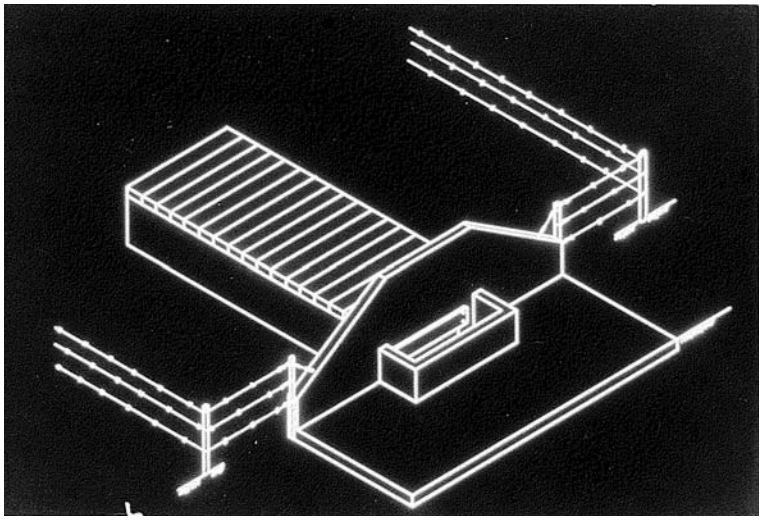
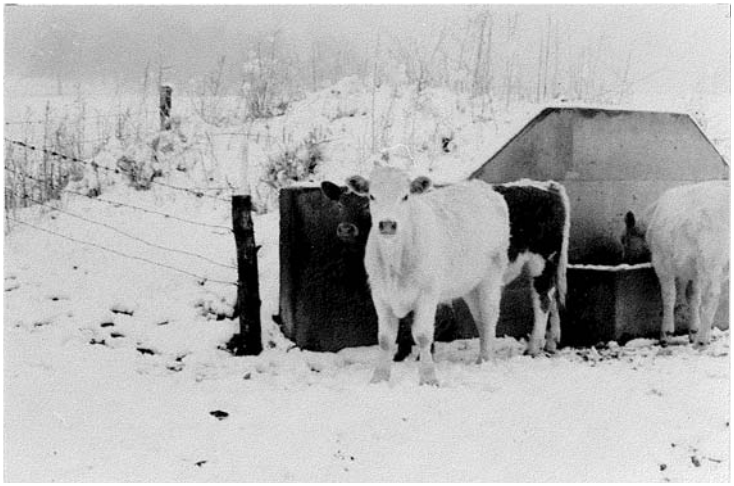


Figure 8.14
Cast-In-Place Concrete Frost-Free Tank (Installation)



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CHAPTER 9

DESIGN EXAMPLES AND CALCULATIONS
(Pumped Artesian Well)

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CHAPTER 9

DESIGN EXAMPLES AND CALCULATIONS
Example 1

9.0 General

The example illustrated in this chapter show the steps necessary to complete a stock water pipeline system from the initial planning, through design, preparation of construction plans and specifications, and construction checkout. Systems of differing levels of complexity, whether simpler or more complex, will follow the same basic procedure. The example goes into fairly indepth evaluations of the various reasons for the decisions made and components selected.

1. Gather information from operator during **initial planning** and subsequent follow-up visits specific to installing the water system.
2. Finalize pipeline route and gather **pipeline stationing and elevation data** for use in hydraulic calculations
3. Design the pipeline including **sizing and hydraulic calculations**
4. Design **pipeline appurtenances**
5. Label **Plan View** with appropriate details
6. **Complete Construction Plans** including Table of Quantities
7. **Complete Construction Check**

9.1 Initial Planning Information

Two ranches sharing a water system using an ECP pooling agreement in the western part of the state:

Ranch A – new well, 2,610 feet deep
- 7-inch casing to 500 feet level
- 90^0F water temperature
- Static water level at 100 feet (below surface)
- Drawdown estimated at 170 feet @ 30 gpm pumping rate
- House at headquarters will be served by the system (existing cistern and booster), up to 100 head of livestock maximum around farmstead.
- 150 cow/calf pairs, summer use

Ranch B – house at headquarters will be served by the system (without cistern and booster) - 350 cow/calf pairs, summer use**:**

1. The field copy of the digital ortho/topo map was used for the initial planning with the two operators.

2. Once the proposed hydrant and tank locations were identified, the proposed route was then drawn connecting the well with the headquarter locations and outlets.

3. This map was then used at the start of the design process to label each line and determine the design capacity for each line segment. There is no set format for labeling lines but usually one or more lines are considered “main” lines serving smaller lateral lines which branch off the main. These main lines usually run from the water source to the furthest extremities of the project. Smaller lateral lines which branch off the main are subsequently designated a label, also extending the furthest extremity of the project. This method results in the least amount of lines and the simplest set of hydraulic calculations and documentation. An example of the preferred labeling is illustrated in the following Figures 9.1 and 9.2.

Figure 9.1
Plan View Labeling
(Labeling too Complex)

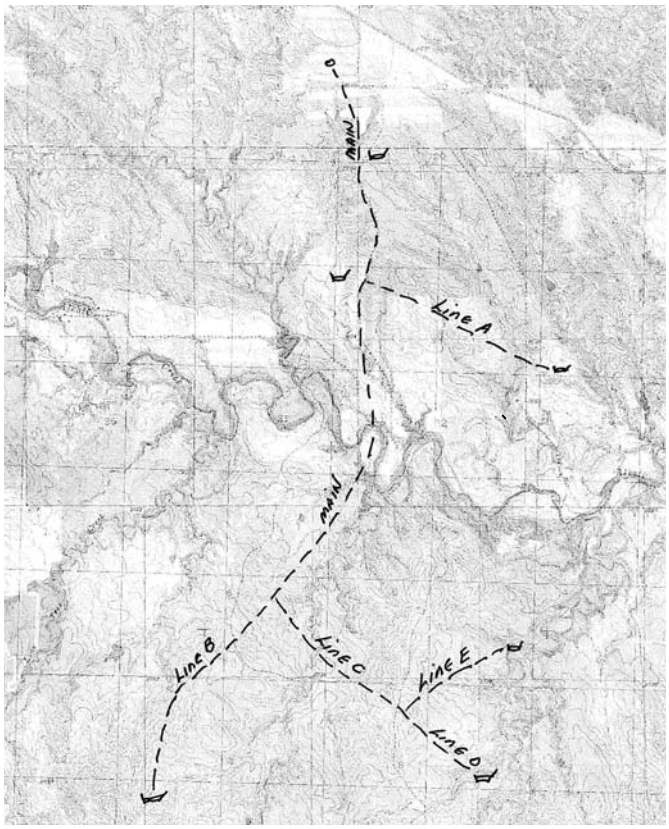
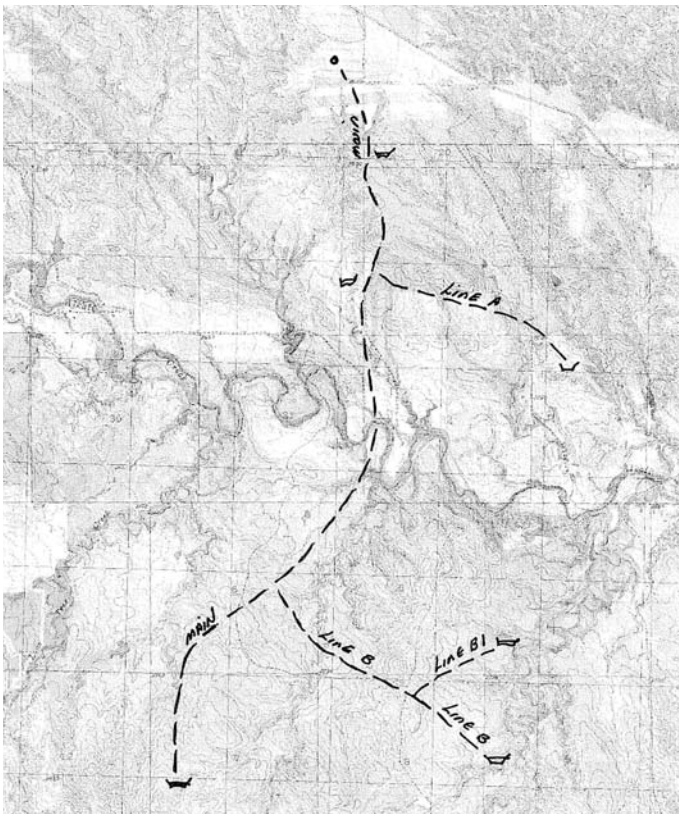


Figure 9.2
Plan View Labeling
(Recommended Labeling Format)



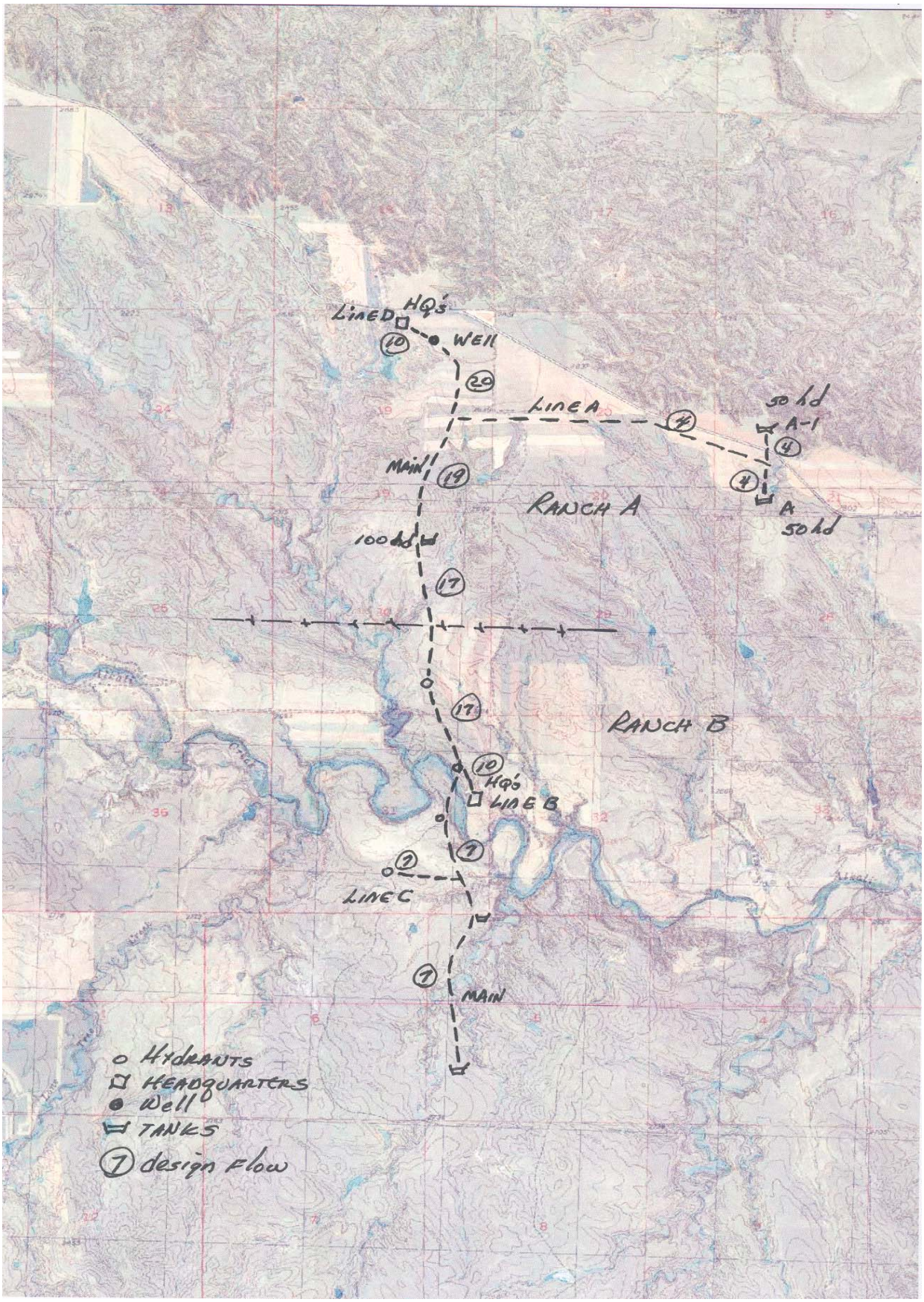
The actual labeling system could be of one of the following formats. On the larger group systems, a labeling system which uses some approximation of the compass directions has the advantage of the lines general location identified simply by the designated label.

Mainline
Line A, B, C
Line A1, A2 Line B1

Mainline
Line 1, 2, 3
Line 1a, 1b Line 2a, 2b

Line N, Line S, Line E
Line NE, Line SW, Line SE Line E1,
NE1, NE2 SW1, SW2, E2, E3, E4, E5

Planning Map – Field Copy



3. (Continued)

The process for determining the design capacity usually starts at the most distant end of the main lines. The design capacity for the outlet at the end of the line is determined, and then working toward the water source, as each outlet or lateral junction is passed, the capacity is increased accordingly. The design capacity for the example was determined as follows:

- Starting at the south end of the Main, this outlet serves a summer grazing herd of 350 cow/calf pair in the western part of the state – the minimum design flow is considered to be 2 gpm/ 100 hd cows = 7 gpm.
- Line C – the total herd for Ranch A is 350 head and is moved from pasture to pasture or could be split in multiple pastures. Design flow line C = 7 gpm.
- Main between line C and Line B – the total livestock served by the main and line C are totaled. In this example, there is no increase in flow after passing line C, design flow = 7 gpm.
- Line B – this line serves a single house with no livestock needs. Line B is plumbed directly into the house without using a cistern and booster. Design flow = 10 gpm.
- Main between line B and first outlet on Ranch A – Design flow = 17 gpm This volume provides the full design flow to the livestock, even while the 10 gpm design flow is being used at the house. If the water source did not have adequate capacity to supply 17 gpm, then the line would be designed for the maximum volume available. If the livestock outlets were drawing a full 7 gpm at the same time as the house demand was 10 gpm, then operating pressure and flow would be reduced on one or both lines until the demand was reduced. Those outlets lowest in elevation or with the highest operating pressure would be least affected. One alternative would be to install a cistern at the house to supply a booster pump, or install an in-line booster at the house to insure the house always has adequate pressure and flow (while temporarily robbing from the livestock outlets). If the livestock tanks are adequately sized, the temporary loss of flow for a couple hours each day will not short the livestock of water.
- Main downstream of Line A – An additional 2 gpm is added for the 100 hd. served on Ranch A. Design flow = 19 gpm
- Line A serves 50 hd. and the minimum flow at 2 gpm/ 100 hd. would be 1 gpm. The practical minimum design flow for any line should probably not be less than 4 gpm, regardless of livestock numbers served, unless there are other extenuating circumstances. Design flow for Lines A and A1 = 4 gpm
- Main between well and Line A – Total of 500 livestock (10 gpm) and 1 house (10 gpm) = Design Flow 20 gpm. The 10 gpm demand required at the house actually provides additional capacity available for the stock water outlets during the balance of the day when water is not being used in the house.
- Line D – The house at the headquarters has a cistern and the 360 gpd design volume could be supplied easily with 1 gpm flow (1,440 gpd). An additional nine gpm is provided to supply the livestock at the headquarters and other incidental uses around the buildings. Design flow = 10 gpm

9.2 Pipeline Stationing and Elevation Data

The station and elevation data necessary for the hydraulic calculations is obtained from the route as drawn on a USGS topographic map. There may be situations (i.e., low pressure gravity systems) when information from a field survey is required for the design, but these are rare other than with systems supplied by spring developments. The use of ArcMap allows the topo map to be transposed over the aerial photo image and the stationing obtained with the measuring tool; however, hard copies of the USGS topog can be used. Station and elevation data are obtained at all water sources, outlets, lateral line tees, and most summits and low points along the line. Data may be needed at intermediate points between summits and low points on long segments. The station and elevation data for the example are as follows on Figures 9.3 and 9.4

Figure 9.3
Station and Elevation Data

Computation Sheet
NRCS–ENG-523A Rev. 6-2002

U.S. Department of Agriculture
Natural Resources Conservation Service

State	Project			
	Ranch A & B			
By	Date	Checked by	Date	Job No.
	1/6/08			
Subject				Sheet 1 of 2
Stations & Elevations				

Main	STA.	Elev.	
	0+00	2852	well
	0+05	2852	Tee line "C"
	12+50	2850	
	27+25	2825	line A
	52+25	2800	
	61+50	2765	tank
	83+50	2675	creek crossing — Ranch A / Ranch B Boundary
	84+50	2700	
	100+50	2695	hydrant
	122+25	2650	hydrant
	124+50	2650	tee line B
	126+00	2635	low
	132+00	2650	
	135+00	2665	hydrant
	153+50	2700	tee line C
	161+00	2655	
	165+00	2695	Tank
	181+50	2705	
	188+00	2670	
	205+25	2735	Tank (end) (high)

Figure 9.4
Station and Elevation Data

Computation Sheet
NRCS–ENG-523A Rev. 6-2002

U.S. Department of Agriculture
Natural Resources Conservation Service

State		Project Ranch A & B		
By	Date	Checked by	Date	Job No.
Subject Stations & Elevations				Sheet 2 of 2

	Sta.	Elev.	
Line A	0+00	2825	= 27+25 main
	10+50	2840	
	33+00	2820	
	41+50	2825	
	44+50	2820	
	52+50	2830	
	81+00	2823	tee A1
	87+00	2800	tank
Line A1	0+00	2650	= 81+00 Line A
	0+50	2825	Alkali Road
	10+75	2820	tank
Line B	0+00	2650	= 124+50 main
	6+50	2645	house
Line C	0+00	2700	= 153+50 main
	11+50	2695	Hydrant
Line D	0+00	2852	= 0+05 main (well)
	3+00	2850	Headgates

9.3 Sizing and Hydraulic Calculations

The design procedure currently used, in SD, for pipelines utilizes an Excel spreadsheet (Class II Pipeline Design and Job Forms) which can be downloaded from the SD NRCS Web site http://www.sd.nrcs.usda.gov/technical/Engineering_Tools.html.

The spreadsheet includes a sheet giving instructions for the hydraulics. The following steps were used to develop the design example:

1. The stations and elevations along the pipeline route (part 9.2) are entered in the spreadsheet along with the design flows and the water temperature. Use of the appurtenance column helps to identify locations along the route (**see Figure 9.5**).

2. The static and hydraulic pressures are also entered. There is no existing pressure tank; however, a pressure switch is planned for use in controlling the pump. The starting pressures will be by trial and error and then after examining the results, will be changed as needed. The well is one of the highest points on the system, and; therefore, a minimum of pressure is needed at the well. A starting point of 20/50 psi for pressure setting is used. The 20 psi will be the hydraulic pressure at the lowest part of the operating range, at the point where the pump starts. The 50 psi will be the maximum pressure at the well site, at the point when the pump shuts off. A 30 psi pressure differential was selected to increase the pressure tank efficiency and keep the pressure tank size to a minimum.

3. The pipe sizes and pressure ratings (SDR no.) are now selected and entered. This is also a trial and error procedure for the larger lines. Usually the lines with low design capacity are sized based on the practical minimum pipe size of 1¼" or 1½". Two inch pipe works satisfactorily for this example down to line B, even though the friction loss is somewhat on the high side (.6 ft./100 ft.), because the line is dropping in elevation and hydraulic pressures are adequate. If the mainline were rising in elevation, a 2½" pipe would most likely have been used (Hf = .24 ft./100 ft.). SDR 21 200 psi pipe was used for this example even though SDR 26 160 psi pipe would be adequate for those portions of the line with less that 115 psi static pressure. The heavier walled 200 psi pipe is generally considered by many contractors, cooperators, and designers to be the minimum standard which should be used in a water system due to the heavier wall having greater durability and fewer long term problems.

4. Once the spreadsheet is populated with the initial data, the hydraulic and static pressures are reviewed. The hydraulic pressures (Figure 9.5) are all acceptable (no warning messages or negative pressures). The static pressures are below the maximum allowed for SDR 21 pipe; however, the pressures at all of the outlets from station 61+45 to the end of the line at 205+25 are in excess of 80 psi (88 – 137 psi). Any pressures over 80 psi should be scrutinized for acceptability, since seals on frost-free hydrants and many floats not specifically manufactured for high pressure installations can have operating problems at high pressures. The designer should consider protecting all outlets with static pressures over 100 psi. A pressure regulator installed just upstream of the tee to the tank at station 61+50 will reduce the static pressure to acceptable levels for all of the downstream outlets. The pipeline stationing includes stations 61+45 and 61+48 which were added to the profile after it was evident a pressure regulator would be needed. Station 61+48 defines in the calculations that the regulator is to be installed upstream of the tank location and Station 61+45 allows the regulator inlet pressure to be defined in the hydraulic calculations. This information is helpful when reviewing with others the need for the valve. Adding these stations to the spreadsheet requires re-entry of the stations downstream of the valve.

Figure 9.5 (Sheets 1 & 2)
Pipeline Design Calculations

United States Department of Agriculture
Natural Resources Conservation Service

SD-ENG-5D
REV. 10/08

Pipeline Design Calculations

Project:	Ranch A and Ranch B							Sec.		T.	00 N	R.	00 E	Any County		County
Designer:	C.E.T					Date:	1/6/2008	Checker:				Date:			Sheet	1
Line No.	Station	Appurts.	Total AU's	Ground Elev.	Flow gpm	Pipe Size	Material & SDR #	H_F/100 ft	Length	H_F	HGL Elev.	Hydr. Press. psi	SGL Elev.	Static Press. psi	Water Temp (F)	Max Press. Allowed for Pipe (psi)
Main	0+00	Well	500	2852							2898	20	2968	50	90	108
					20	2	PVC SDR 21	0.601	2	0.01						
	0+02	Tee Line D	0+05	2852							2898	20	2968	50	90	108
					20	2	PVC SDR 21	0.601	1248	7.50						
	12+50			2850							2891	18	2968	51	88	112
					20	2	PVC SDR 21	0.601	1475	8.86						
	27+25	Line A	450	2825							2882	25	2968	62	85	118
					19	2	PVC SDR 21	0.546	2500	13.66						
	52+25			2800							2868	30	2968	73	80	128
					19	2	PVC SDR 21	0.546	920	5.03						
	61+45			2765							2863	42	2968	88	78	132
					19	2	PVC SDR 21	0.546	3	0.02						
	61+48	Press. Reg.		2765							2863	42	2968	88	78	132
					19	2	PVC SDR 21	0.546	2	0.01						
	61+50	Tank	350	2765							2863	42	2968	88	78	132
					17	2	PVC SDR 21	0.445	2000	8.89						
	81+50			2700							2854	67	2968	116	75	140
					17	2	PVC SDR 21	0.445	200	0.89						
	83+50	creek crossing		2675							2853	77	2968	127	74	141
					17	2	PVC SDR 21	0.445	100	0.44						
	84+50			2700							2853	66	2968	116	74	142
					17	2	PVC SDR 21	0.445	1600	7.11						
	100+50	Hydrant		2695							2846	65	2968	118	71	144
					17	2	PVC SDR 21	0.445	2175	9.67						
	122+25	Hydrant		2650							2836	81	2968	137	71	144
					17	2	PVC SDR 21	0.445	225	1.00						
	124+50	Line B	350	2650							2835	80	2968	137	71	144
					7	1 1/2	PVC SDR 21	0.254	150	0.38						
	126+00	low		2635							2835	86	2968	144	70	144
					7	1 1/2	PVC SDR 21	0.254	600	1.53						
	132+00			2650							2833	79	2968	137	70	144
					7	1 1/2	PVC SDR 21	0.254	300	0.76						
	135+00	Hydrant		2665							2832	72	2968	131	70	144

☐ Check box if a pressure reducer is used. STA 61+48 Pressure Setting 30 PSI

☐ Check box to add a Booster Pump. STA Hydraulic Pressure PSI Static Pressure PSI

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Pressures too high at outlets

Pipeline Design Calculations

Project:	Ranch A and Ranch B							Sec.		T.	00 N	R.	00 E	Any County		County
Designer:	C.E.T					Date:	4/3/2008	Checker:				Date:			Sheet	2
Line No.	Station	Appurts.	Total AU's	Ground Elev.	Flow gpm	Pipe Size	Material & SDR #	H_F/100 ft	Length	H_F	HGL Elev.	Hydr. Press. psi	SGL Elev.	Static Press. psi	Water Temp (F)	Max Pressure Allowed for
	135+00	Hydrant	350	2665							2832	72	2968	131	70	144
					7	1 1/2	PVC SDR 21	0.254	1850	4.70						
	153+50	Tee to Line C		2700							2828	55	2968	116	70	144
					7	1 1/2	PVC SDR 21	0.254	750	1.91						
	161+00			2655							2826	74	2968	135	70	144
					7	1 1/2	PVC SDR 21	0.254	450	1.14						
	165+50	Tank		2695							2825	56	2968	118	70	144
					7	1 1/2	PVC SDR 21	0.254	1600	4.07						
	181+50			2705							2821	50	2968	114	70	144
					7	1 1/2	PVC SDR 21	0.254	650	1.65						
	188+00			2670							2819	64	2968	129	70	144
					7	1 1/4	PVC SDR 21	0.492	1725	8.49						
	205+25	Tank	350	2735							2810	33	2968	101	70	144

☐ Check box if a pressure reducer is used? STA Pressure Setting PSI

☐ Check box to add a Booster Pump. STA #N/A Hydraulic Pressure PSI Static Pressure PSI

Figure 9.6
Pipeline Design Calculations

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Pipeline Design Calculations

Project:	Ranch A and Ranch B							Sec.		T.	00 N	R.	00 E	Any County		County
Designer:	C.E.T					Date:	1/6/2008	Checker:				Date:			Sheet	1
Line No.	Station	Appurts.	Total AU's	Ground Elev.	Flow gpm	Pipe Size	Material & SDR #	H_F/100 ft	Length	H_F	HGL Elev.	Hydr. Press. psi	SGL Elev.	Static Press. psi	Water Temp (F)	Max Press. Allowed for Pipe (psi)
Main	0+00	Well	500	2852							2898	20	2968	50	90	108
					20	2	PVC SDR 21	0.601	2	0.01						
	0+02	Tee Line D	0+05	2852							2898	20	2968	50	90	108
					20	2	PVC SDR 21	0.601	1248	7.50						
	12+50			2850							2891	18	2968	51	88	112
					20	2	PVC SDR 21	0.601	1475	8.86						
	27+25	Line A	450	2825							2882	25	2968	62	85	118
					19	2	PVC SDR 21	0.546	2500	13.66						
	52+25			2800							2868	30	2968	73	80	128
					19	2	PVC SDR 21	0.546	920	5.03						
	61+45			2765							2863	42	2968	88	78	132
					19	2	PVC SDR 21	0.546	3	0.02						
	61+48	Press. Reg.		2765							2834	30	2834	30	78	132
					19	2	PVC SDR 21	0.546	2	0.01						
	61+50	Tank	350	2765							2834	30	2834	30	78	132
					17	2	PVC SDR 21	0.445	2000	8.89						
	81+50			2700							2825	54	2834	58	75	140
					17	2	PVC SDR 21	0.445	200	0.89						
	83+50	creek crossing		2675							2825	65	2834	69	74	141
					17	2	PVC SDR 21	0.445	100	0.44						
	84+50			2700							2824	54	2834	58	74	142
					17	2	PVC SDR 21	0.445	1600	7.11						
	100+50	Hydrant		2695							2817	53	2834	60	71	144
					17	2	PVC SDR 21	0.445	2175	9.67						
	122+25	Hydrant		2650							2807	68	2834	80	71	144
					17	2	PVC SDR 21	0.445								
	124+50	Line B	350	2650								68	2834	80	71	144
					7	1 1/2	PVC SDR 21	0.254								
	126+00	low		2635								74	2834	86	70	144
					7	1 1/2	PVC SDR 21	0.254								
	132+00			2650							2804	67	2834	80	70	144
					7	1 1/2	PVC SDR 21	0.254	300	0.76						
	135+00	Hydrant		2665							2804	60	2834	73	70	144

☑ Check box if a pressure reducer is used. STA 61+48 Pressure Setting 30 PSI

☐ Check box to add a Booster Pump. STA Hydraulic Pressure PSI Static Pressure PSI

Stations added for pressure regulator

Inlet Pressure

Outlet Pressure

Acceptable Pressure

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Pipeline Design Calculations

Project:	Ranch A and Ranch B							Sec.		T.	00 N	R.	00 E	Any County		County
Designer:	C.E.T					Date:	4/7/2008	Checker:				Date:			Sheet	2
Line No.	Station	Appurts.	Total AU's	Ground Elev.	Flow gpm	Pipe Size	Material & SDR #	H_F/100 ft	Length	H_F	HGL Elev.	Hydr. Press. psi	SGL Elev.	Static Press. psi	Water Temp (F)	Max Pressure Allowed for
Main	135+00	Hydrant	350	2665							2804	60	2834	70	70	144
					7	1 1/2	PVC SDR 21	0.254	1850	4.70						
	153+50	Tee to Line C		2700							2799	43	2834	58	70	144
					7	1 1/2	PVC SDR 21	0.254	750	1.91						
	161+00			2655							2797	61	2834	78	70	144
					7	1 1/2	PVC SDR 21	0.254	450	1.14						
	165+50	Tank		2695							2796	44	2834	60	70	144
					7	1 1/2	PVC SDR 21	0.254	1600	4.07						
	181+50			2705							2792	38	2834	56	70	144
					7	1 1/2	PVC SDR 21	0.254	650	1.65						
	188+00			2670							2790	52	2834	71	70	144
					7	1 1/2	PVC SDR 21	0.254	1725	4.39						
	205+25	Tank	350	2735							2786	22	2834	43	70	144

☐ Check box if a pressure reducer is used? STA Pressure Setting PSI

#N/A

☐ Check box to add a Booster Pump. STA Hydraulic Pressure PSI Static Pressure PSI

Acceptable Pressures

5. After the stations are added for the pressure regulator, the box is checked activating the pressure regulator at station 61+48. All of the static pressures are now within acceptable limits. The hydraulic pressures were also reduced slightly since the pressure regulator setting of 30 psi is below the 42 psi hydraulic pressure at the inlet at station 61+45. All of the hydraulic pressures are adequate.

6. Note that the water temperature is no longer reducing the maximum allowable pressure for the pipe after station 84+50 when the temperature cools to 730.

7. The lateral lines are usually designed simultaneously with the mainline. As changes are made to the main line, such as determining what pressure setting to use on the regulator, the effect of these changes is also reviewed for the lateral lines to determine if the changes will work for all locations. The mainline hydraulic and static pressures at each location where a lateral tees off the main become the starting pressures for station 0+00 of each respective lateral line. Pipe size used on line A for the 4 gpm design flow is 1¼" which is considered the minimum line size typically used in SD (**Figure 9.7**).

Figure 9.7
Pipeline Design Calculations

United States Department of Agriculture
Natural Resources Conservation Service

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Pipeline Design Calculations

Project:	Ranch A and Ranch B						Sec.		T.	00 N	R.	00 E	Any County		County
Designer:	C.E.T				Date:	4/3/2008	Checker:				Date:			Sheet	3
Line No.	Station	Appurts.	Total AU's	Ground Elev.	Flow gpm	Pipe Size	Material & SDR #	H_f/100 ft	Length	H_f	HGL Elev.	Hydr. Press. psi	SGL Elev.	Static Press. psi	Water Temp (F)	Max Pressure Allowed for
Line A	0+00	27+25 main		2825							2882	25	2968	62	85	118
					4	1/4	PVC SDR 21	0.175	1050	1.83						
	10+50			2840							2880	17	2968	55	83	122
					4	1 1/4	PVC SDR 21	0.175	2250	3.93						
	33+00			2820							2876	24	2968	64	79	131
					4	1 1/4	PVC SDR 21	0.175	850	1.48						
	41+50			2825							2875	21	2968	62	77	135
					4	1 1/4	PVC SDR 21	0.175	300	0.52						
	44+50			2820							2874	23	2968	64	76	136
					4	1 1/4	PVC SDR 21	0.175	800	1.40						
	52+50			2830							2873	18	2968	60	75	139
					4	1 1/4	PVC SDR 21	0.175	2850	4.98						
	81+00	tee A1		2823							2868	19	2968	63	75	139
					4	1 1/4	PVC SDR 21	0.175	600	1.05						
	87+00	Tank		2800							2867	29	2968	73	74	142

☐ Check box if a pressure reducer is used? STA [ ] Pressure Setting [ ] PSI

☐ Check box to add a Booster Pump. STA [ ] Hydraulic Pressure [ ] PSI Static Pressure [ ] PSI

8. A pressure regulator set at 50 psi was used at the house on Line B (**Figure 9.8**). The static pressure of 80 psi is generally considered excessive at a residential location, particularly for older plumbing and appliances.

Figure 9.8
Pipeline Design Calculations

United States Department of Agriculture
Natural Resources Conservation Service

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Pipeline Design Calculations

Project:	Ranch A and Ranch B							Sec.		T.	00 N	R.	00 E	Any County		County
Designer:	C.E.T					Date:	4/3/2008	Checker:				Date:			Sheet	4
Line No.	Station	Appurts.	Total AU's	Ground Elev.	Flow gpm	Pipe Size	Material & SDR #	H_F/100 ft	Length	H_F	HGL Elev.	Hydr. Press. psi	SGL Elev.	Static Press. psi	Water Temp (F)	Max Pressure Allowed for
Line B	0+00	124+50 Main		2650							2806	68	2834	80	71	144
					10	1 1/2	PVC SDR 21	0.492	640	3.15						
	6+40			2645							2803	68	2834	82	71	144
					10	1 1/2	PVC SDR 21	0.492	5	0.02						
	6+45	Press Reg		2645							2761	50	2761	50	71	144
					10	1 1/2	PVC SDR 21	0.492	5	0.02						
	6+50	House		2645							2760	50	2761	50	71	144

☑ Check box if a pressure reducer is used? STA 6+45 Pressure Setting 50 PSI

☐ Check box to add a Booster Pump. STA _____ Hydraulic Pressure _____ PSI Static Pressure _____ PSI

9. Lines C, D, and A1 have acceptable static and hydraulic pressures (**Figures 9.9 & 9.10**).

Figure 9.9
Pipeline Design Calculations

United States Department of Agriculture
Natural Resources Conservation Service

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Pipeline Design Calculations

Project:	Ranch A and Ranch B					Sec.		T.	00 N	R.	00 E	Any County		County
Designer:	C.E.T			Date:	4/4/2008	Checker:				Date:			Sheet	5

Line No.	Station	Appurts.	Total AU's	Ground Elev.	Flow gpm	Pipe Size	Material & SDR #	H_f/100 ft	Length	H_f	HGL Elev.	Hydr. Press. psi	SGL Elev.	Static Press. psi	Water Temp (F)	Max Pressure Allowed for
Line C	0+00	153+50 Main		2700							2799	43	2834	58	70	144
					7	1 1/2	PVC SDR 21	0.254	1150	2.92						
	11+50	hydrant	350	2695							2796	44	2834	60	70	144
Line D	0+00	0+02 Main		2852							2898	20	2968	50	90	108
					10	1 1/2	PVC SDR 21	0.492	300	1.48						
	3+00	HDQT's	100	2850							2897	20	2968	51	89	109

Figure 9.10
Pipeline Design Calculations

United States Department of Agriculture
Natural Resources Conservation Service

SD-ENG-5D
REV. 10/08

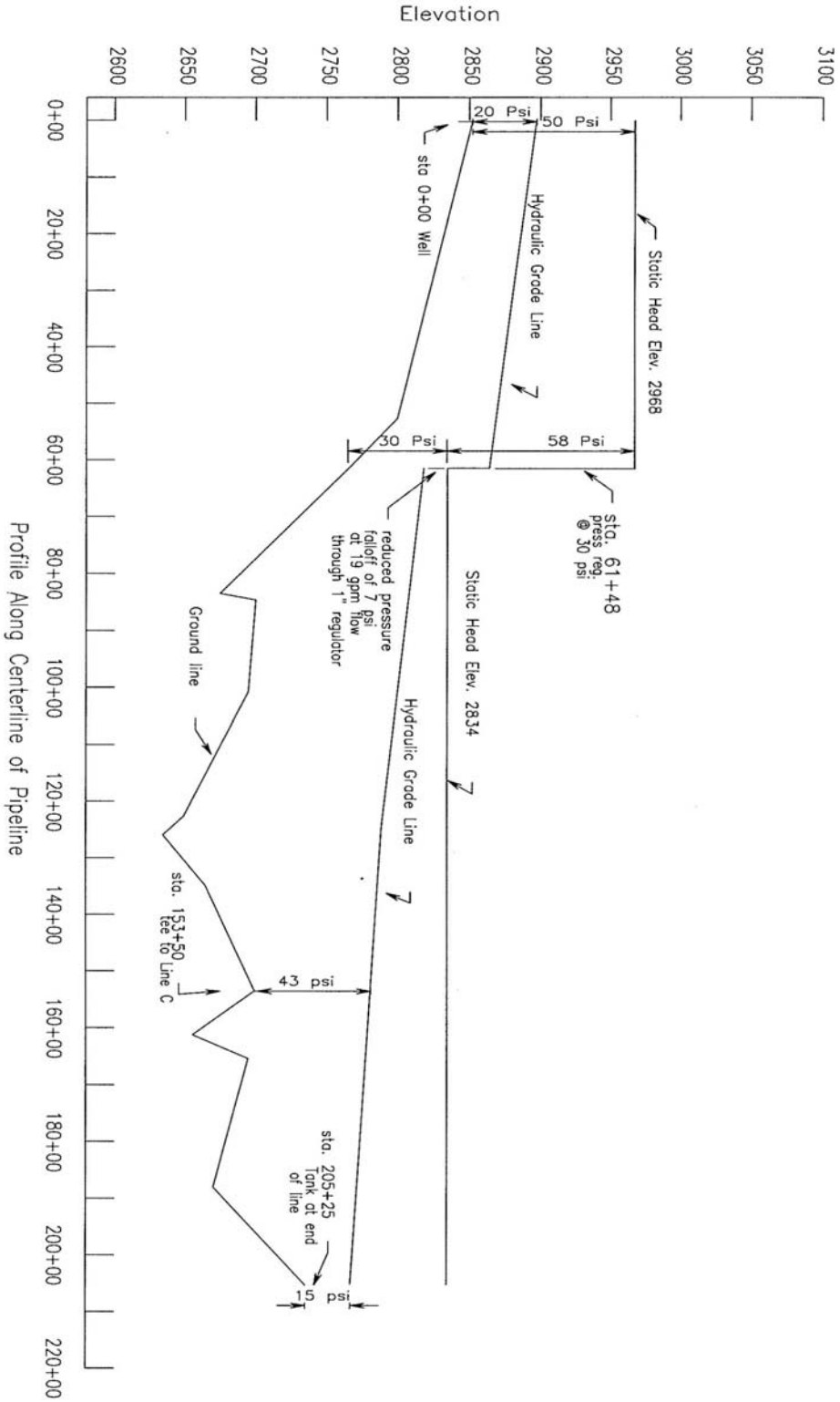
Pipeline Design Calculations

Project:	Ranch A and Ranch B					Sec.		T.	00 N	R.	00 E	Any County		County
Designer:	C.E.T			Date:	4/3/2008	Checker:				Date:			Sheet	6

Line No.	Station	Appurts.	Total AU's	Ground Elev.	Flow gpm	Pipe Size	Material & SDR #	H_f/100 ft	Length	H_f	HGL Elev.	Hydr. Press. psi	SGL Elev.	Static Press. psi	Water Temp (F)	Max Pressure Allowed for
A1	0+00	81+00 A	50	2823							2868	19	2968	63	75	139
					4	1 1/4	PVC SDR 21	0.175	50	0.09						
	0+50	Alkali Road		2825							2868	18	2968	62	75	140
					4	1 1/4	PVC SDR 21	0.175	1025	1.79						
	10+75	tank		2820							2866	20	2968	64	73	144

10. A plot of the Static Head Elevations and Hydraulic Grade Lines is shown for the main line in this illustration. This is a **graphical representation of the hydraulic calculations in Figure 9.6** and allows the designer to visually seen the relationship between the line pressures and the ground elevation along the pipeline.

Figure 9.10A
State Head Elevation and Hydraulic Grade Line Plot



9.4 Design Pipeline Appurtenances

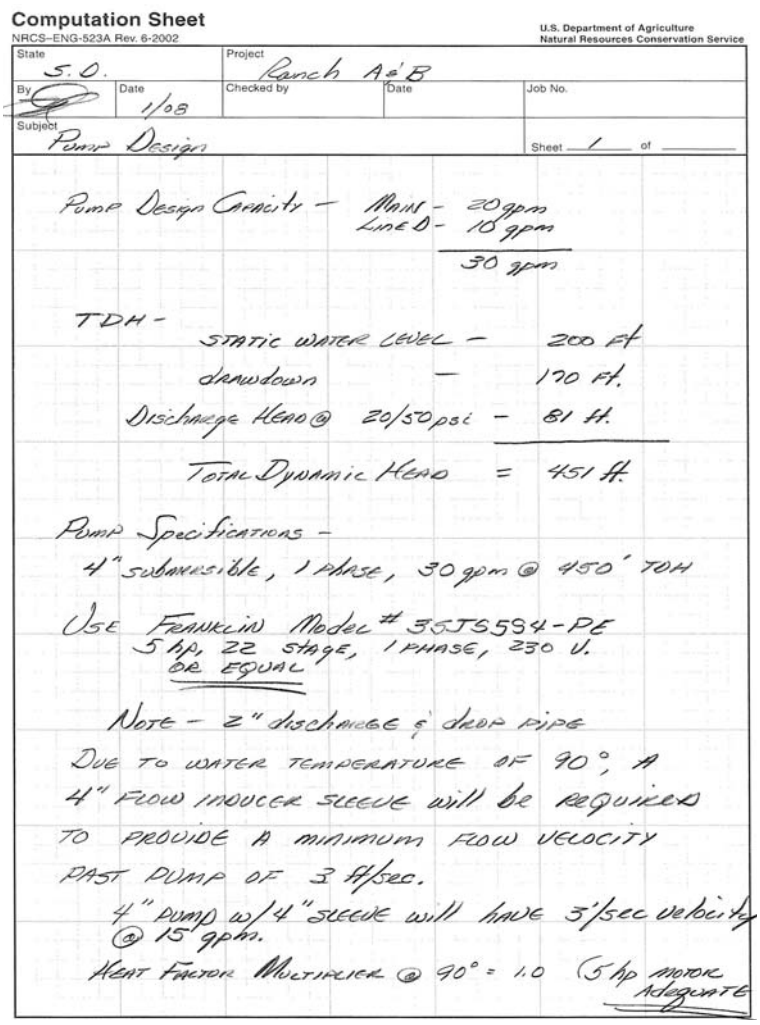
1. **Calculations** for the submersible pump design are shown in F**igure 9.11.** A design pump capacity of 30 gpm will provide enough capacity to meet the design capacity for the mainline and line D. The pump does not need to be over-sized, since the 10 gpm volume provided for the house on Line B and the headquarters on Line C are intermittent flows. Therefore, the livestock will have a 30 gpm flow available during the majority of the day which is more than adequate.

2. The specifications for the **pump** selected are given in **Figure 9.11** and the pump curve is provided in F**igure 9.12**. Manufacturer's pump curves should be used to insure a pump is commercially available which will meet the flow requirements specified, and that the electrical requirements match what is available at the site.

   The mid-range of the 20/50 psi operating cycle (450 ft. TDH) falls in the most efficient part of the efficiency curve at a pumping rate of 30 gpm. This is the very desirable. The operating characteristics for a pump fall exactly on the curve and flows vary with variations in TDH. At pump kick-on the flow will be 32.5 gpm and at kick-off the flow the flow will be 26.5 gpm.

3. **Flow inducer sleeves** may be needed for water temperatures over 86^0 F or on systems where a submersible pump is installed in a casing or reservoir of larger **Figure 9.11** diameter than the nominal pump diameter. Refer to Appendix C.

Figure 9.11
Pump Specification Calculations



Computation Sheet
NRCS–ENG-523A Rev. 6-2002
U.S. Department of Agriculture
Natural Resources Conservation Service

State: S.D. | Project: Ranch A & B
By: [illegible] | Date: 1/08 | Checked by: | Date: | Job No.:
Subject: Pump Design | Sheet 1 of

Pump Design Capacity – Mains – 20 gpm
Line D – 18 gpm
30 gpm

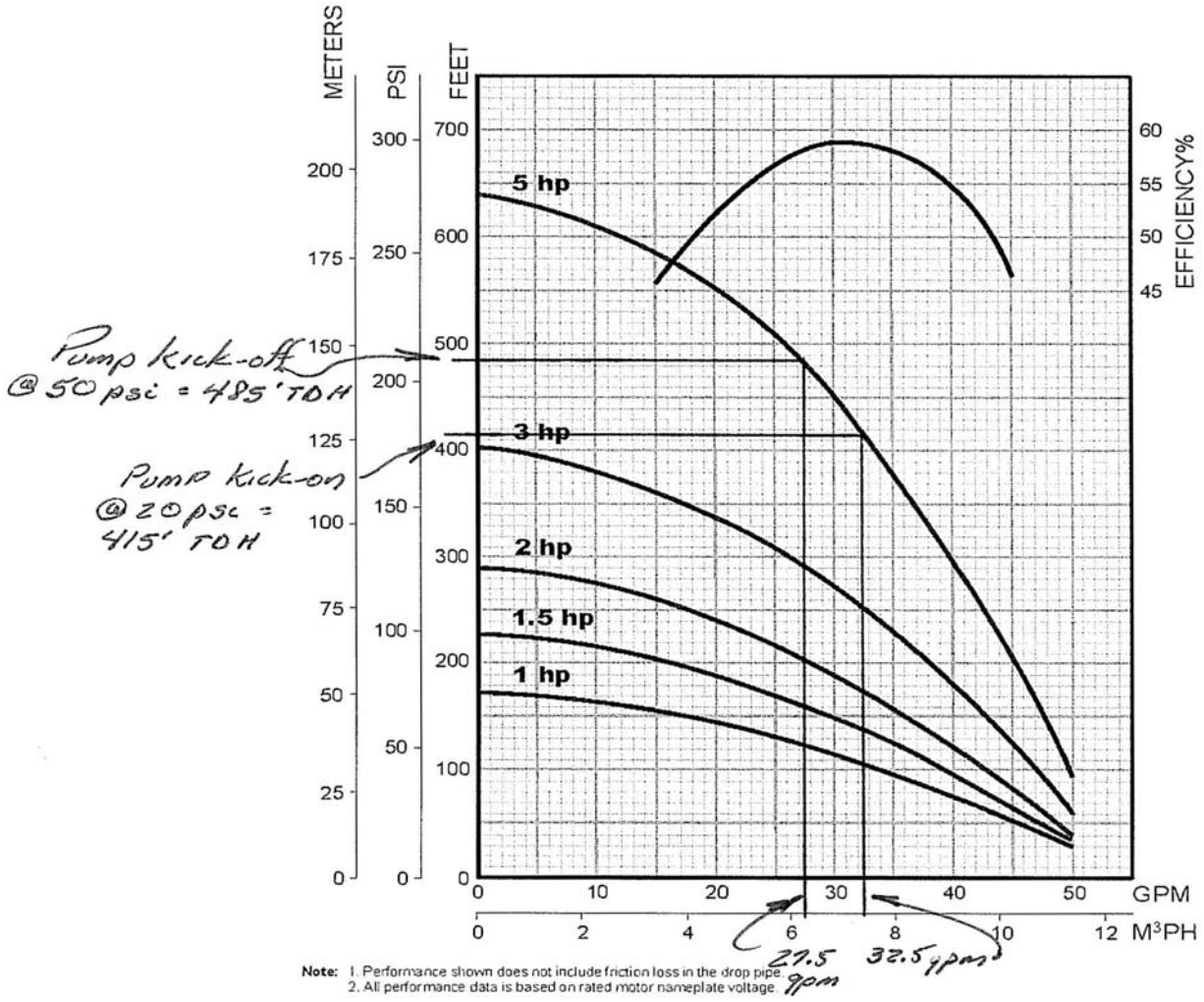
TDH –
STATIC WATER LEVEL – 200 ft
drawdown – 170 ft.
Discharge Head @ 20/50 psi – 81 ft.
Total Dynamic Head = 451 ft.

Pump Specifications –
4" submersible, 1 phase, 30 gpm @ 450' TDH

Use Franklin Model # 35JS594-PE
5 hp, 22 stage, 1 phase, 230 V.
OR EQUAL

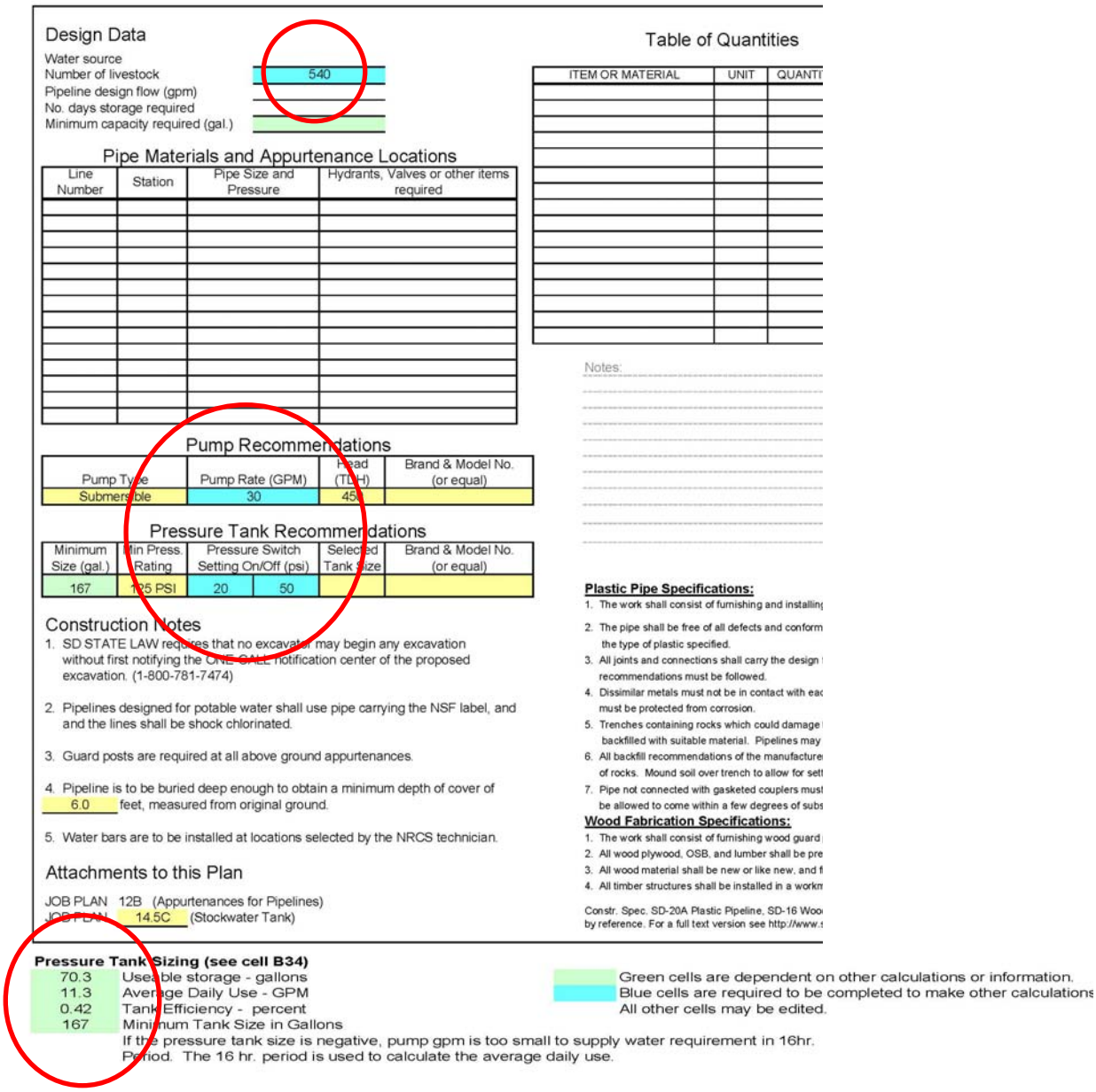
Note – 2" discharge & drop pipe
Due to water temperature of 90°, a
4" flow inducer sleeve will be required
to provide a minimum flow velocity
past pump of 3 ft/sec.
4" pump w/4" sleeve will have 3'/sec velocity
@ 15 gpm.
Heat Factor Multiplier @ 90° = 1.0 (5 hp motor Adequate

Figure 9.12
Pump Curve



Note: 1. Performance shown does not include friction loss in the drop pipe.
2. All performance data is based on rated motor nameplate voltage.

4. The **pressure tank sizing** can be done manually using the average daily use and the methods in Part 7.3.6, or the appropriate cells can be populated on Job Plan 12.1 and the pressure tank size is calculated by the spreadsheet. The spreadsheet requires livestock numbers which it then uses to calculate an **average daily use** based on a 16 hr. day and average daily water use for the livestock of 20 gallons per animal. For this example, in addition to the 500 hd. of livestock, two houses are involved. To account for the houses, the 360 gallons per day used per house is converted to an equivalent number of livestock (720 gal./20 = 36 livestock) which, as a rule of thumb, would equal about 20 livestock per house. For this example, the 540 hd. are entered, along with the pressure switch setting (20/50) and the pump rate (30 gpm) giving a pressure tank size of 167 gallons. Two pressure tanks of approximately 80 gallons each should be specified. (A pressure switch setting with only a pressure differential of 20 psi. would have required 212 gallons of capacity.)



Design Data

Water source	
Number of livestock	540
Pipeline design flow (gpm)	
No. days storage required	
Minimum capacity required (gal.)	

Pipe Materials and Appurtenance Locations

Line Number	Station	Pipe Size and Pressure	Hydrants, Valves or other items required

Pump Recommendations

Pump Type	Pump Rate (GPM)	Head (TDH)	Brand & Model No. (or equal)
Submersible	30	45	

Pressure Tank Recommendations

Minimum Size (gal.)	Min Press. Rating	Pressure Switch Setting On/Off (psi)		Selected Tank Size	Brand & Model No. (or equal)
167	125 PSI	20	50		

Construction Notes

1. SD STATE LAW requires that no excavator may begin any excavation without first notifying the ONE CALL notification center of the proposed excavation. (1-800-781-7474)
2. Pipelines designed for potable water shall use pipe carrying the NSF label, and and the lines shall be shock chlorinated.
3. Guard posts are required at all above ground appurtenances.
4. Pipeline is to be buried deep enough to obtain a minimum depth of cover of 6.0 feet, measured from original ground.
5. Water bars are to be installed at locations selected by the NRCS technician.

Attachments to this Plan

JOB PLAN 12B (Appurtenances for Pipelines)
JOB PLAN 14.5C (Stockwater Tank)

Table of Quantities

ITEM OR MATERIAL	UNIT	QUANTI

Notes:

Plastic Pipe Specifications:

1. The work shall consist of furnishing and installing
2. The pipe shall be free of all defects and conform the type of plastic specified.
3. All joints and connections shall carry the design recommendations must be followed.
4. Dissimilar metals must not be in contact with eac must be protected from corrosion.
5. Trenches containing rocks which could damage backfilled with suitable material. Pipelines may
6. All backfill recommendations of the manufacture of rocks. Mound soil over trench to allow for set
7. Pipe not connected with gasketed couplers must be allowed to come within a few degrees of subs

Wood Fabrication Specifications:

1. The work shall consist of furnishing wood guard
2. All wood plywood, OSB, and lumber shall be pre
3. All wood material shall be new or like new, and f
4. All timber structures shall be installed in a workm

Constr. Spec. SD-20A Plastic Pipeline, SD-16 Woo by reference. For a full text version see http://www.

Pressure Tank Sizing (see cell B34)

70.3	Usable storage - gallons
11.3	Average Daily Use - GPM
0.42	Tank Efficiency - percent
167	Minimum Tank Size in Gallons

If the pressure tank size is negative, pump gpm is too small to supply water requirement in 16hr. Period. The 16 hr. period is used to calculate the average daily use.

Green cells are dependent on other calculations or information.
Blue cells are required to be completed to make other calculations
All other cells may be edited.

5. **Pressure Regulators** can be specified as ¾" or 1" size for flows in the 10-15 gpm range as long as hydraulic pressure downstream is at least 20 psi or more. Regulators of three-quarter-inch and one-inch are priced nearly equal; however, as the size is increased above 1" the cost of the valve rise significantly. With flows above 15 gpm or with hydraulic pressures less than approximately 20 psi, capacity charts should be checked to determine the size of valve needed. On this system, a ¾" or 1" valve is adequate for the house on line B; however, manufacturer capacity charts (Web site) were checked for the regulator on the main line at station 61+48 with a flow of 19 gpm. The reduced pressure falloff for a 1" standard capacity Watts U5 at 19 gpm is approximately 9.5 psi and for the high capacity Watts 223 is 6.8 psi. The 1" 223 was chosen to provide at least 15 psi at the end of the line at the design flow. Also, when there is no demand at the Ranch B house, the high capacity valve will permit larger flow volumes to the end of the main line.

6. Check valves, curb stops, and ball valves are typically sized two sizes smaller than the pipeline the valve is installed on. This system used all 1" valves which would be adequate for the 1¼", and 1½" lines but will work on the 2" line as well (head loss at 20 gpm on the 1" size is acceptable).

7. A two-inch continuous acting air vent and vacuum relief valve (equal to Waterman CRP-8) was chosen to provide additional venting capacity over the one inch size due to the expected potential for gas accumulation at the high point (well pit).

9.5 Construction Plans and Specifications

Construction plans were developed using the "Class II Pipeline Design and Job Forms" which were also used in Section 9.3 for the hydraulic calculations (http://www.sd.nrcs.usda.gov/technical/Engineering_Tools.html).

These forms are titled as "Class II" which refers the Engineering Job Approval, Job Class II, but the forms can work well with minor modifications, even for some pipelines up to Job Class IV.

Modifications which may be necessary for the larger systems include adding a separate sheet just for the plan view (**Figure 9.15**) rather than using the standard block (used as location map in F**igure 9.13**), and adding additional Table of Quantities and Appurtenance tables (**Figure 9.14).**

A plan view is one of the most important details on a set of construction plans. With an adequate amount of detail and labeling, the plan view can convey the intent of the designer on many of the major details of the system in a way which can be easily understood.

Job Plan 22 Well Pit **(Figure 9.16)** can be used to provide additional details for the pumping plant, pump, well pit, and well pit plumbing.

The appurtenance details **(Figure 9.17)** can be easily tailored to the project by crossing out the details which do not apply and marking those details which are part of the design.

Any review of construction plans with the operators should include a discussion of route changes and the effect it may have on system pressures. A specific route may be critical on many systems which have low operating (hydraulic pressures) at the outlets or at summits along the route. If subsequent route changes result in an increase in elevation, the change may result in the line not functioning properly. The operator needs to be aware of these limitations if they exist.

Figure 9.13
Construction Plans Sheet 1

Design Data

Water source	Deep Well	
Number of livestock	540	2 Households
Pipeline design flow (gpm)	20	
No. days storage required		
Minimum capacity required (gal.)	#REF!	

Pipe Materials and Appurtenance Locations

Line Number	Station	Pipe Size and Pressure	Hydrants, Valves or other items required
Main	0+00	2" 200 PSI PVC	Well, well pit appurtenances incl.
			continuousacting Air Vent
	0+05	2" 200 PSI PVC	Tee to Line D
	27+25	2" 200 PSI PVC	Tee to Line A
	61+48	2" 200 PSI PVC	1" Press. Reg set @ 30 PSI
	61+50	2" 200 PSI PVC	tee stop & drain then 1" curb stop
	100+50	2" 200 PSI PVC	hydrant
	122+25	2" 200 PSI PVC	hydrant, then 1" curb stop
	124+50	End 2" 200 PSI PVC	Tee Line B, then 1" check valve
		Begin 1 1/2" 200 PSI	Sta 124+50
	135+00	1 1/2" 200 PSI PVC	hydrant
	153+50	1 1/2" 200 PSI PVC	Tee to Line C
	165+50	1 1/2" 200 PSI PVC	tee to stop & drain then curb stop
	205+25	1 1/2" 200 PSI PVC	stop& drain

Pump Recommendations

Pump Type	Pump Rate (GPM)	Head (TDH)	Model No. (or equal)
4" submersible	30	450	5 HP

Pressure Tank Recommendations

Size (gal.)	Min. Press. Rating	Pressure Switch Setting (psi)			Model
172 Gal total	100	ON-OFF	20	50	(2) WX-302

Construction Notes

1. SD STATE LAW requires that no excavator may begin any excavation without first notifying the ONE-CALL notification center of the proposed excavation. (1-800-781-7474)
2. Pipelines designed for potable water shall use pipe carrying the NSF label, and the lines shall be shock chlorinated.
3. Guard posts are required at all above ground appurtenances.
4. Pipeline is to be buried deep enough to obtain a minimum depth of cover of 6.0 feet, measured from original ground.
5. Water bars are to be installed at locations selected by the NRCS technician.

Attachments to this Plan

JOB PLAN 12B (Appurtenances for Pipelines)
JOB PLAN 14.5C (Stockwater Tank)

Notes: **Pump shall be 4" submersible, 1 ph., 230V, rated at 30 gpm @ 450 ft. TDH equal to Franklin Model # 35JS5S4-PE, 22 stage**

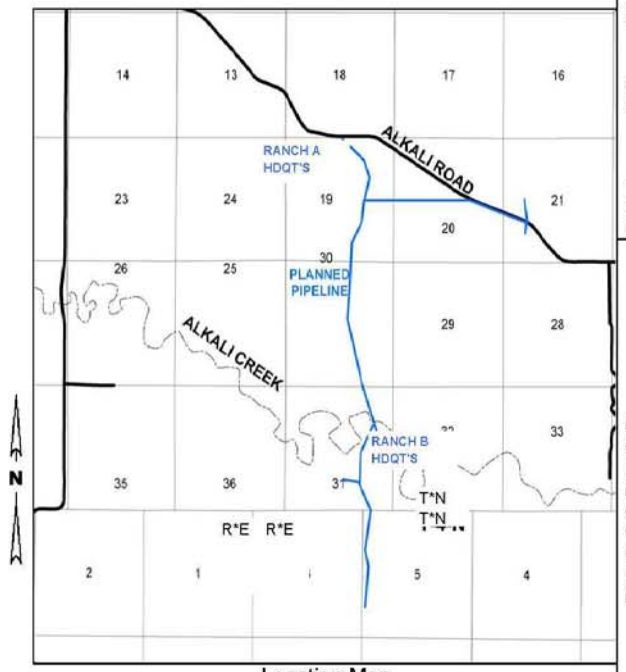
Due to water temperature, a 4" flow inducer sleeve will be required to provide min. 3 ft/sec flow velocity past pump.

Use two 88 gallon pressure tanks to provide a total 172 gallon storage.

1" double check valves must be installed on all lines, hydrants, and stop and drain valves teeing off off main line between well and Ranch B HDQT"s in order to provide sanitary protection for Ranch B house.

See pg 2 for table of quantities and appurtenance locations for other lines

Section * Town. *N Range *E



Location Map
Scale 1 inch = 5280 Ft.

Plastic Pipe Specifications:

1. The work shall consist of furnishing and installing plastic pipe, fittings and appurtenances.
2. The pipe shall be free of all defects and conform to all applicable ASTM specifcations for the type of plastic specified.
3. All joints and connections shall carry the design flow without leakage. Manufacturers recommendations must be followed.
4. Dissimilar metals must not be in contact with each other. Steel or other corrosive metals must be protected from corrosion.
5. Trenches containing rocks which could damage the pipe shall be over excavated and backfilled with suitable material. Pipelines may be "plowed-in" where soils are suitable.
6. All backfill recommendations of the manufacturer shall be met with the initial 6" being free of rocks. Mound soil over trench to allow for settlement.
7. Pipe not connected with gasketed couplers must be "snaked" in the trench. The pipe shall be allowed to come within a few degrees of subsoil temperature before backfilling.

Wood Fabrication Specifications:

1. The work shall consist of furnishing wood guard posts and protective structures.
2. All wood plywood, OSB, and lumber shall be pressure treated or exterior grade.
3. All wood material shall be new or like new, and free of major defects.
4. All timber structures shall be installed in a workmanlike manner.

Constr. Spec. SD-20A Plastic Pipeline, SD-16 Wood Fabrication and SD-55 Plastic Pipe are incorporated by reference. For a full text version see http://www.sd.nrcs.usda.gov/technical/SD_Engineering.html

CONTRACTOR/PRODUCER CERTIFICATION
I certify that this pipeline and related appurtenances were installed in accordance with these approved/"as-built" NRCS plans and specifications. The information included on this form is a true and factual record of the job performed by me.

Contractor/Producer Signature Date

The contractor shall furnish the owner a one-year guarantee covering materials and construction.

STATEMENT OF COMPLIANCE
Construction (was) (was not) completed in accordance with approved construction plans and specifications.

NRCS JAA Date

Designed: C.E.T. Date: 1/30/08
Drawn: C.E.T. Date: 1/30/08
Checked: Date:
Approved: Date:

Ranch A & Ranch B
Sect. * Township *N Range *E
Any County County
South Dakota

NRCS
Natural Resources Conservation Service
United States Department of Agriculture

File Name
Drawing Name
JOB PLAN 12.1 3/05
Sheet 1 of 5

Figure 9.14
Construction Plans Sheet 2

Section _____*_____ Town. _____*N_____ Range _____*E_____

Pipe Materials and Appurtenance Locations

Line Number	Station	Pipe Size and Pressure	Hydrants, Valves or other items required
A	0+00	1 1/4" 200 PSI PVC	1" curb stop, 1" check valve
	87+00	1 1/4" 200 PSI PVC	stop & drain valve
B	0+00	1 1/2" 200 PSI PVC	1" curb stop in riser
	6+48	1 1/2" 200 PSI PVC	1" Press. Reg Set @ 50 PSI
	6+50	1 1/2" 200 PSI PVC	Ranch B House
C	0+00	1 1/2" 200 PSI PVC	1" curb stop in riser
	11+50	1 1/2" 200 PSI PVC	hydrant
D	0+00	1 1/2" 200 PSI PVC	1" curb stop in riser
	3+00	1 1/2" 200 PSI PVC	Ranch A HQTS
	3+01		1" Check Valve after tee to house
A1	0+00	1 1/4" 200 PSI PVC	
	0+10	1 1/4" 200 PSI PVC	Begin 2" Sleeve
	1+10	1 1/4" 200 PSI PVC	End 2" Sleeve
	10+75	1 1/4" 200 PSI PVC	stop and drain

Table of Quantities

ITEM OR MATERIAL	UNIT	QUANTITY	AS-BUILT
2" SDR 21 200 PSI PVC Pipe	lf.	12,550	
Includes 100' for Road Sleeve			
1 1/2" SDR 21 200 PSI PVC	lf.	10,175	
1 1/4" SDR 26 200 PSI PVC	lf.	9,775	
1" curb stop	ea.	6	
2" Continuous Acting Air Vent	ea.	1	
Waterman CRP-8 or equal			
1" double Check Valve	ea.	6	
1" Watts 223 press regulator	ea.	1	
or equal, set @ 30 psi			
1" Press. Reg. set @ 50 PSI	ea.	1	
Frost Free Hydrant	ea.	4	
Stop and Drain Installation	ea.	5	
36" x 6' Culvert w/ lid (PressR)	ea.	2	
Guard Post Installation	ea.	14	
Trenching & Backfill	lf.	32,400	
Press. Tank Pit	ea.	1	
86 gal. Press. Tank (see specs	ea.	2	
5 hp Pump (see specs. Pg. 1)	ea.	1	

Note: All above ground appurtenances must be protected
With guard post installations

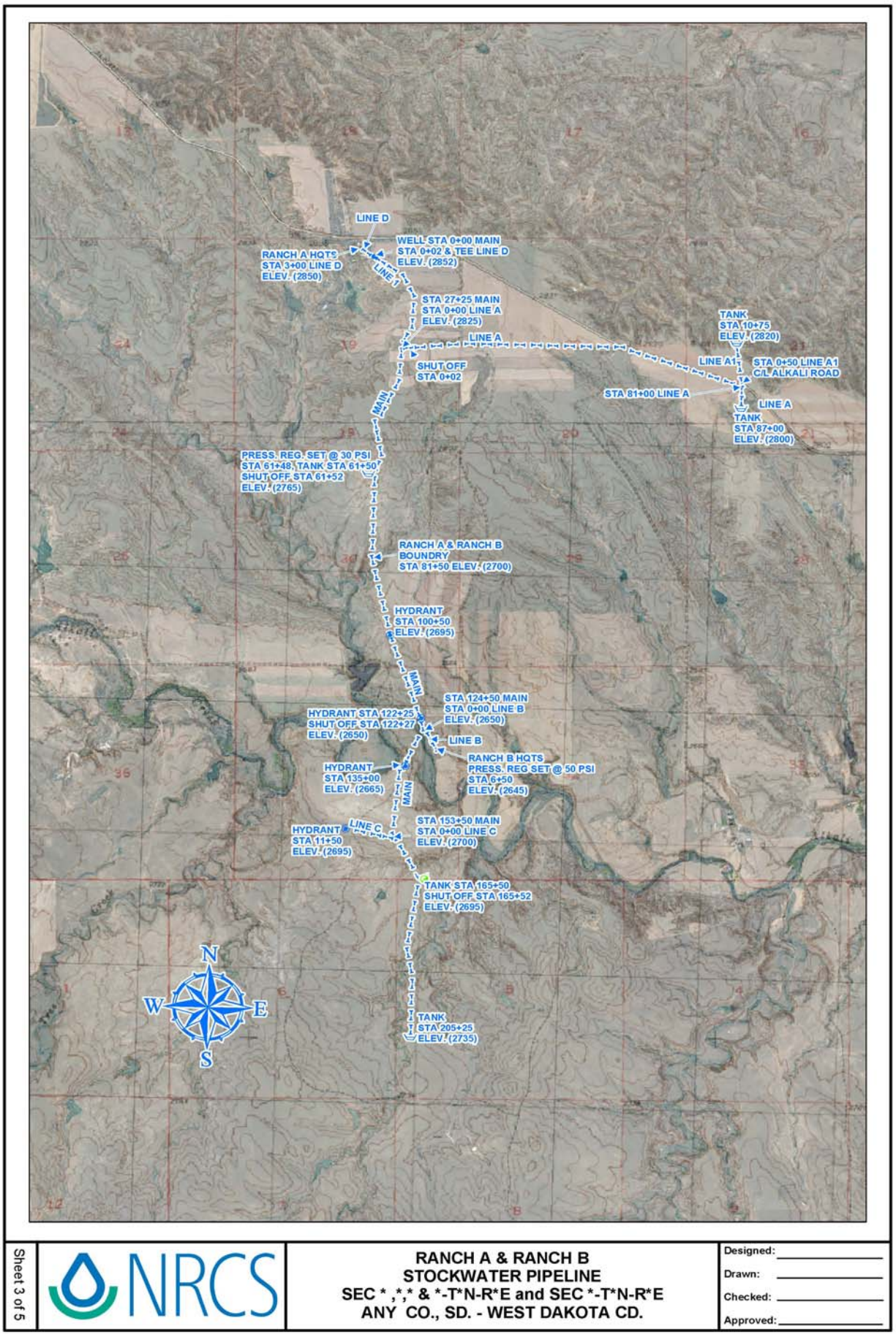
Designed: C.E.T Date: 4/8/08
Drawn: C.E.T Date: 4/8/08
Checked: Date:
Approved: Date:

Ranch A & Ranch B
Sect. * Township *N Range *E
Any County County
South Dakota

NRCS
Natural Resources Conservation Service
United States Department of Agriculture

File Name
Drawing Name
JOB PLAN 12.1 3/05
Sheet 2 of 5

Figure 9.15
Construction Plans Sheet 3 (Plan View)



Sheet 3 of 5

NRCS

RANCH A & RANCH B
STOCKWATER PIPELINE
SEC * ,*,* & *-T*N-R*E and SEC *-T*N-R*E
ANY CO., SD. - WEST DAKOTA CD.

Designed: _____
Drawn: _____
Checked: _____
Approved: _____

Figure 9.16
Construction Plans Sheet 4 (Well Pit)

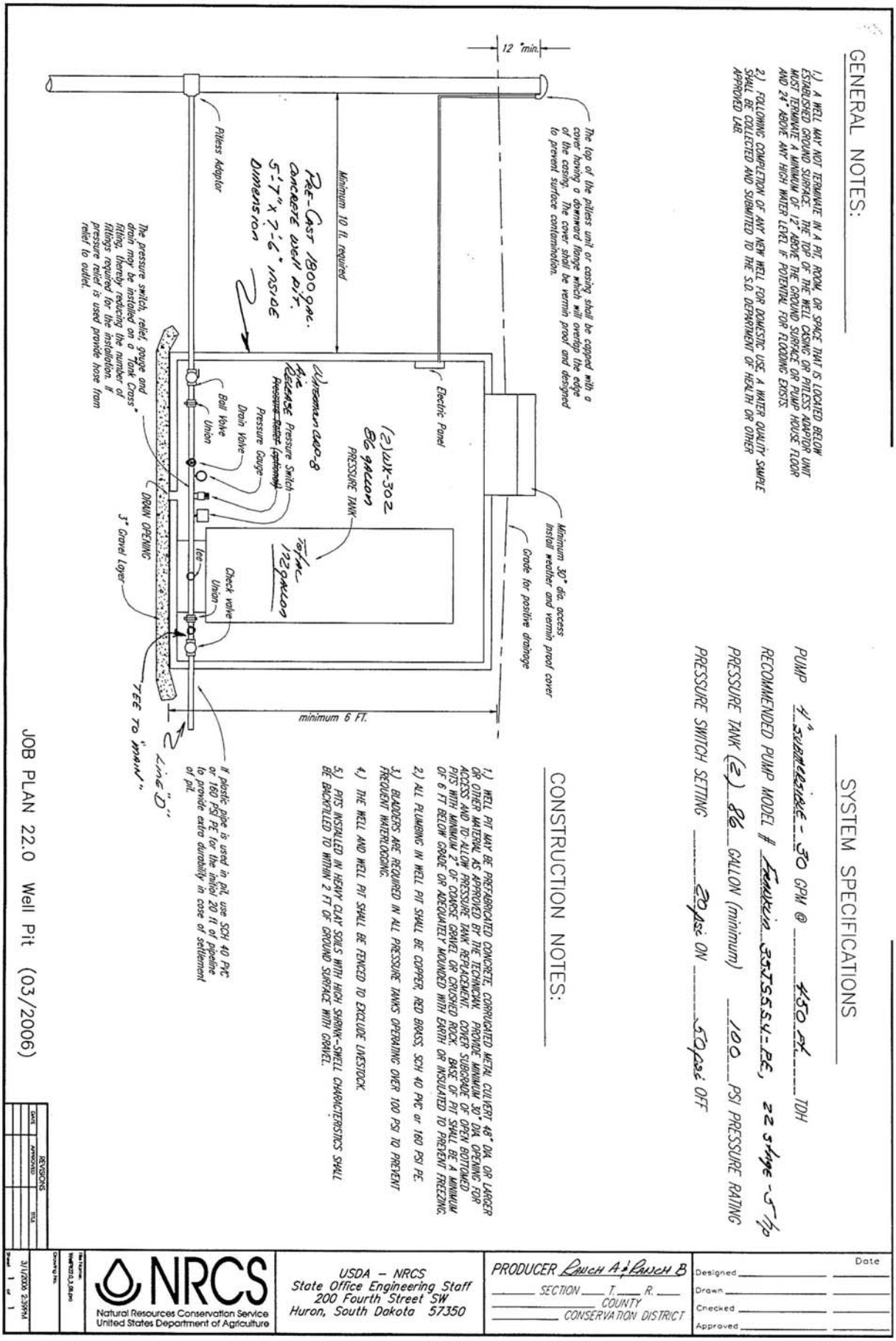
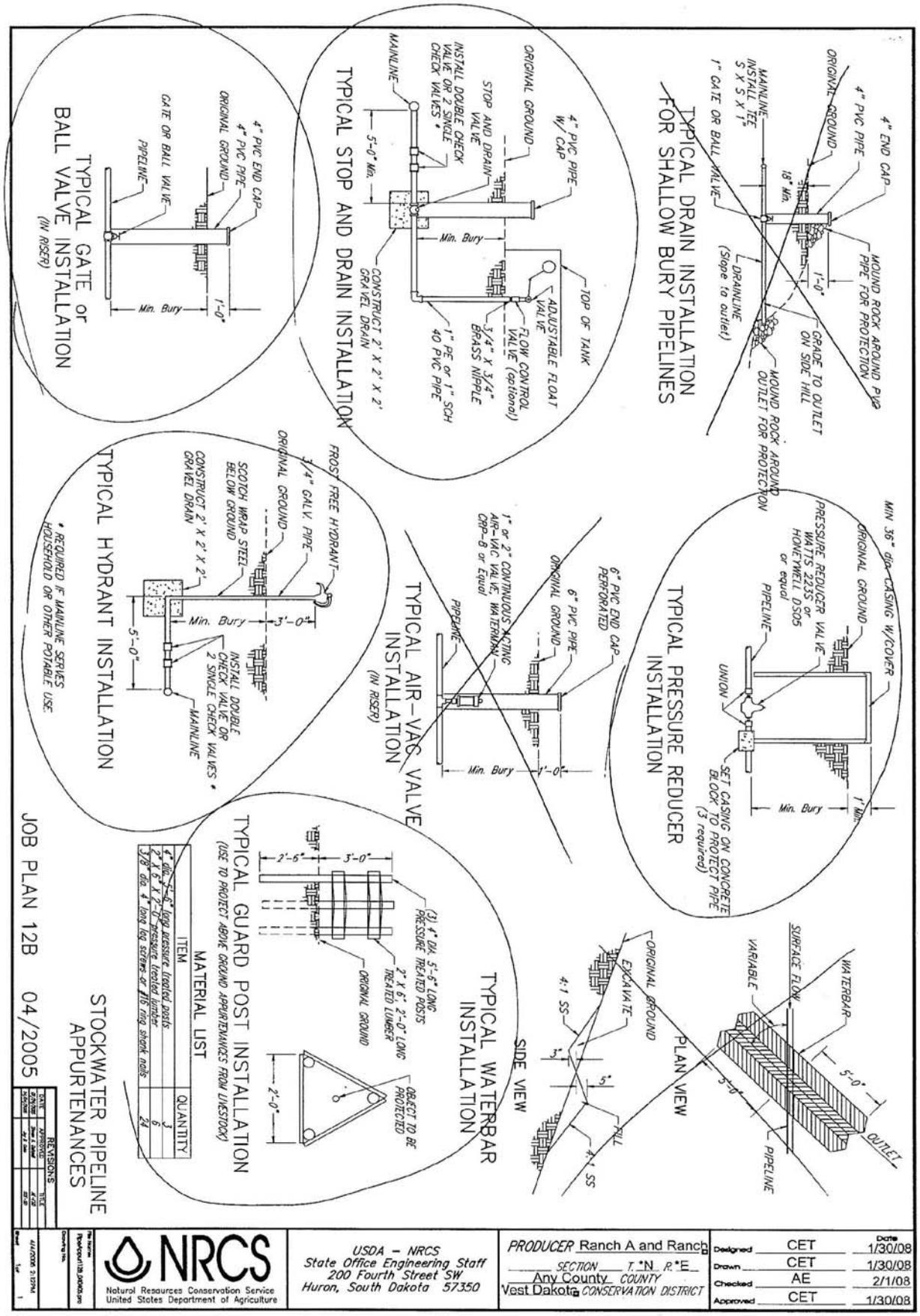


Figure 9.17
Construction Plans Sheet 5 (Pipeline Appurtenances)



CHAPTER 10

DESIGN EXAMPLES AND CALCULATIONS
(Rural Water Connection)
Example 2

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Part 10.3	Sizing and Hydraulic Calculations	10-6
Part 10.4	Design of Pipeline Appurtenances	10-8
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CHAPTER 10

DESIGN EXAMPLES AND CALCULATIONS
Example 2

10.0 General

The example illustrated in this chapter shows the steps necessary to complete a stock water pipeline system from the initial planning, through design, preparation of construction plans and specifications, and construction checkout for a system connecting to an existing rural water system. This system has a fairly low level of complexity. The same basic procedure outlined in Chapter 9 will be followed with less emphasis given to indepth explanation of procedures. For a more detailed review of procedures for labeling, stationing, etc., see Chapter 9, Example 1.

1. Gather information from operator during **initial planning** and subsequent follow-up visits specific to installing the water system.
2. Finalize pipeline route and gather **pipeline stationing and elevation data** for use in hydraulic calculations.
3. Design the pipeline including **sizing and hydraulic calculations.**
4. Design **pipeline appurtenances.**
5. Label plan view with appropriate details.
6. Complete Construction Plans including Table of Quantities.
7. **Complete Construction Check.**

10.1 Initial Planning Information

- Source of water is a rural water main line running along the north boundary of the property. The rural water association will be installing a meter pit which will include a water meter, pressure regulator set at 50 psi double check valves, and two shut-off valves.

- Pressures in the system at the meter location (as provided by the association) vary with a maximum static head of 92 psi and hydraulic pressure not less than 50 psi.

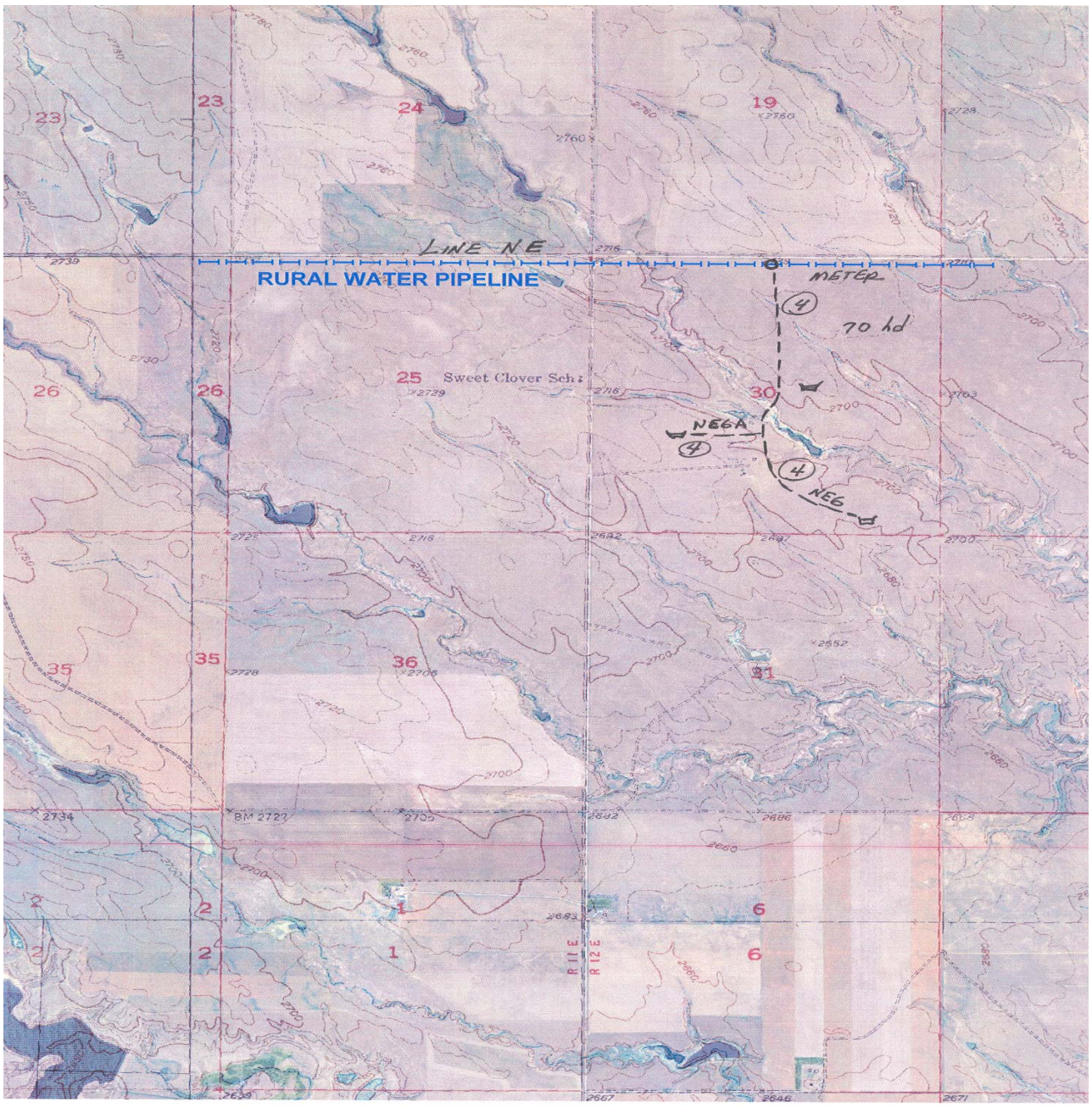
- This operation, which is located in the eastern part of the state, runs 70 cow/calf pairs which may be at any one tank location or split between tanks.

1. The field copy of the digital ortho/topo map was used for the initial planning.

2. The meter location was agreed on between the water association and the operator. The pipeline route was selected after working with the operator on tank locations and with consideration for topographic features.

3. This map was then used at the start of the design process to label the lines and determine the design capacity for each line segment. The lines were labeled with a continuation of the same format originally used for the rural water system design. The minimum design capacity (24-hr. flow) for any of the line segments based on 1.5 gpm/100 hd. cows (21.6 gpd per cow) would be 1.1 gpm. The designer bases the minimum design flow on delivering the daily water needs of the livestock in no more than 12 hours rather than the 24 (2.2 gpm). The design will reflect a practical minimum for design flow for a line segment of no less than approximately four gpm. A pipeline flow less than this would not be acceptable for most users, since there is an expectation of what a water line should deliver.

Figure 10.1
Planning Map – Field Copy



10.2 Pipeline Stationing and Elevation Data

The station and elevation data necessary for the hydraulic calculations is obtained from the route as drawn on a USGS topographic map. The station and elevation data for the example are as follows on Figure 10.2.

Figure 10.2
Station and Elevation Data

Computation Sheet
NRCS–ENG-523A Rev. 6-2002

U.S. Department of Agriculture
Natural Resources Conservation Service

State	Project: Ranch C		
By: [signature] Date: 4/08	Checked by	Date	Job No.
Subject: Station & Elev.			Sheet 1 of

Line NE6

STA	ELEV.	
0+00	2730	RW main
0+01	2730	Press Reg. @ 50 psi
25+00	2700	Tank
30+00	2695	draw
32+00	2700	Tee to NE6A
51+00	2710	Tank

Line NE6A

0+00	2700	32+00 line NE6
8+50	2710	TANK

10.3 Sizing and Hydraulic Calculations

The design procedure currently used, in SD, for pipelines utilizes an Excel spreadsheet (Class II Pipeline Design and Job Forms) which can be downloaded from the SD NRCS Web site http://www.sd.nrcs.usda.gov/technical/Engineering_Tools.html.

The spreadsheet includes a sheet giving instructions for the hydraulics. The following steps were used to develop the design example:

1. The stations and elevations along the pipeline route (part 10.2) are entered in the spreadsheet along with the design flows. Since the water temperature is less than 73°F, there will be no effect on the pipe pressure rating, but the temperature must be entered into the spreadsheet. Use of the appurtenance column helps to identify locations along the route, s**ee Figure 10.3.**

2. The static and hydraulic pressures are also entered. The static pressure at the main of 90 psi is entered at station 0+00. The hydraulic pressure of 50 psi is used both at the main and as the pressure regulator setting at station 0+01.

3. The pipe sizes and pressure ratings (SDR no.) are now selected and entered. The pipe selected for the design is 1¼" SDR 21, 200 psi. The 1¼" size should be considered the minimum installed for any system. Even though many rural water associations have a policy of 1½" being minimum for size, the operator has the flexibility to install a larger size if desired. The heavier walled 200 psi pipe is specified rather than 160 psi for increased durability.

4. Once the spreadsheet is populated with the initial data, the hydraulic and static pressures are reviewed. The hydraulic pressures (**Figure10.3**) are all acceptable (no warning messages or negative pressures). The static pressures are below the maximum allowed for SDR 21 pipe,

5. Since the hydraulic pressures all along these lines and at all outlets is between 50 and 60 psi, in actual operation, the pipeline will flow at a rate much greater than the 4 gpm design flow. The rural water main will not be a limiting factor for flow. The head losses in the pressure regulator and other valves at the manhole and the other line losses will balance with the hydraulic pressure available at the manhole and the flow will be maximized when the hydraulic pressure at the outlet is near zero. This will be the maximum flow available (most likely in the 10-15 gpm range).

Figure 10.3
Pipeline Design Calculations
(Sheets 1 and 2)

Pipeline Design Calculations

Project:	Ranch C							Sec.		T.	0N	R.	0E	Any County		County
Designer:	CET					Date:	4/23/2008	Checker:				Date:			Sheet	1
Line No.	Station	Appurts.	Total AU's	Ground Elev.	Flow gpm	Pipe Size	Material & SDR #	H_F/100 ft	Length	H_F	HGL Elev.	Hydr. Press. psi	SGL Elev.	Static Press. psi	Water Temp (F)	Max Press. Allowed for Pipe (psi)
NE6	0+00	Meter Pit	70	2730							2846	50	2943	92	73	144
	Sta 442+00 Line NE RW main				4	1 1/4	PVC SDR 21	0.175	1	0.00						
	0+01	Press. Regulator		2730							2845	50	2846	50	73	144
					4	1 1/4	PVC SDR 21	0.175	2499	4.36						
	25+00	Tank		2700							2841	61	2846	63	73	144
					4	1 1/4	PVC SDR 21	0.175	500	0.87						
	30+00	draw		2695							2840	63	2846	65	72	144
					4	1 1/4	PVC SDR 21	0.175	200	0.35						
	32+00	Tee NE6A		2700							2840	61	2846	63	72	144
					4	1 1/4	PVC SDR 21	0.175	1900	3.32						
	51+00	tank		2710							2837	55	2846	59	72	144

Pipeline Design Calculations

Project:	Ranch C							Sec.		T.	0N	R.	0E	Any County		County
Designer:	CET					Date:	4/23/2008	Checker:				Date:			Sheet	2
Line No.	Station	Appurts.	Total AU's	Ground Elev.	Flow gpm	Pipe Size	Material & SDR #	H_F/100 ft	Length	H_F	HGL Elev.	Hydr. Press. psi	SGL Elev.	Static Press. psi	Water Temp (F)	Max Pressure Allowed for
NE6A	0+00	32+00 NE6	70	2700							2840	61	2846	63	72	144
					4	1 1/4	PVC SDR 21	0.175	850	1.48						
	8+50	Tank		2710							2838	56	2846	59	70	144

☐ Check box if a pressure reducer is used? STA [ ] Pressure Setting [ ] PSI

10.4 Design Pipeline Appurtenances

1. All of the appurtenances in the Rural Water Association manhole are most likely a standard plumbing configuration used by that association. If the system being installed has abnormally high design flows or low hydraulic pressure, then the association may need to be consulted concerning valve sizing, otherwise, the standard configuration should be adequate.

2. The curb stop which is used as a shut-off on line NE6A is sized two sizes smaller than the pipeline size. Shut-off valves are recommended on the tees to lateral lines and along a mainline spaced at approximately one mile intervals. Shut-off valves provide flexibility in operation of the system allowing portions of line to remain in operation while other portions are down for service or maintenance problems; and valves also allow sections of the line to be isolated to limit volumes of water which must be dealt with in case of a leak or other maintenance problem.

3. Systems should be evaluated for the need for air relief. The summits on this line occur at the meter pit and at the two hydrants at the end of each respective line. There should be little need for air relief on this system with the RW as its source; however, with the anticipated flow potential of this system, any air will be carried through the system to outlet at the hydrants. The hydrants will act as manual air vents.

10.5 Construction Plans and Specifications

Construction plans **(Figures 10.4 and 10.5)** were developed using the "Class II Pipeline Design and Job Forms" which were also used in Section 10.3 for the hydraulic calculations (http://www.sd.nrcs.usda.gov/technical/Engineering_Tools.html).

These forms are titled as "Class II" which refers the Engineering Job Approval Job Class II, but the forms can work well with minor modifications, even for some pipelines up to Job Class IV.

A plan view along with the table of quantities is two of the most important details on a set of construction plans. With an adequate amount of detail and labeling, these plan details can convey the intent of the designer on many of the major details of the system in a way which can be easily understood.

The appurtenance details **(Figure 10.5)** can be easily tailored to the project by crossing out the details which do not apply and marking those details which are part of the design.

Any review of construction plans with the operators should include a discussion of route changes and the effect it may have on system pressures. A specific route may be critical on many systems which have low operating (hydraulic pressures) at the outlets or at summits along the route. If subsequent route changes result in an increase in elevation, the change may result in the line not functioning properly. The operator needs to be aware of these limitations if they exist.

Figure 10.4
Construction Plans Sheet 1

Design Data

Water source	RW Association
Number of livestock	70
Pipeline design flow (gpm)	4
No. days storage required	0
Minimum capacity required (gal.)	8 ft tank

Pipe Materials and Appurtenance Locations

Line Number	Station	Pipe Size and Pressure	Hydrants, Valves or other items required
NE6	0+00	1 1/4" PVC SDR 21	Meter Pit (provided by RW Assoc)
			Includes Shut-offs,
			Press. Reg. set @ 50 PSI,
			Water Meter and Check Valves
	25+00	1 1/4" PVC SDR 21	Hydrant w/ guard post inst.
	51+00	1 1/4" PVC SDR 21	Hydrant w/ guard post inst.
NE6A			
	0+00	1 1/4" PVC SDR 21	3/4" curb stop in riser
	8+50	1 1/4" PVC SDR 21	Hydrant w/ guard post inst.

Pump Recommendations

Pump Type	Pump Rate (GPM)	Head (TDH)	Model No. (or equal)
N/A			

Pressure Tank Recommendations

Size (gal.)	Min. Press. Rating	Pressure Switch Setting (psi)		Model
N/A		ON-OFF		

Construction Notes

1. SD STATE LAW requires that no excavator may begin any excavation without first notifying the ONE-CALL notification center of the proposed excavation. (1-800-781-7474)
2. Pipelines designed for potable water shall use pipe carrying the NSF label, and the lines shall be shock chlorinated.
3. Guard posts are required at all above ground appurtenances.
4. Pipeline is to be buried deep enough to obtain a minimum depth of cover of 6.0 feet, measured from original ground.
5. Water bars are to be installed at locations selected by the NRCS technician.

Attachments to this Plan

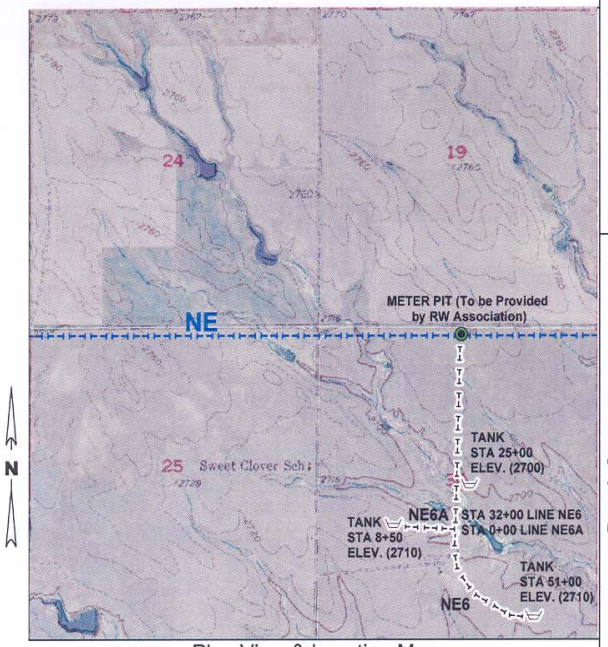
JOB PLAN 12B (Appurtenances for Pipelines)
JOB PLAN 14.5C (Stockwater Tank)

Table of Quantities

ITEM OR MATERIAL	UNIT	QUANTITY	AS-BUILT
1 1/4" PVC SDR 21 200 PSI	lf.	5,950	
Trenching & Backfill	lf.	5,950	
3/4" curb stop	ea.	1	
Frost free hydrant 6' bury	ea.	3	
Guard Post Installation	ea.	3	

Notes:

Section 0 Town. 0N Range 0E



Plan View & Location Map
Scale 1 inch = 2000 Ft.

Plastic Pipe Specifications:

1. The work shall consist of furnishing and installing plastic pipe, fittings and appurtenances.
2. The pipe shall be free of all defects and conform to all applicable ASTM specifications for the type of plastic specified.
3. All joints and connections shall carry the design flow without leakage. Manufacturers recommendations must be followed.
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CONTRACTOR/PRODUCER CERTIFICATION
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Contractor/Producer Signature Date

The contractor shall furnish the owner a one-year guarantee covering materials and construction.

STATEMENT OF COMPLIANCE
Construction (was) (was not) completed in accordance with approved construction plans and specifications.

NRCS JAA Date

Designed:	CET	Date: 4/23/08
Drawn:	CET	Date: 4/23/08
Checked:		Date:
Approved:		Date:

Ranch C
Sect. 0 Township 0N Range 0E
Any County County
South Dakota

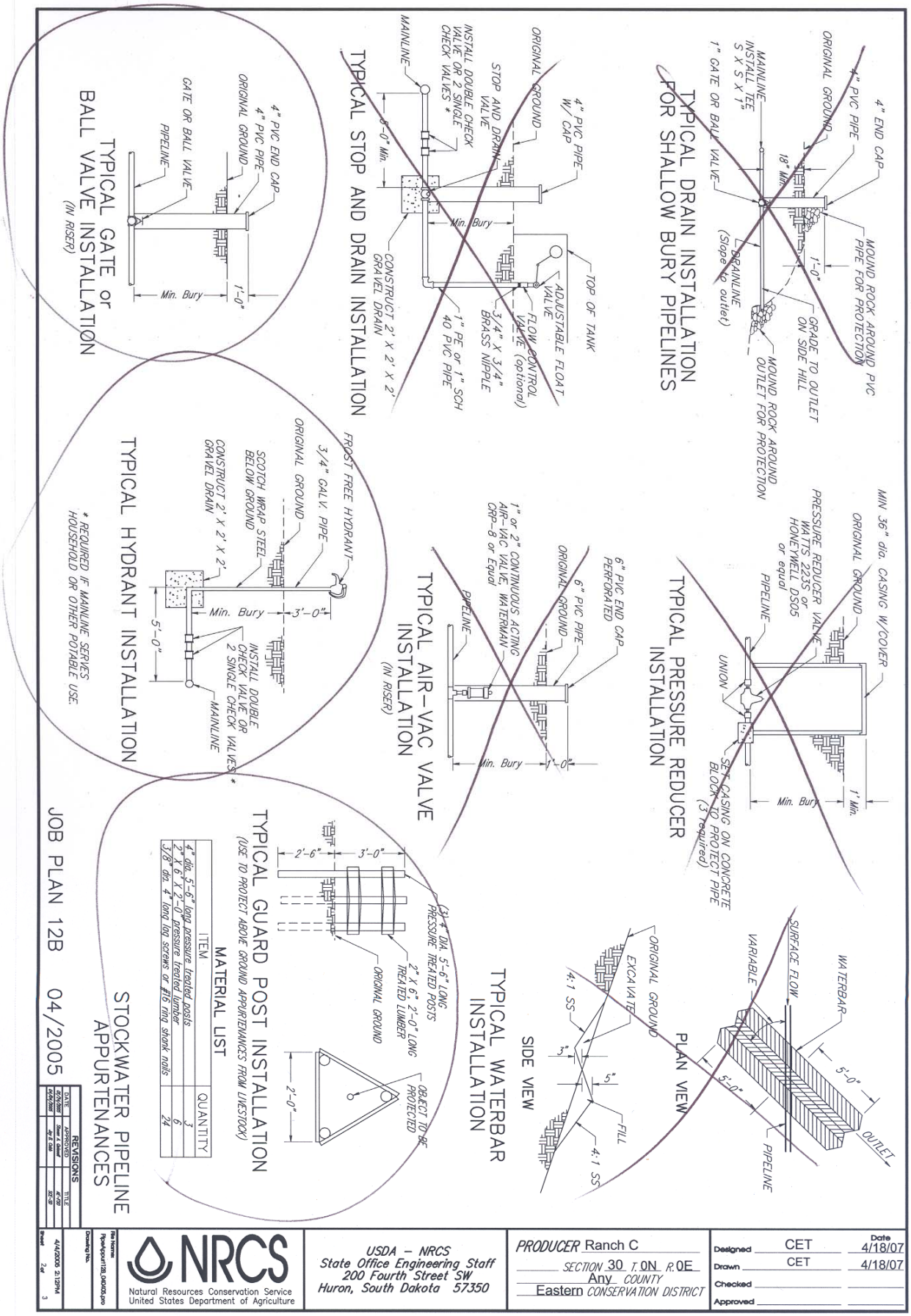
NRCS
Natural Resources Conservation Service
United States Department of Agriculture

File Name

Drawing Name
JOB PLAN 12.1 3/05

Sheet 1 of 3

Figure 10.5
Construction Plans Sheet 2 (Pipeline Appurtenances)



APPPENDIX A

GROUND WATER DATA

South Dakota Ground Water Resources A-3
USGS Water Supply Paper 2275

Generalized Stratigraphic Column of Central and Northwestern South Dakota, South Dakota Geological Survey A-9

Dakota-New Castle Artesian Aquifer Contours A-11

South Dakota Ground Water Quality A-13
USGS Water Supply Paper 2325

South Dakota Wind Resource Map A-21
United States Department of Energy

Identifying and Correcting Water Problems A-23
SD Cooperative Extension Service FS 877P

Softening A-27
SD Cooperative Extension Service FS 877S

Iron and Manganese Removal A-33
SD Cooperative Extension Service FS 877IM

Activated Carbon Filtration A-39
SD Cooperative Extension Service FS 877A

Reverse Osmosis A-45
SD Cooperative Extension Service FS 877RO

Distillation A-49
SD Cooperative Extension Service FS 877D

Chlorination A-55
SD Cooperative Extension Service FS 877C

Nitrates in South Dakota Drinking Water A-61
SD Cooperative Extension Service FS 604

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SOUTH DAKOTA
Ground-Water Resources

Ground water constitutes a large and reliable source of water for domestic, stock, public-supply, irrigation, and industrial use in South Dakota. Most of the State is underlain by one or more aquifers that yield small to very large supplies of water of differing quality. Seventy-seven percent of the population of 695,000 is served by ground water. Ground-water withdrawals in 1980 and related statistics are given in table 1.

West of the Missouri River, 76 percent of the water used is from surface sources; irrigation accounts for 73 percent of this use. In contrast, municipalities and industry in this area depend on ground water for more than 50 percent of their supplies. Ground water supplies about 95 percent of the rural domestic demand for fresh water.

East of the Missouri River, ground water is by far the largest source of freshwater and accounts for about 70 percent of all water used. Of the total ground water withdrawn, irrigation uses 60 percent, and municipalities and industry together use 6 percent. Ground water also provides more than 90 percent of the rural-domestic supply. The presence of relatively shallow ground-water sources, greater annual rainfall than in the west, and a lack of convenient on-stream storage sites have contributed to this pattern of water use in eastern South Dakota.

GENERAL SETTING

The Missouri River divides the State into two distinct physiographic and geologic areas (fig. 1). West of the river, bedrock generally is at or near the surface, and the area is characterized by deep valleys and canyons, buttes, and broad flat uplands typical of the Great Plains physiographic province (Fenneman, 1931). East of the river, the area is characterized by low, rolling hills and potholes typical of the glaciated parts of the Central Lowland physiographic province. These distinct differences in the geology and topography east and west of the Missouri River result in major differences in ground-water conditions, development, and use in the two areas.

The average annual precipitation in South Dakota is about 18 inches (in.); it ranges from about 13 in. in the northwestern corner of the State to about 25 in. in the southeastern corner. However, precipitation can vary greatly from year to year. The annual precipitation has ranged from 7.5 to 50 in. Periods of successive dry years or years that are wetter than normal are frequent (U.S. Geological Survey and U.S. Bureau of Reclamation, 1975).

Recharge to the shallow aquifer in the glaciated and unglaciated areas is largely through infiltration of precipitation that falls on the immediate area. The mechanism of recharge to the deeper bedrock aquifers is not yet fully understood. However, some recharge doubtlessly occurs in the Black Hills because streams cross the exposed surfaces of the aquifers (U.S. Geological Survey and U.S. Bureau of Reclamation, 1964).

PRINCIPAL AQUIFERS

The principal aquifers in South Dakota can be grouped into glacial drift and alluvial and consolidated sedimentary bedrock aquifers. The aquifers are described below and in table 2, from youngest to oldest; their areal distribution is shown in figure 1.

Table 1. Ground-water facts for South Dakota

[Withdrawal data rounded to two significant figures and may not add to totals because of independent rounding. Mgal/d = million gallons per day; gal/d = gallons per day. Source: Solley, Chase, and Mann, 1983]

Population served by ground water, 1980	
Number (thousands)	533
Percentage of total population	77
From public water-supply systems:	
Number (thousands)	321
Percentage of total population	46
From rural self-supplied systems:	
Number (thousands)	212
Percentage of total population	31
Freshwater withdrawals, 1980	
Surface water and ground water, total (Mgal/d)	690
Ground water only (Mgal/d)	330
Percentage of total	48
Percentage of total excluding withdrawals for thermoelectric power	48
Category of use	
Public-supply withdrawals:	
Ground water (Mgal/d)	52
Percentage of total ground water	16
Percentage of total public supply	68
Per capita (gal/d)	162
Rural-supply withdrawals:	
Domestic:	
Ground water (Mgal/d)	21
Percentage of total ground water	6
Percentage of total rural domestic	94
Per capita (gal/d)	99
Livestock:	
Ground water (Mgal/d)	81
Percentage of total ground water	25
Percentage of total livestock	88
Industrial self-supplied withdrawals:	
Ground water (Mgal/d)	26
Percentage of total ground water	8
Percentage of total industrial self-supplied:	
Including withdrawals for thermoelectric power	54
Excluding withdrawals for thermoelectric power	55
Irrigation withdrawals:	
Ground water (Mgal/d)	150
Percentage of total ground water	45
Percentage of total irrigation	33

GLACIAL-DRIFT AND ALLUVIAL AQUIFERS

One of the two principal ground-water systems in the State is the glacial drift that constitutes the surface deposits over most of the area east of the Missouri River. Most of these glacial deposits are till (Flint, 1955), a relatively impermeable and heterogeneous mixture of boulders, gravel, and rock fragments of all sizes incased in fine-grained material, such as silt and clay. The aquifers in the drift primarily are unconsolidated sand and gravel outwash deposited by meltwaters from glaciers. Although they may occur as sheets or ribbons of permeable, water-yielding material lying on or beneath the till, they are more commonly complex systems of sand and gravel layers within the body of till. The drift is as

Table 2. Aquifer and well characteristics in South Dakota

[Ft = feet; gal/min = gallons per minute; mg/L = milligrams per liter. Sources: Reports of the U.S. Geological Survey and the South Dako Geological Survey]

Aquifer name and description	Well characteristics			Remarks
	Depth (ft)	Yield (gal/min)		
	Common range	Common range	May exceed	
Glacial-drift and alluvial aquifers: Outwash and alluvium; unconsolidated sand, gravel, and silt. May be confined or unconfined.	20 - 400	3 - 50	2,000	Glacial drift underlies most of State east of Missouri River. Alluvium found along major streams. Water fresh to moderately saline; commonly suitable for irrigation. Big Sioux aquifer in southeastern South Dakota yields adequate supplies for Sioux Falls, State's largest city.
Sedimentary bedrock aquifers:				
High Plains aquifer: Sand, fine to medium; unconsolidated to poorly consolidated sandstone, silt, gravel, and clay. Unconfined.	10 - 570	5 - 100	1,500	Most common source of water on Pine Ridge and Rosebud Indian Reservations. Supplies towns of Martin and Pine Ridge. Some irrigation development. Water quality generally suitable for most uses. Consists of lower Ogallala Formation and Arikaree Formation Miocene age.
Fort Union-Hell Creek-Fox Hills aquifers: Sandstone, very fine to fine-grained, poorly consolidated; soft clay; lignite beds. Unconfined.	100 - 1,000	2 - 40	500	Most common source of water in northwestern South Dakota. Fox Hills aquifer supplies towns of Bison, Lemmon, and Timber Lake. Water commonly fresh.
Niobrara-Codell aquifer: Shale, chalky, and fine-grained quartz sandstone. Confined or unconfined.	150 - 300	2 - 30	300	Used extensively for livestock and domestic purposes in central South Dakota and southern James River basin. Water generally soft and moderately saline.
Dakota-Newcastle aquifer: Sandstone, interbedded with shale and siltstone. Confined.	300 - 4,000	2 - 50	1,500	Major source of water for domestic and stock use. Supplies water to many small public-supply systems. Water commonly moderately saline to very saline.
Inyan Kara aquifer: Sandstone, interbedded with shale and siltstone. Confined.	200 - 4,900	5 - 40	1,000	Considered to be an underdeveloped source of water for domestic and stock use. Water quality ranges from fresh in west to moderately saline in east to very saline in north.
Sundance aquifer: Shale interbedded with fine-grained sandstone, limestone, and sandy shale. Confined.	100 - 5,400	5 - 100	1,000	Important source of water for livestock in central part of State. Water commonly saline except near surface exposures in the west.
Minnelusa aquifer: Five major sandstone units separated by limestone, dolomite, shale, and anhydrite beds. Confined.	100 - 6,800	5 - 100	4,000	Major ground-water reservoir. Source for stock and domestic wells in central and western South Dakota. Water of suitable quality for irrigation (slightly saline or fresh) obtained from several wells near outcrops in the Black Hills. Most wells completed in Minnelusa flow.
Madison aquifer: Limestone, and dolomite containing beds of shale, anhydrite, and halite. Confined.	100 - 9,000	10 - 100	2,000	May be most important bedrock aquifer system in South Dakota. Comprises one or more aquifers that can yield large quantities of fresh to saline water under significant artesian pressure. Several producing wells are more than 4,000 ft deep. Supplies such western South Dakota towns as Philip, Midland, Eagle Butte, and Dupree.
Red River aquifer: Dolomite and dolomitic limestone. Confined.	1,100 - 9,700	5 - 100	1,000	Although not being used as a principal source of water in South Dakota, considered a major artesian aquifer. Dissolved-solids concentrations may exceed 60,000 mg/L. Maximum water temperatures of about 250 degrees Farenheit reported.
Deadwood aquifer: Sandstone, soft, thin-bedded, slabby dolomite and limestone; limestone-pebble conglomerate; and beds of glauconitic shale. Confined.	40 - 10,200	3 - 50	500	Except in the Black Hills area, aquifer not used, and potential for development, although probably significant, is not known. Salinity may range from moderately saline to very saline.

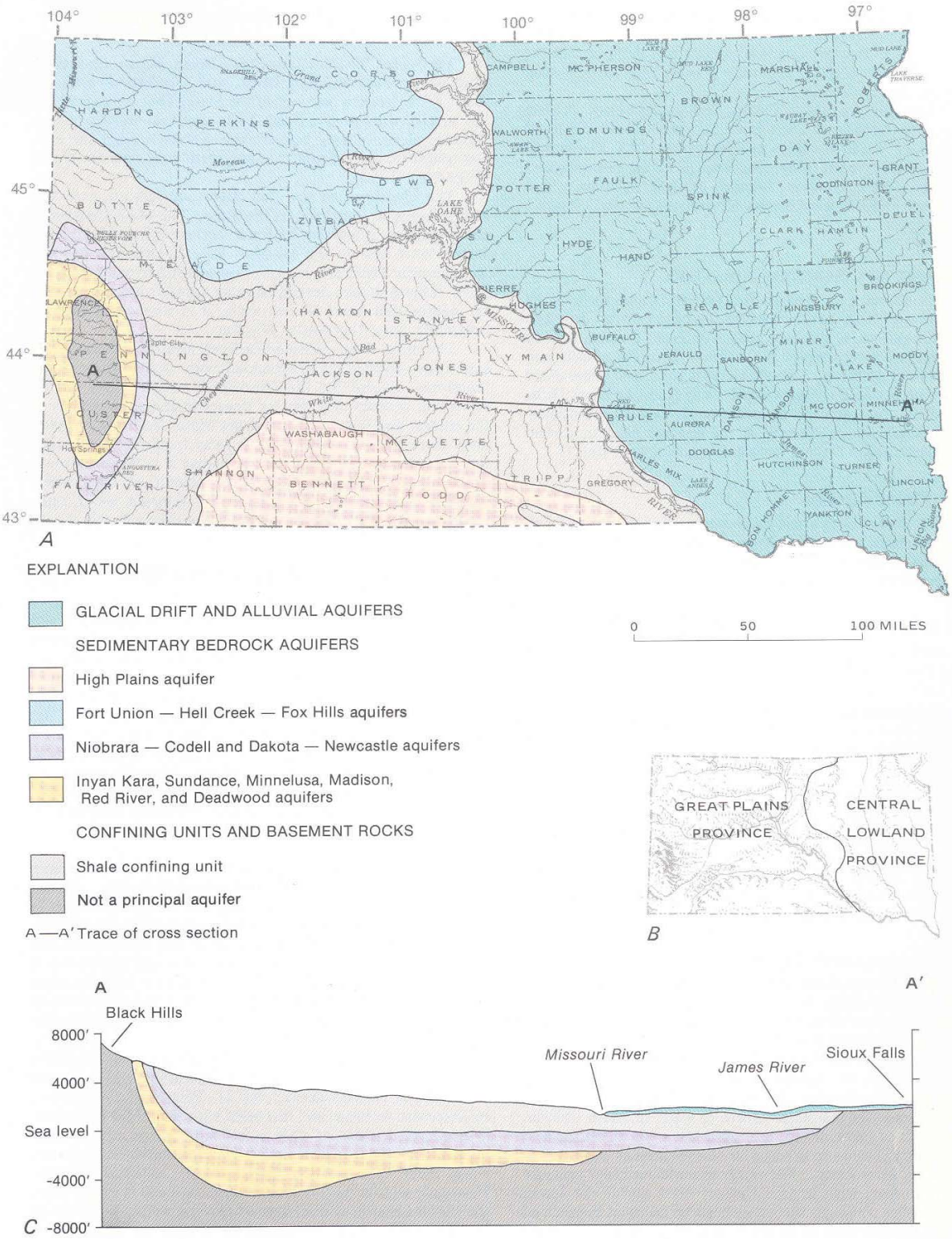


Figure 1. Principal aquifers in South Dakota. *A*, Geographic distribution. *B*, Physiographic diagram and divisions. *C*, Generalized cross section (A-A'). (See table 2 for a more detailed description of the aquifers. Sources: *A*, Modified from U.S. Geological Survey and U.S. Bureau of Reclamation, 1975. *B*, Fenneman, 1931; Raisz, 1954. *C*, Compiled by E. F. LeRoux from U.S. Geological Survey files.)

much as 800 feet (ft) thick in the northeast part of the State but probably averages about 150 ft. The maximum thickness of permeable aquifer material within the drift is 225 ft. Recharge to the aquifers generally is from local precipitation or infiltration from streams.

Some aquifers in glacial drift, such as the Tulare, the Big Sioux, and the Warren, have been mapped in detail as part of cooperative water-resources studies by the U.S. Geological Survey and the South Dakota Geological Survey (Howells and Stephens, 1969); however, because of their complexity and individually limited areal extent, they are not shown in figure 1 of this report.

SEDIMENTARY BEDROCK AQUIFERS

The second principal aquifer system, which includes all aquifers in the State with the exception of the glacial-drift and alluvial aquifers, is the only source of ground water west of the Missouri River, except for a few small areas of alluvium along major streams. Although commonly very mineralized and found at relatively great depth away from the Black Hills, water from these aquifers is used extensively for rural-domestic and stock supply. Several of the bedrock aquifers extend into eastern South Dakota beneath the glacial drift (fig. 1).

High Plains Aquifer

The High Plains aquifer is composed of the lower Ogallala Formation and the Arikaree Formation of Miocene age. The aquifer generally is unconfined and is recharged by local precipitation and snowmelt.

Fort Union-Hell Creek-Fox Hills Aquifers

In the northwestern part of the State, thin beds of lignite in the Fort Union and Hell Creek aquifers provide water. The Fox Hills sandstone yields supplies ample for small towns. The area underlain by these aquifers is sparsely populated, and the aquifers provide adequate quantities of water to farms, ranches, and several small communities.

Niobrara-Codell Aquifer

The Niobrara-Codell aquifer, which underlies much of the State, is at land surface around the Black Hills in western South Dakota and locally in southeastern South Dakota. Although usually not as important as some of the other aquifers in the State, it is important in the central part of South Dakota for domestic and stock use.

Dakota-Newcastle Aquifer

The Dakota-Newcastle aquifer underlies more than 66,000 square miles in South Dakota (fig. 1) and has an average thickness of about 150 ft (Schoon, 1971). It generally is thickest east of the Missouri River where it is as much as 460 ft thick. In the north-central to northwestern part of the State, however, the aquifer is not present or is a silty and sandy shale or siltstone less than 50 ft thick. The Dakota-Newcastle aquifer is a major source of water in South Dakota. Thousands of farm, ranch, and domestic wells and dozens of public-supply wells tap the aquifer. Development is greatest in the James River basin. The water is under artesian pressure and flows from wells in the Missouri River and in the James River valleys, although the water must be pumped in much of the State. Flow rates of as much as 1,500 gallons per minute (gal/min) have been measured by the U.S. Geological Survey, but most yields of flowing wells are less than 15 gal/min.

Inyan Kara, Sundance, Minnelusa, Madison, Red River, and Deadwood Aquifers

The older bedrock aquifers—Inyan Kara, Sundance, Minnelusa, Madison, Red River, and Deadwood—underlie much of the western one-half of the State. They are exposed at the surface around the Black Hills uplift in western South Dakota, plunge deeply beneath the surface toward the east, and terminate against quartzite basement rock near the center of the State (fig. 1).

The Madison and the Red River aquifers are extensive areally in the western part of the State. The Madison aquifer can yield large quantities of water and supplies a number of small towns west of the Missouri River. Although the Red River aquifer exists in a major oil-producing formation in the State, it has not been developed as an aquifer; however, based on information from oil test wells, it is considered to be a potentially important source of water.

The other deep, confined bedrock aquifers primarily are sandstone, commonly interbedded with shale, siltstone, or limestone. Except for the Deadwood aquifer, they are all important sources of water for domestic and stock supply in the central and western parts of the State. Although moderately saline to very saline (table 2) away from the Black Hills, the water is used in many areas because it is the only water economically available. Before the advent of rural water systems, hauling water many miles for domestic use in these areas was a common practice, which continues to this day in some areas.

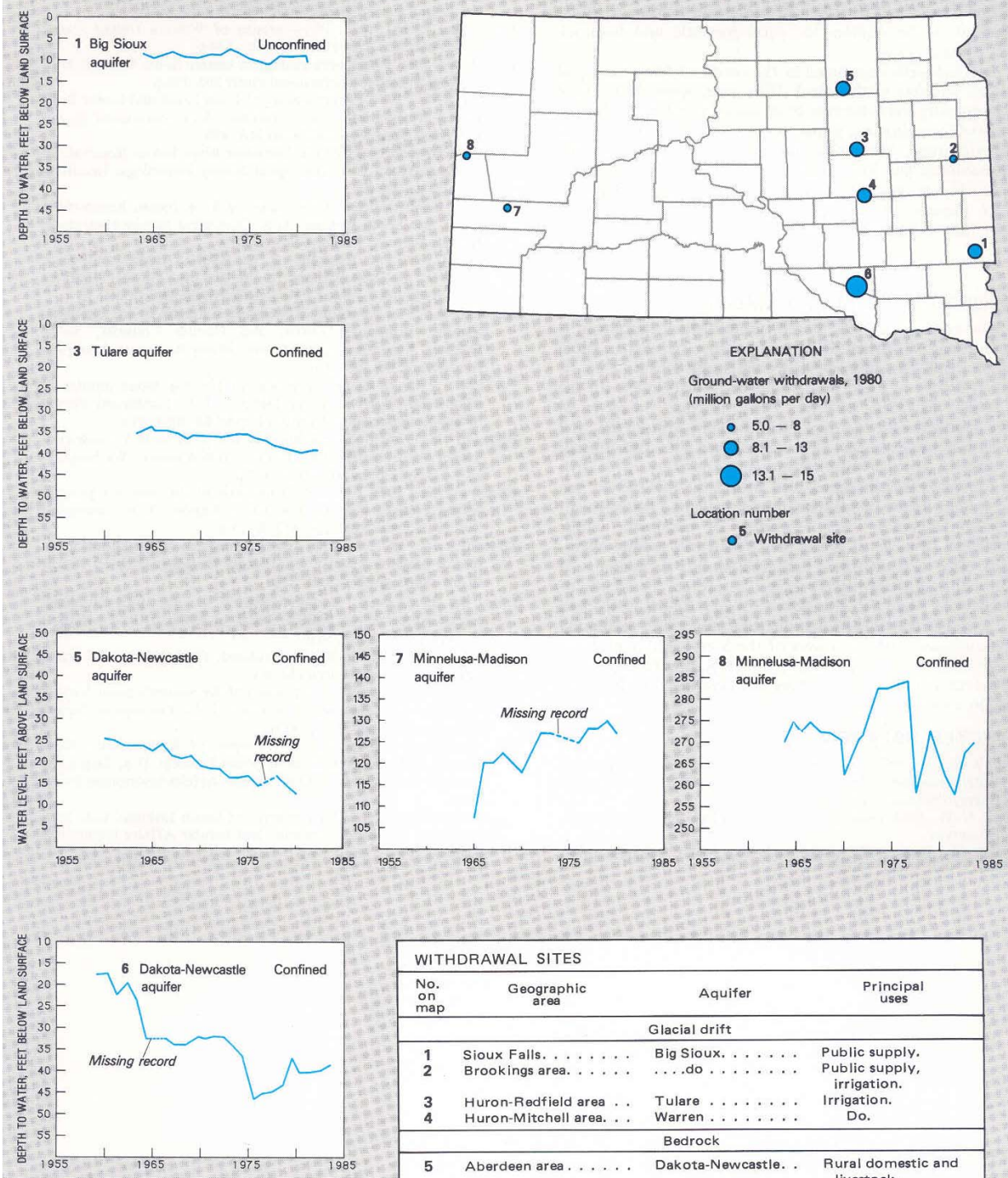
GROUND-WATER WITHDRAWALS AND WATER-LEVEL TRENDS

The distribution of major ground-water withdrawals and trends of ground-water levels near selected withdrawal centers are shown in figure 2. The withdrawal centers generally are broad areas covering parts of several counties. The largest groupings of pumping wells are at Sioux Falls (location 1, fig. 2), in several counties in the Brookings area (location 2, fig. 2), and in the James River valley (locations 3 and 4, fig. 2).

Flowing wells discharge about 170 million gallons per day from bedrock aquifers in South Dakota. Many flowing wells are clustered along major river valleys (locations 5, 6, fig. 2) in the eastern part of the State and also along the periphery of the Black Hills of western South Dakota (locations 7, 8, fig. 2).

Water levels generally decline in response to an increase in withdrawals and recover as withdrawals are decreased. Except for local areas of intensive pumping, the long-term trends in the unconfined aquifers do not show any decline. The hydrographs in figure 2 are representative of one unconfined and five confined aquifers. The water level in a well completed in the unconfined Big Sioux aquifer in the glacial drift (location 1, fig. 2) declined several feet between 1974 and 1976 because of decreased recharge from precipitation and increased withdrawal for public supply at Sioux Falls.

In a well completed in the confined Tulare aquifer in the glacial drift, a water-level decline of several feet was measured from 1974 to 1980 (location 3, fig. 2). This decline was caused by decreased recharge and increased withdrawal for irrigation. Water-level declines of only a few feet in this aquifer have little or no effect on the yield of nearby wells. In contrast, water levels in wells that penetrate the confined Dakota-Newcastle aquifer have declined more than 400 ft locally since the 1880's because of discharge of flowing wells. Water levels in this aquifer have continued to decline in many areas. Between 1960 and 1980, the water level declined 13 ft in one well in the Aberdeen area (location 5, fig. 2) and 30 ft between



WITHDRAWAL SITES

No. on map	Geographic area	Aquifer	Principal uses
		Glacial drift	
1	Sioux Falls.	Big Sioux.	Public supply.
2	Brookings area.	. . . .do	Public supply, irrigation.
3	Huron-Redfield area . .	Tulare	Irrigation.
4	Huron-Mitchell area. . .	Warren	Do.
		Bedrock	
5	Aberdeen area	Dakota-Newcastle. .	Rural domestic and livestock.
6	Yankton-Brule area. . .	. . . .do	Do.
7	Southern Black Hills . .	Minnelusa-Madison.	Public supply, rural domestic.
8	Northern Black Hills . .	. . . .do	Irrigation, public supply, industrial.

Figure 2. Areal distribution of major ground-water withdrawals and graphs of annual greatest depth to water in selected wells in South Dakota. (Sources: Withdrawal data from Solley and others, 1983; water-level data from U.S. Geological Survey files.)

1960 and 1975 in another well in the Yankton–Brule area (location 6, fig. 2). The levels decline as new flowing wells are completed in the aquifer for rural-domestic and livestock water supplies.

In some wells completed in the confined Minnelusa and Madison aquifers in the Black Hills area, water levels have declined nearly 200 ft because of increased numbers of flowing wells used for irrigation, public supply, and industrial supplies (fish hatcheries). Since 1960, however, water levels generally have stabilized and have even risen 20 to 30 ft at location 7 (fig. 2). This is caused by a decrease in the flow of older wells and an increase in recharge from streams during years of greater-than-average runoff.

GROUND-WATER MANAGEMENT

Management of the State's ground-water resources is accomplished through a water record and permit system and a State Water Plan administered by the South Dakota Department of Water and Natural Resources (SDDWNR). In the SDDWNR, the Office of Water Policy provides the technical policy analysis needed to implement the State Water Plan, and the Division of Geological Survey is charged with studying and mapping the ground-water resources of the State. The Division of Water Development, also within the SDDWNR, has the responsibility to coordinate development and management of South Dakota's water resources for maximum public benefit; the Division of Water Quality reviews ground-water-quality data to determine if contamination is occurring or if additional legal authority is required to protect the quality of ground water; and the Division of Water Rights is charged with licensing and other functions concerned with regulation and management of the waters of the State. Although State law does not allow withdrawals from an aquifer to exceed the average annual recharge, it does not regulate the effects of pumping on flowing wells.

SELECTED REFERENCES

Bloyd, R. M., Jr., 1975, Summary appraisals of the Nation's ground-water resources—Upper Mississippi Region: U.S. Geological Survey Professional Paper 813–B, 22 p.

Darton, N. H., 1951, Geologic map of South Dakota: U.S. Geological Survey.

Davis, R. W., Dyer, C. F., and Powell, J. E., 1961, Progress report on wells penetrating artesian aquifers in South Dakota: U.S. Geological Survey Water-Supply Paper 1534, 100 p.

Fenneman, N. M., 1931, Physiography of Western United States: New York, McGraw-Hill Book Co., 534 p.

Flint, R. F., 1955, Pleistocene geology of eastern South Dakota: U.S. Geological Survey Professional Paper 262, 173 p.

Howells, L. W., 1974, Geohydrology of Crow Creek and Lower Brule Indian Reservations, South Dakota: U.S. Geological Survey Hydrologic Investigations Atlas HA–499.

____1979, Geohydrology of the Cheyenne River Indian Reservation, South Dakota: U.S. Geological Survey Hydrologic Investigations Atlas HA–585.

____1982, Geohydrology of the Standing Rock Indian Reservation, North and South Dakota: U.S. Geological Survey Hydrologic Investigations Atlas HA–644.

Howells, L. W. and Stephens, J. C., 1969, Geology and water resources of Beadle County, South Dakota, Part II–Water resources: South Dakota Geological Survey Bulletin 18, 65 p.

Koch, N. C., 1980, Appraisal of the water resources of the Big Sioux aquifer, Brookings, Deuel, and Hamlin Counties, South Dakota: U.S. Geological Survey Water-Resources Investigations Report 80–100, 46 p.

____1983, A digital-computer model of the Big Sioux aquifer in Minnehaha County, South Dakota: U.S. Geological Survey Water-Resources Investigations Report 82–4064, 49 p.

Raisz, Erwin, 1954, Physiographic diagram, p. 59, *in* U.S. Geological Survey, 1970, National atlas of the United States: Washington, D.C., U.S. Geological Survey, 417 p.

Reeder, H. O., 1978, Summary appraisals of the Nation's ground-water resources—Souris–Red–Rainy Region: U.S. Geological Survey Professional Paper 813–K, 25 p.

Schoon, R. A., 1971, Geology and hydrology of the Dakota Formation in South Dakota: South Dakota Geological Survey Report of Investigations No. 104, 55 p.

Solley, W. B., Chase, E. B., and Mann, W. B., IV, 1983, Estimated use of water in the United States in 1980: U.S. Geological Survey Circular 1001, 56 p.

South Dakota Geological Survey, undated, Geologic map of South Dakota: Educational Series Map 1.

Taylor, O. J. 1978, Summary appraisals of the Nation's ground-water resources—Missouri Basin Region: U.S. Geological Survey Professional Paper 813–Q, 41 p.

U.S. Geological Survey and U.S. Bureau of Reclamation, 1964, Mineral and water resources of South Dakota: U.S. 88th Congress, 2d Session, Interior and Insular Affairs Committee Print, 295 p.

____1975, Mineral and water resources of South Dakota: U.S. 94th Congress, 1st Session, Interior and Insular Affairs Committee Print, 313 p.

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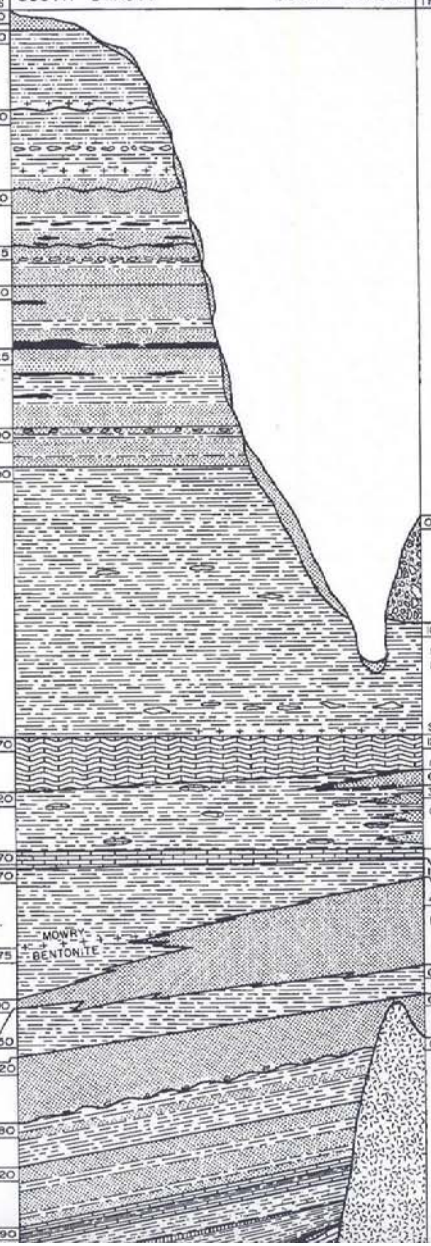
Department of Natural Resource Development
South Dakota Geological Survey

GENERALIZED STRATIGRAPHIC COLUMN OF CENTRAL AND NORTHWESTERN SOUTH DAKOTA—by Robert A. Schoon

Educational Series
Map Six

PERIOD / EPOCH	GROUP / FORMATION	DESCRIPTION	THICKNESS
QUATERNARY	PLEISTOCENE	Sand, gravel, boulders.	0-60
TERTIARY — MIOCENE	ARIKAREE GROUP	Clay and silt, light colored, soft to cemented white ash bed at base.	0-500
TERTIARY — OLIGOCENE	WHITE RIVER GROUP	Clay, pink, sandy and silty, chalcedony veins, massive.	0-600
TERTIARY — PALEOCENE	FORT UNION — TONGUE RIVER	Clay and sand, light colored, minor thin coal beds.	0-400
	FORT UNION — CANNONBALL	Shale, greenish gray, sandstone, yellow to buff as concretions and channel filling.	0-225
	FORT UNION — LUDLOW	Clay and sandstone, somber gray with some thin lignite beds. Shadehill (?) coal at base.	0-350
CRETACEOUS	HELL CREEK FORMATION	Shale, drab, soft brown (somber beds) and sandstone gray. Sandstone increases toward base. Thin lenses of lignite in upper part.	0-325
	FOX HILLS FORMATION	Sandstone, grayish white to carbonaceous gray shale. Ironstone concretions at top.	0-200
	PIERRE SHALE	Shale, light gray to dark gray.	2800
	NIOBRARA FORMATION	Chalk, light to dark gray, white speckled, microfossiliferous.	270
	CARLILE SHALE	Shale, medium to dark gray plastic to fissile—scattered ironstone concretions.	320
	GREENHORN LIMESTONE	Limestone, white to light gray, slabby, very fossiliferous with dark gray, white speckled shale at top and at base.	70
	BELLE FOURCHE SHALE	Shale, dark gray, dolomite and ironstone concretions.	370
	MOWRY SHALE	Shale, medium gray, siliceous, bentonite marker at top.	275
	NEWCASTLE SANDSTONE	Sandstone, white to light gray, fine-grained in part, very shaley.	0-100
	SKULL CREEK SHALE	Shale, dark gray with thin glauconitic siltstone near middle of interval.	200-250
	INYAN KARA GROUP (FALL RIVER AND LAKOTA SANDSTONE)	Sandstone, white to light gray, fine to medium-grained quartz, predominately friable.	320
JURASSIC	MORRISON FORMATION	Shale, medium gray, interbedded with sandstone, white, fine grained, glauconitic.	180
	SUNDANCE FORMATION	Sandstone, white, fine to medium grained, glauconitic, interbedded with shale, gray, green and brown.	320
	PIPER LIMESTONE	Limestone, white to brown, fine grained, interbed-	90

STRATIGRAPHIC SECTION



DESCRIPTION	THICKNESS	GROUP / FORMATION	PERIOD / EPOCH
Clay, sand, pebble and boulder mixture.	0-500	PLEISTOCENE	QUATERNARY
Shale, medium to dark gray with limestone and ferruginous concretions. Many thin bentonites.	000-1300	PIERRE SHALE	CRETACEOUS
Shale, dark gray, carbonaceous. Bentonite at base.			
Chalk, light to dark gray, white, speckled, microfossiliferous	120-150	NIOBRARA FORMATION	
Sandstone, white to gray, glauconitic.	0-70	CODELL SANDSTONE	
Shale, medium to dark gray, plastic, ironstone concretions and stringers of fine grained sandstone.	330	CARLILE SHALE	
Limestone, white to light gray, fossiliferous.	40	GREENHORN LIMESTONE	
Shale, dark gray, fissile to blocky, ironstone concretions.	110	GRANEROS SHALE	
Sandstone, white, fine to medium grained, friable to well consolidated.	450	DAKOTA SANDSTONE	
Sandstone, dark gray, glauconitic, siltstone near middle part.	0-150	SKULL CREEK SHALE	
Sandstone, white, fine to coarse grained quartz.	0-225	INYAN KARA GROUP	
Sioux Ridge composed of pale maroon to red orthoquartzite.	0-7000 ?	SIOUX QUARTZITE	ECAMBRIAN

		Shale, dark gray with thin glauconitic siltstone near middle of interval. 200-250	0-7000 ? Sioux Ridge composed of pale maroon to red orthoquartzite.	SIOUX QUARTZITE
	INYAN KARA GROUP (FALL RIVER AND LAKOTA SANDSTONE)	Sandstone, white to light gray, fine to medium-grained quartz, predominately friable. 320		
JURASSIC	MORRISON FORMATION	Shale, medium gray, interbedded with sandstone, white, fine grained, glauconitic. 180		
	SUNDANCE FORMATION	Sandstone, white, fine to medium grained, glauconitic, interbedded with shale, gray, green and brown. 320		
TRIASSIC	PIPER LIMESTONE	Limestone, white to brown, fine grained, interbedded with shale, green, red and brown. 90		
	SPEARFISH FORMATION	Shale, silty, orange, brick red, green and minor gray. Interbedded with anhydrite, gypsum and salt. 0-600		
PERMIAN	MINNEKAHTA LIMESTONE	Limestone, white to lavender, fine, dense. 0-50		
	OPECHE SHALE	Shale, brick red, silty. 0-50		
	MINNELUSA: CASSA 2	Sandstone, white, brick red, clayey. 0-80		
	MINNELUSA: BROOM CREEK 2	Anhydrite, white to light brown, limestone and dolomite, white to light gray, silty. 80-300		
PENNSYLVANIAN	MINNELUSA: WENDOVER-MEEK 3	Limestone, dolomite, light gray, fine, silty, anhydrite, light brown and gray. "Red Shale Marker" at top. 175-200		
	MINNELUSA: HAYDEN 2	Limestone, light gray to brown interbedded with black radioactive shale. 140-170		
	MINNELUSA: ROUNDTOP 2	Shale, green to minor red, plastic, sands up eastward 100-160		
	MINNELUSA: RECLAMATION 2	Ls, white to black, lithographic, varicolored shale 0-80		
	MINNELUSA: FAIRBANK 2	Sandstone, white to red, in part shaley. 0-100		
MISSISSIPPIAN	KIBBEY SANDSTONE	Sandstone, white to gray, medium to coarse grained. 0-120		
	CHARLES FORMATION	Limestone, white to light tan, lithographic, interbedded with anhydrite, white to light blue and light brown. 0-400		
	MISSION CANYON FORMATION	Limestone, white to light tan, fine to oolitic, in part anhydritic. 120-320		
	LODGEPOLE FORMATION	Limestone, light to medium brown, gray, fine to medium grained, in part sucrosic. 120-550	Igneous and metamorphic rock.	
	ENGLEWOOD	Dolomitic siltstone and varicolored shale 0-60		
DEVONIAN	DUPEROW	Light brown, fine grained limestone and dolomite, interbedded with thin gray shale. 0-240		
SILURIAN	SOURIS RIVER	Varicolored shale and red dolomitic siltstone 0-30		
	INTERLAKE	Light tan to brown dolomite, fine grained clastics at base. 0-250		
ORDOVICIAN	STONEWALL	Light tan to pale dolomite, locally sandy. 0-75		
	STONY MOUNTAIN	Brownish gray fine grained dolomite at top with green waxy shale and siltstone at base. 0-155		
	RED RIVER (UNIT A)	Light brown to pale red 0-115		
	RED RIVER (UNIT B)	limestone, in part dolomitized, and light colored chert. Threefold subdivision is mainly based 0-320		
	RED RIVER (UNIT C)	E-log characteristics. 0-100		
	WINNIPEG	Fine grained quartz sandstone at base, green, splintery to subwaxy shale with small vitreous black phosphate nodules interbedded with siltstone at top. 0-150		
CAMBRIAN	DEADWOOD	White to reddish-orange, fine to medium grained quartz sandstone and dolomite, contains green shale partings and locally abundant glauconite. 0-630		
PRECAMBRIAN		Igneous and metamorphic rock.		PRECAMBRIAN

1 As defined by Hattin, D.E., 1965. Stratigraphy of the Graneros Shale (Upper Cretaceous) in Central Kansas. Kansas Geological Survey, Bull. 178, 83 pp.

2 As described by Meek, F.B., and Hayden, F.V., 1861. Philadelphia Academy of Natural Resources Proceedings, v. 13, p. 419-20.

3 Condra, G.E., Reed, E.C., and Scherer, O.S., 1940. Correlations of the Formations of the Laramie Range, Hartville Uplift, Black Hills and western Nebraska, Nebraska Geological Survey Bull. 13, 52 pp.

In view of the equivalency of the Hartville "Formation" and the Minnelusa, the Hartville subdivisions are employed in the Minnelusa in South Dakota.

SOUTH DAKOTA GEOLOGICAL SURVEY

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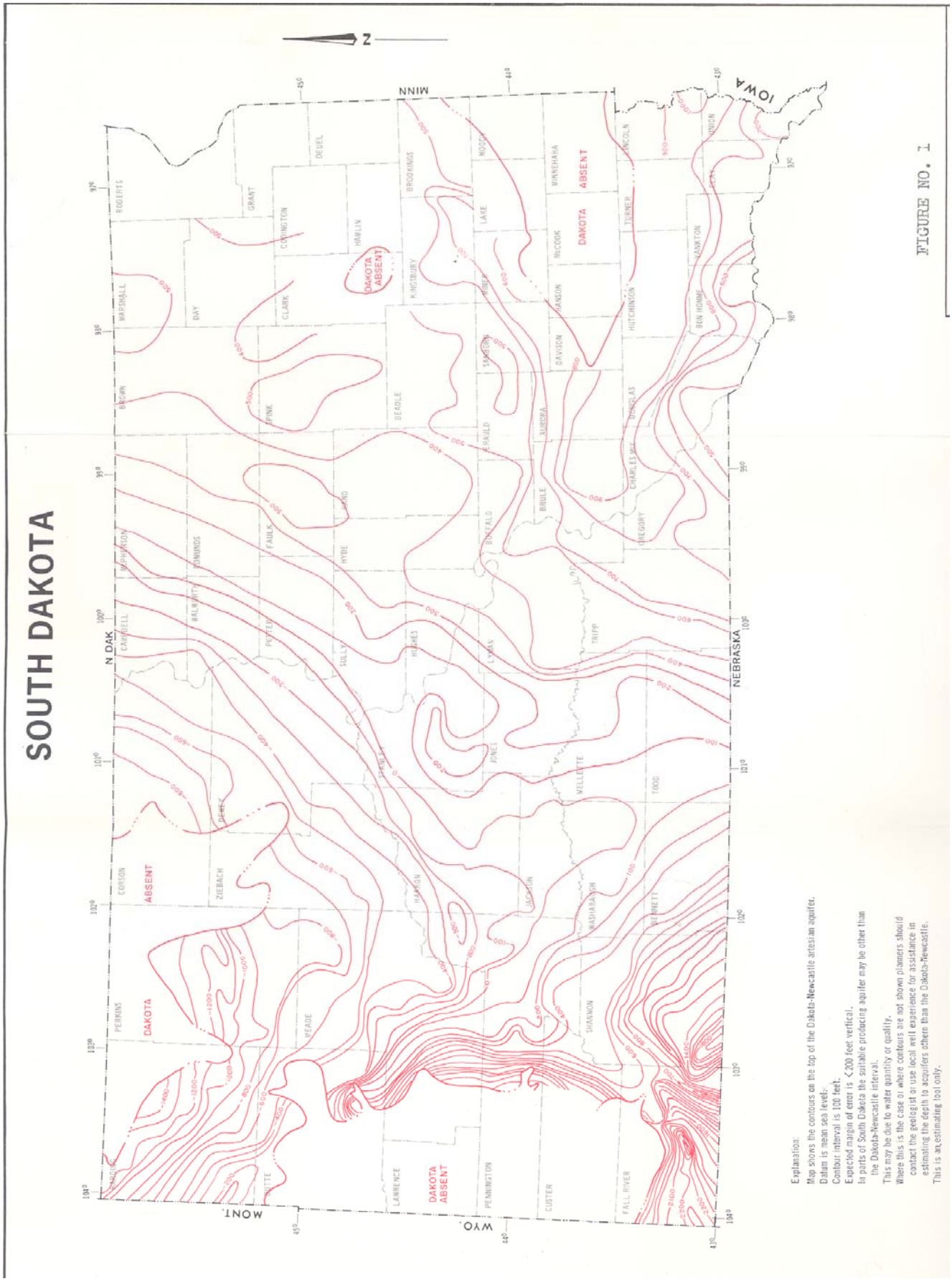

FIGURE NO. 1

Explanation:
Map shows the contours on the top of the Dakota-Newcastle artesian aquifer.
Datum is mean sea level.
Contour interval is 100 feet.
Expected margin of error is < 200 feet vertical.
In parts of South Dakota the suitable producing aquifer may be other than the Dakota-Newcastle interval.
This may be due to water quantity or quality.
Where this is the case or where contours are not shown planners should contact the geologist or use local well experience for assistance in estimating the depth to acquifers others than the Dakota-Newcastle.
This is an estimating tool only.

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SOUTH DAKOTA
Ground-Water Quality

Ground water provides 77 Mgal/d (million gallons per day) for about 77 percent of South Dakota's population of 690,000 people (fig. 1). The majority of the State's 934 community wells, 301 noncommunity wells, and 60,350 private wells are located near the more populated areas of South Dakota. There is no evidence of widespread human-induced contamination in the glacial-drift and alluvial aquifers, and the sedimentary bedrock aquifers (fig. 2). The principal water-quality concern in South Dakota is that the quality of water from large areas of the State commonly exceeds the U.S. Environmental Protection Agency's (EPA) (1986a,b) primary or secondary standards for drinking-water supplies. Dissolved solids, chloride, fluoride, nitrate, sulfate, iron, manganese, selenium, and radionuclides are constituents that most commonly exceed the standards. Although the concentrations of most of these constituents are due to the mineralogy of the aquifers within the State, elevated concentrations of dissolved solids and nitrate are known to result from human activities.

Although areas of ground-water contamination do exist within the State, most cases are isolated (fig. 3). Inorganic and organic nutrients resulting from feedlots, septic tanks, and improper handling and storage of fertilizers have contaminated several community and private water-supply wells. Additional inorganic contaminants affecting wells include dissolved solids resulting from leaking artesian aquifers, saltwater intrusion from saline lakes, brine spills, and leaking brine pits. Arsenic contamination of ground-water supplies in the Black Hills in western South Dakota is known to occur from mine tailings.

Organic contamination of ground water, primarily from pesticides and petroleum products, has been documented in South Dakota (South Dakota Department of Water and Natural Resources, 1984). However, areas of known contamination are limited to those downgradient of spills, leaky storage tanks, and landfills. A hazardous-waste site is present within the Whitewood Creek drainage in western South Dakota as a result of the movement of trace metals from mine tailings to the Whitewood Creek alluvium. Also, the Whitewood Creek site was identified as part of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and is part of EPA's Superfund program. U.S. Department of Defense has identified 16 sites at one facility as having potential for ground-water contamination.

Data assessing organic contaminants in ground water in South Dakota are limited because no statewide ground-water-monitoring network exists and because analyses of organic chemicals are not part of routine water-quality analyses of samples from water-supply and observation wells. The potential for organic contamination is particularly great in shallow glacial-drift and alluvial aquifers. For example, the Big Sioux aquifer, a glacial-drift and alluvial aquifer, in eastern South Dakota, provides drinking water for more than 80 percent of the population in the Big Sioux River basin (about 26 percent of the State's population) and is especially vulnerable to contamination because of the shallow depth to water, the extension of permeable material to the land surface, and urban areas where organic materials are produced and stored overlying substantial parts of the aquifer.

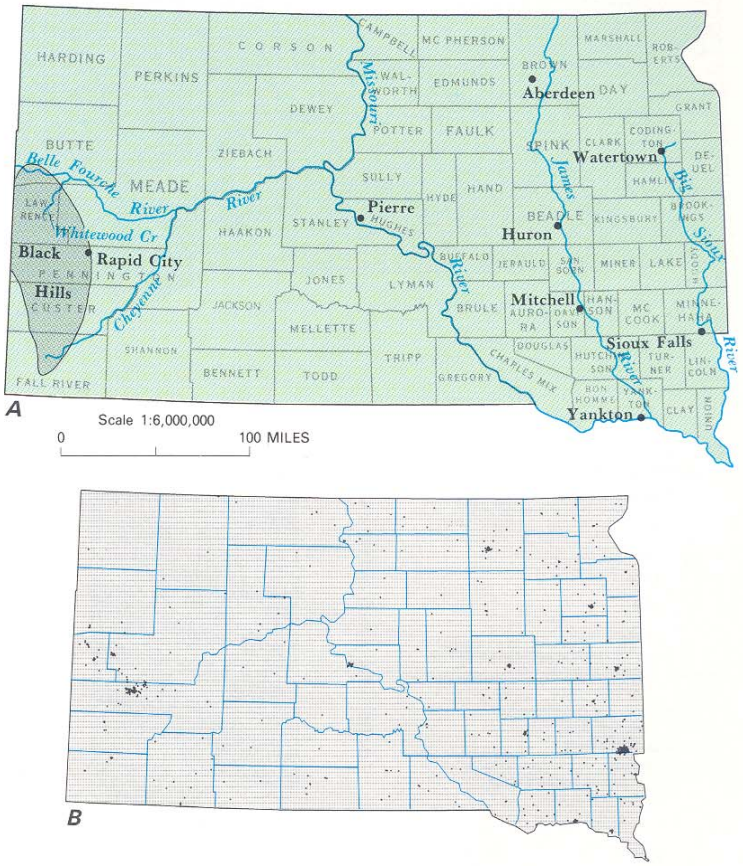

Figure 1. Selected geographic features and 1985 population distribution in South Dakota. *A*, Counties, selected cities, and major drainages. *B*, Population distribution, 1985; each dot on the map represents 1,000 people. (Source: *B*, Data from U.S. Bureau of the Census 1980 decennial census files, adjusted to the 1985 U.S. Bureau of the Census data for county populations.)

WATER QUALITY IN PRINCIPAL AQUIFERS

South Dakota has two principal types of aquifers (fig. 2*A*)—glacial-drift and alluvial aquifers, and sedimentary bedrock aquifers (U.S. Geological Survey, 1985, p. 385). Glacial-drift aquifers underlie most of the State east of the Missouri River and alluvium occurs along major streams throughout the State. Glacial-drift aquifers and alluvial aquifers consist of unconsolidated sand and gravel. Water from the glacial-drift and alluvial aquifers is fresh to slightly saline and is suitable for domestic, livestock, and irrigation uses. Water from shallow glacial-drift and alluvial aquifers contains predominately calcium, bicarbonate, and sulfate ions. Water from deeper glacial-drift aquifers contains predominately calcium, sodium, and sulfate ions. The Big Sioux aquifer, a glacial-drift and alluvial aquifer within the Big Sioux River basin, is the most im-

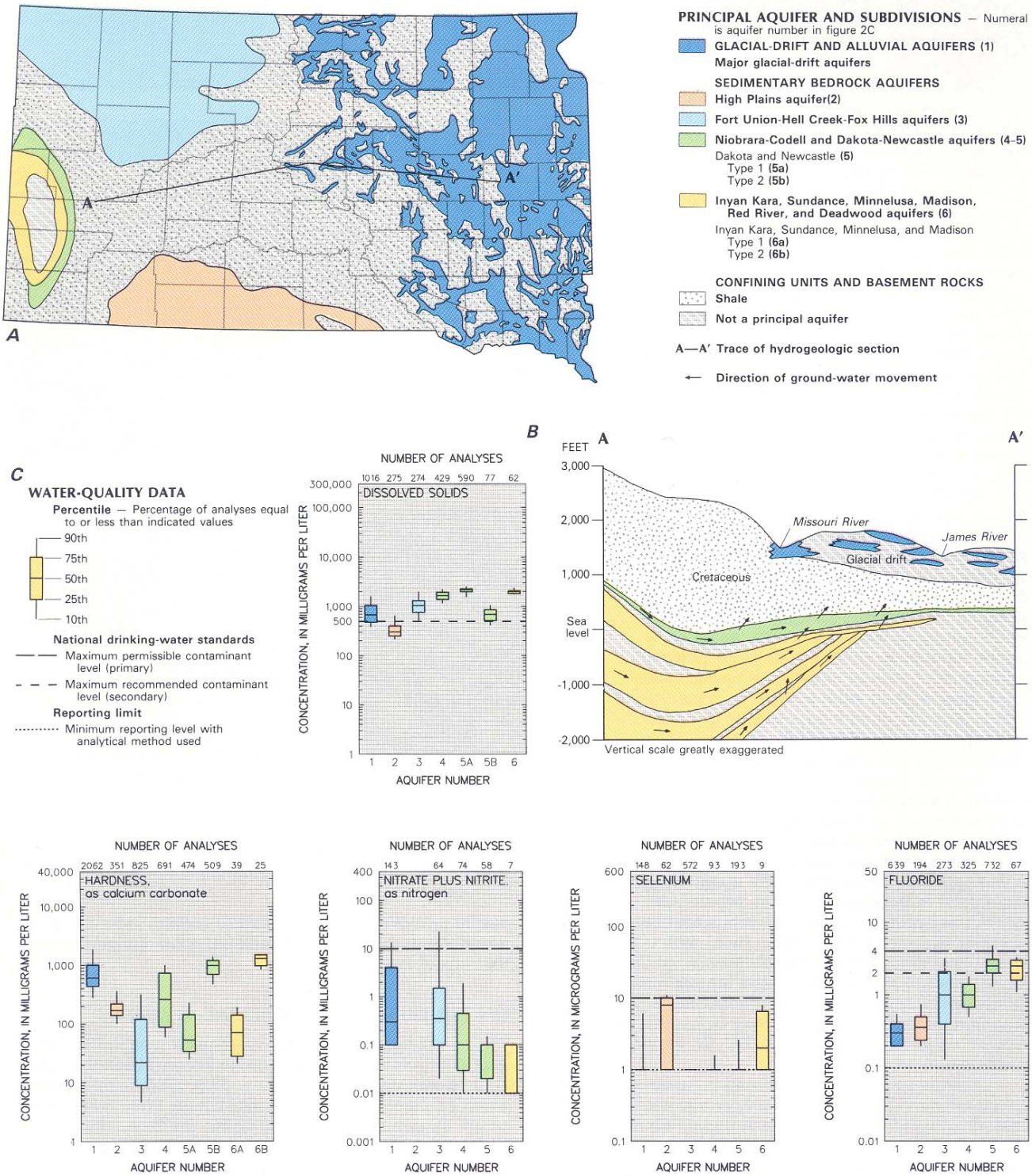

Figure 2. Principal aquifers and related water-quality data in South Dakota. *A*, Principal aquifers. *B*, Generalized hydrogeologic section. *C*, Selected water-quality constituents and properties, as of 1930-85. (Sources: *A*, U.S. Geological Survey; 1985; Bardwell, 1984. *B*, Modified from Swenson, 1968. *C*, Analyses compiled from U.S. Geological Survey files; national drinking-water standards from U.S. Environmental Protection Agency, 1986 b,c.)

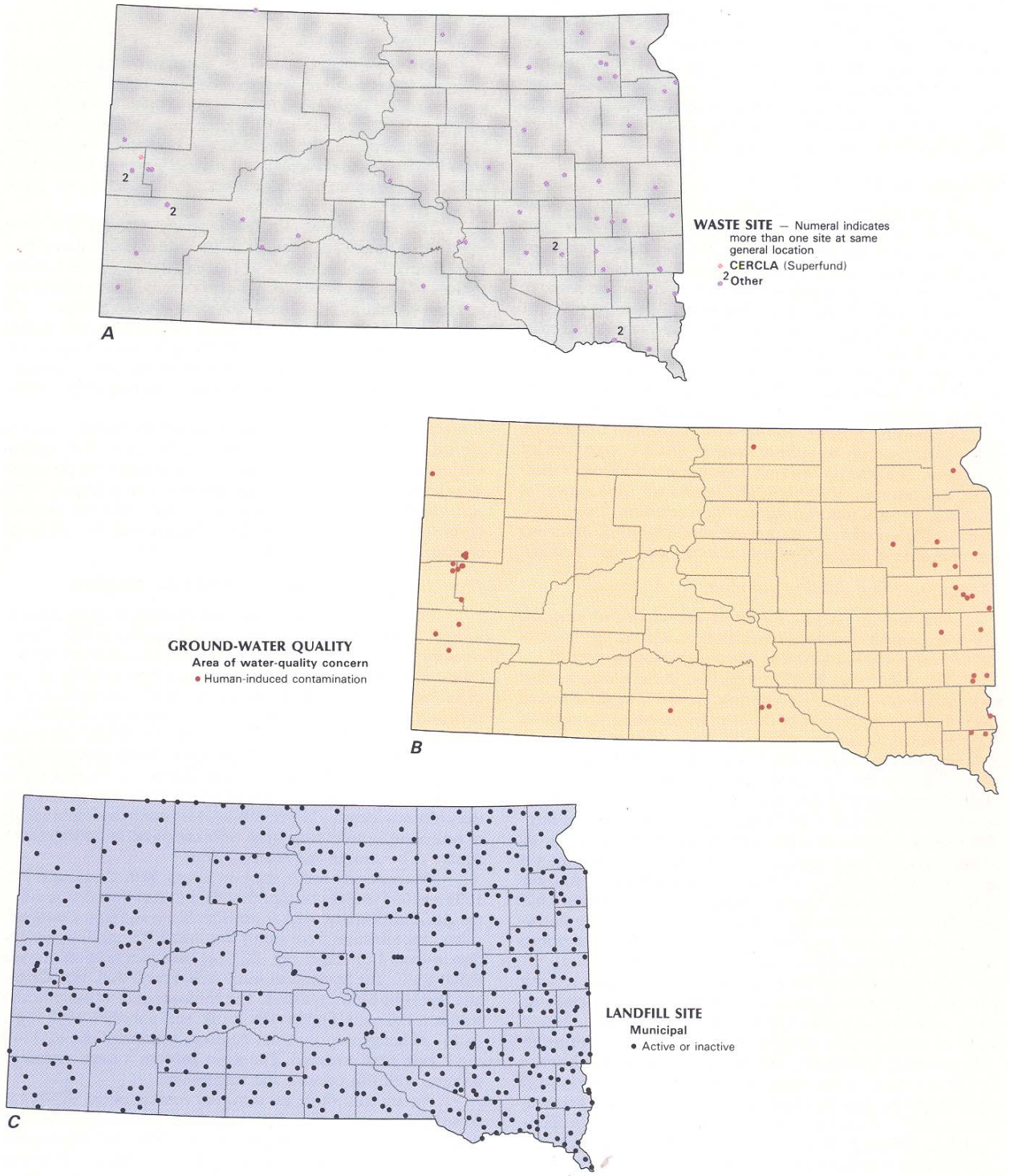

Figure 3. Selected waste sites and ground-water-quality information in South Dakota. *A*, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites, as of 1986; and other selected waste sites, as of 1986. *B*, Areas of human-induced contamination, as of 1985. *C*, Municipal landfills, as of 1986. (Sources: *A*, Jeanne Goodman, South Dakota Department of Water and Natural Resources, written commun., 1986. *B*, William Markley, South Dakota Department of Water and Natural Resources, written commun., 1985. *C*, Jeanne Goodman, South Dakota Department of Water and Natural Resources, written commun., 1986.)

portant surficial aquifer in the State. There are 14 sedimentary bedrock aquifers in South Dakota (fig. 2*A*). These aquifers are the only source of ground water west of the Missouri River, except for a few small ares of alluvium along major streams. Although commonly very mineralized, except for the High Plains aquifer, and found at relatively great depth away from the Black Hills, water from these aquifers is used extensively for rural-domestic and stock supply. Several of the bedrock aquifers extend into eastern South Dakota beneath the glacial drift (fig. 2*A*).

Background Water Quality

A graphic summary of selected water-quality variables compiled from the U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) data base is presented in figure 2*C*. The summary is based on dissolved-solids, hardness, nitrate-plus-nitrite (as nitrogen), selenium, and fluoride analyses of water samples collected from 1930 to 1985 from the principal aquifers in South Dakota. Percentiles of these variables are compared to national standards that specify the maximum concentration or level of a contaminant in drinking-water supply as established by the U.S. Environmental Protection Agency (1986b,c). The primary maximum contaminant level standards are health related and are legally enforceable. The secondary maximum contaminant level standards apply to esthetic qualities and are recommended guidelines. The primary drinking-water standards include a maximum concentration of 10 mg/L (milligrams per liter) nitrate (as nitrogen), 10 μg/L (micrograms per liter) selenium, and 4 mg/L fluoride. The secondary drinking-water standards include maximum concentrations of 500 mg/L dissolved solids and 2 mg/L fluoride.

Glacial-Drift and Alluvial Aquifers

Glacial-drift aquifers consist of unconsolidated sand and gravel deposited by meltwaters from glaciers. Alluvial aquifers consist of unconsolidated sand and gravel deposited by streams.

The water within the shallow glacial-drift and alluvial aquifers had a median dissolved-solids concentration of 670 mg/L; dissolved solids in about 75 percent of the samples exceeded the national drinking-water standard of 500 mg/L. Water from deeper glacial-drift aquifers had a median dissolved-solids concentration of 1,250 mg/L. Whereas dissolved solids provide an indication of the total mineral content of the water, hardness (as calcium carbonate) provides a general indication of the calcium and magnesium content. The median hardness of water from the glacial-drift and alluvial aquifers was 605 mg/L; hardness in 75 percent of the samples was less than 1,000 mg/L (fig. 2*C*). Although uncommon, maximum dissolved-solids and hardness concentrations were as much as 8,300 and 5,000 mg/L, respectively. Calcium and magnesium are the major components of the dissolved-solids concentration in water from the glacial-drift and alluvial aquifers.

Concentrations of nitrate plus nitrite (as nitrogen) in water from the glacial-drift and alluvial aquifers tended to differ somewhat, with a median concentration of 0.3 mg/L. Nitrate plus nitrite in about 10 percent of the samples exceeded the national drinking-water standard of 10 mg/L, with concentrations ranging between 13 and 143 mg/L. Water from many domestic water-supply wells contained large concentrations of nitrate plus nitrite primarily because such wells are downgradient from septic drainage fields, feedlots, or barnyards. In addition, excessive nitrate-plus-nitrite concentrations have been detected downgradient from fertilizer storage areas.

Seventy-five percent of the samples analyzed for selenium contained concentrations less than the detection limit of 1.0 μg/L. Although uncommon, selenium concentrations have exceeded the national drinking-water standard of 10 μg/L. Fluoride concentrations in water from the glacial-drift and alluvial aquifers were less than 0.60 mg/L in 90 percent of the samples. The maximum national drinking-water standard for fluoride concentration is 4.0 mg/L.

High Plains Aquifer

The High Plains aquifer in south-central South Dakota primarily is composed of unconsolidated and slightly consolidated sandstone of the Ogallala and Arikaree Formations. The High Plains aquifer generally is a water-table aquifer in South Dakota, but may be confined in places within the Arikaree Formation. Water in the High Plains aquifer predominately is a calcium-bicarbonate type, and is suitable for domestic, livestock, and irrigation uses; about 90 percent is used for irrigation.

The High Plains aquifer generally contains the least mineralized water of any aquifer in the State although water from the Arikaree Formation tends to contain relatively large concentrations of sodium. Dissolved-solids concentrations generally are less than 400 mg/L (fig. 2*C*) but have been as much as about 1,400 mg/L. The hardness concentration also is smaller than other aquifers in the State with a median value of 170 mg/L and a range of 100 to 770 mg/L. The water generally is hard to very hard. No water samples from the High Plains aquifer have been analyzed for nitrate in South Dakota.

About 25 percent of the selenium concentrations exceeded the national drinking-water standard of 10 μg/L. The median selenium concentration was 8 μg/L. Ground-water samples from some areas have contained selenium concentrations as large as 5,600 μg/L. Selenium concentrations tend to be largest where the Ogallala Formation overlies the Pierre Shale, and the smallest where the Ogallala overlies the Arikaree.

Fort Union, Hell Creek, and Fox Hills Aquifers

The Fort Union, Hell Creek, and Fox Hills aquifers in northwestern South Dakota mostly are confined aquifers but may be unconfined in certain areas. These aquifers are composed of very fine unconsolidated sandstone (U.S. Geological Survey and U.S. Bureau of Reclamation, 1975). Water from these aquifers generally is fresh to slightly saline. Major ions in the water are predominately sodium, sulfate, and bicarbonate. The water is used for public water supplies and agricultural and domestic purposes. Molybdenum is known to be associated with uranium in lignite deposits in the Fort Union and Hell Creek aquifers at concentrations large enough to cause molybdenosis in cattle (Meyer, 1984a). Methane or hydrogen sulfide or both occur in water from some wells completed in the Hell Creek aquifer (Thorstensen and others, 1979).

Water quality within the Fort Union, Hell Creek, and Fox Hills aquifers tends to be significantly different than that in either the glacial-drift and alluvial or the High Plains aquifers. Dissolved-solids concentrations were mostly less than 2,000 mg/L with a median of about 1,050 mg/L (fig. 2*C*), but have been as much as about 8,500 mg/L. The hardness of water from Fort Union, Hell Creek, and Fox Hills aquifers differs. The hardness of most samples was less than 120 mg/L (moderately hard), with a median of 22 mg/L (soft). Although not common, hardness concentrations of 2,000 mg/L have been recorded. The water contains a large amount of sodium, with less calcium and magnesium.

Nitrate plus nitrite (as nitrogen) concentrations differed in these aquifers. Although 75 percent of the samples contained less than 1.5 mg/L, the maximum nitrate plus nitrite concentration was 180 mg/L. The median concentration was 0.35 mg/L The source of the larger nitrate plus nitrite concentrations is not known.

Selenium concentrations were mostly less than the detection limit of 1.0 μg/L, although the maximum concentration was 15 μg/L. Fluoride concentrations in about 75 percent of the samples were less than 2.0 mg/L. The median fluoride concentration was 1.0 mg/L. Concentrations in about 18 percent of the samples were more than 2.4 mg/L.

Niobrara and Codell Aquifers

The Niobrara and Codell aquifers in eastern South Dakota primarily are confined, and composed of shale, chalk, and fine-grained quartz sandstone (U.S. Geological Survey and U.S. Bureau of Reclamation, 1975). The water is slightly saline and contains predominately sodium and sulfate ions. The water is used for domestic and livestock purposes but generally is too mineralized for irrigation use.

The median dissolved-solids concentration in water from the Niobrara and Codell aquifers was 1,670 mg/L (fig. 2*C*). Eighty percent of the samples from these aquifers contained dissolved solids concentrations between 1,150 and 2,250 mg/L. The maximum dissolved-solids concentration was 9,140 mg/L. The hardness of water from these aquifers generally ranged between about 90 mg/L (moderately hard) and 730 mg/L (very hard) with a median value of 260 mg/L (very hard). However, the maximum hardness concentration was 2,900 mg/L.

The concentrations of nitrate plus nitrite generally were less than 1.0 mg/L, but the maximum concentration was 35 mg/L. The median concentration was 0.1 mg/L. The cause of nitrate plus nitrite concentrations greater than 10 mg/L in ground water is not known.

Selenium concentrations generally were less than the detection limit (fig. 2*C*), although water from several wells contained concentrations of about 10 μg/L. Fluoride concentrations were less than the national drinking-water standard in water from most wells. The median concentration was 1.0 mg/L; concentrations in 90 percent of the samples were less than 1.8 mg/L. Fluoride concentrations were as much as 3.2 mg/L.

Dakota and Newcastle Aquifers

The Dakota and Newcastle aquifers, which underlie most of South Dakota (fig. 2*C*), are confined and composed of sandstone interbedded with shale and siltstone (U.S. Geological Survey and U.S. Bureau of Reclamation, 1975). The water is slightly to moderately saline and contains predominately sodium, chloride, and sulfate ions. The water is used primarily for livestock, but is too mineralized for irrigation use and commonly is not used for human consumption.

Two water types were identified within the Dakota and Newcastle aquifers. Type 2 water occurs in southeastern South Dakota, and type 1 water occurs elsewhere in the State. Type 1 had a median dissolved-solids concentration of 2,170 mg/L, which is larger than water from the previously described aquifers (fig. 2*C*). Ninety percent of the dissolved-solids concentrations were less than 2,550 mg/L. Type 2 water had a median dissolved-solids concentration of 690 mg/L. Ninety percent of the dissolved-solids concentrations in the type 2 water were less than 1,060 mg/L. In some areas in Brown County, the Dakota aquifer is being recharged by underlying aquifers that contain freshwater under greater pressure; this recharge has resulted in a decrease in chloride concentration from 200 to 160 mg/L from 1938 to 1963 (Koch and Bradford, 1976).

Hardness concentrations were the major difference between the two water types. Type 1 water is soft to moderately hard, whereas type 2 is classified as very hard. The median hardness concentration of type 1 is 53 mg/L, with 90 percent of the concentrations less than 230 mg/L. Type 2 water had a median hardness concentration of 990 mg/L, with 90 percent of the concentrations less than 1,400 mg/L. Type 1 water has a large proportion of sodium to calcium and magnesium. Type 2 water has a large proportion of calcium and magnesium to sodium.

A differentiation between water types was not made for nitrate plus nitrite, selenium, or fluoride concentrations because their differences were minimal. Seventy-five percent of the nitrate plus nitrite concentrations were less than 0.1 mg/L. The median concentration was also 0.1 mg/L. The maximum nitrate plus nitrite concentration was 1.1 mg/L. Seventy-five percent of the selenium concentrations were less than the detection limit of 1 μg/L. The maximum selenium concentration was 35 μg/L, which exceeded the national drinking-water standard of 10 μg/L. Fluoride concentrations in water from the Dakota and Newcastle aquifers tend to be more than 2.4 mg/L. The median fluoride concentration in water from these aquifers was 2.5 mg/L, with 90 percent of the concentrations less than 4.8 mg/L. The maximum fluoride concentration in water from this aquifer was 26 mg/L. These large fluoride concentrations were caused by naturally occurring minerals in the aquifers.

Inyan Kara, Sundance, Minnelusa, Madison, Red River, and Deadwood Aquifers

The Inyan Kara is a confined aquifer composed of sandstone interbedded with shale and siltstone; the Sundance aquifer also is confined but composed of shale interbedded with limestone, sandstone, and shale. The Minnelusa aquifer is confined and is composed of sandstone interbedded with limestone, dolomite, and shale; the Madison aquifer also is a confined aquifer but composed of limestone and dolomite interbedded with shale, anhydrite, and halite (U.S. Geological Survey and U.S. Bureau of Reclamation, 1975).

Water in the Inyan Kara, Sundance, Minnelusa, and Madison aquifers is a sodium-sulfate type in western South Dakota and a calcium-sulfate type in eastern parts of the State. The least mineralized water occurs where these aquifers are exposed at land surface in the western part of the State. In some areas, water from the Inyan Kara and Madison aquifers have concentrations of radium-226 and gross alpha that exceed national primary drinking-water standards [5 and 15 pCi/L (picocuries per liter), respectively]. Uranium concentrations also are greater than background concentrations but do not exceed national standards (South Dakota Department of Water and Natural Resources, 1984). Water is used for public supply, domestic, and livestock purposes and is suitable for irrigation use in some areas, particularly within the Black Hills.

Water from the Red River and Deadwood aquifers appears to be markedly different from water in other sedimentary bedrock aquifers within the State. Water from the Red River aquifer is predominately a sodium-chloride type. Water from the Deadwood aquifer is fresh within the Black Hills. These aquifers generally are undeveloped, and their potential for development is unknown.

The differences of dissolved-solids concentration for this group of aquifers appear to be very small except for the Red River and Deadwood aquifers. The median dissolved-solids concentration for the group was 1,996 mg/L and 90 percent of the concentrations were less than 2,400 mg/L (fig. 2*C*). The maximum dissolved-solids concentration was 4,300 mg/L. Nearly all water samples from these aquifers had dissolved-solids concentrations greater than the national drinking-water standard of 500 mg/L. Water from the Red River aquifer had a maximum dissolved-solids concentration of 25,000 mg/L. Water from the Deadwood aquifer had a minimum dissolved-solids concentration of 400 mg/L.

The hardness concentrations for the Inyan Kara, Sundance, Minnelusa, and Madison aquifers can be grouped into two water types. Type 1 water is soft to moderately hard. The median hardness concentration was 71 mg/L, and 90 percent of the concentrations were less than 190 mg/L. The maximum hardness concentration for type 1 water was 219 mg/L. Type 2 water is hard to very hard. The median hardness concentration was 1,300 mg/L. Eighty percent of the concentrations were between 840 and 1,600 mg/L. Type 1 water has a large proportion of sodium to calcium and magnesium; whereas type 2 water has a large proportion of calcium and magnesium to sodium.

Water types were not differentiated for nitrate plus nitrite, selenium, and fluoride concentrations because their differences were

minimal. Seventy-five percent of the nitrate plus nitrite concentrations were less than 0.1 mg/L. The median concentration was 0.01 mg/L as nitrogen.

All total selenium concentrations were less than the National drinking-water regulation of 10 μg/L; the median concentration was 2 μg/L. Fluoride concentrations in water from these aquifers tended to be greater than the national drinking-water standard of 2 mg/L. The median fluoride concentration was 2.5 mg/L, and 80 percent of the concentrations were between 1.1 and 3.3 mg/L. The maximum fluoride concentration was 7.2 mg/L.

Effects of Land Use on Water Quality

As of 1986, there was no evidence of widespread contamination of ground water in South Dakota. However, ground water has been contaminated in local areas due to the effects of flowing wells, releases of petroleum products and agricultural chemicals, wastewater-disposal systems, feedlots, mining activities, and oil and gas activities (South Dakota Department of Water and Natural Resources, 1984). The contamination of ground-water supplies for about 15,000 people, about 2.6 percent of the 586,000 people served by ground water, has been documented (fig. 3*B*). Contamination of most water wells in the State is associated with chemical spills, feedlots, and septic systems. Commonly, the wells are contaminated with one or more of the following: nitrate, bacteria, hydrocarbons, or pesticides.

There are 58 permitted solid-waste facilities (fig. 3*A*) and about 350 municipal landfills (fig. 3*C*) in South Dakota. Contamination of potable water supplies at or near these facilities and landfills has not been documented. As of September 1985, 16 hazardous waste-sites at 1 facility in South Dakota had been identified by the U.S. Department of Defense (DOD) as part of their Installation Restoration Program (IRP) as having potential for contamination (U.S. Department of Defense, 1986). The IRP, established in 1976, parallels the EPA Superfund program under CERCLA. EPA presently ranks these sites under the hazard ranking system and may include them in the National Priorities List (NPL).

Flowing Wells

Shallow glacial-drift aquifers in the James River basin have been contaminated by saline water from flowing wells completed in bedrock aquifers. Flowing wells completed in bedrock aquifers have discharged billions of gallons of saline water onto the land surface during the last 70 years (Koch and Bradford, 1976). Today (1986), the casing in many of these wells has corroded, and saline water is leaking directly into the glacial-drift aquifers. Saline water from about 15,000 wells completed in bedrock aquifers is contaminating overlying aquifers (South Dakota Department of Water and Natural Resources, 1984).

Petroleum Products and Agricultural Chemicals

Releases of petroleum products and agricultural chemicals can occur as leaks from storage tanks, as improper disposal of rinse water, or as spills during transport. Petroleum products are the most common material involved in releases and are responsible for the contamination of 16 water-supply wells and about 6.1 mi^2 (square miles) of land (Jeanne Goodman, South Dakota Department of Water and Natural Resources, written commun., 1986).

Agricultural chemicals account for the remainder of the contamination problems. Leaking tanks, improper disposal of rinse water, and improper storage of the chemicals and associated equipment have resulted in the contamination of 22 water-supply wells and about 4.23 mi^2 of land (Jeanne Goodman, South Dakota Department of Water and Natural Resources, written commun., 1986)

Wastewater Disposal Systems

According to the 1980 census (U.S. Bureau of the Census, 1982), there were 72,000 individual wastewater-disposal systems serving 185,600 people in South Dakota. More than 443,000 people are served by about 350 centralized wastewater-disposal systems. Individual systems, mostly septic tanks, have caused nitrate and bacterial contamination in domestic water wells because the systems commonly are near domestic wells. However, contamination caused by septic tanks usually is localized.

The majority of the municipal wastewater-disposal systems are stabilization ponds. Localized ground-water degradation has occurred near some of the ponds as a result of leakage. No known water-supply wells have been affected.

Feedlots

Nitrate-plus-nitrite concentrations in excess of 10 mg/L as nitrogen are common in water from wells in or near feedlots. An undetermined number of domestic water wells have been contaminated by feedlot wastes. The extent of ground water contaminated by feedlots is not defined because of the numerous feedlots throughout the State, the diffused movement of nitrogen compounds from feedlots, and the effects of septic systems and improper storage of fertilizers on the nitrate concentrations in ground water. Shallow glacial-drift and alluvial aquifers are particularly susceptible to contamination by feedlots.

Mining Activities

Gold-mining in the Black Hills for about 100 years has produced large quantities of tailings that were discharged directly into Whitewood Creek. This resulted in arsenic and mercury contamination of the alluvial sediments along the creek and identification of the site as part of the EPA's Superfund program (CERCLA, fig. 3*A*). Arsenic concentrations have exceeded the national drinking-water standard of 50 μg/L in water from 10 water-supply wells. At least 5 mi^2 of land have been contaminated (Jeanne Goodman, South Dakota Department of Water and Natural Resources, written commun., 1986). The construction of new water wells in the alluvial aquifer along Whitewood Creek is prohibited in some areas.

Oil and Gas Activities

Oil and gas production in South Dakota is limited to two areas in the western part of the State. These activities have caused increases in dissolved-solids concentrations in ground water, mostly as a result of increases in chloride and sodium concentrations. These increases commonly are associated with leakage from unlined mud pits and from brine-disposal pits. Contamination has been documented (Meyer, 1984a), but no potable water supplies are known to be affected.

Potential for Water-Quality Changes

Shallow, near-surface aquifers are susceptible to contamination by human activities because of the thin, permeable soils overlying the aquifers and shallow depth to water. An example is the Big Sioux aquifer (a glacial drift and alluvial aquifer) in eastern South Dakota, which supplies water to about 26 percent of the State's population. Numerous gasoline, fertilizer, and agricultural-chemical spills have occurred in recent years. Such spills, coupled with a shallow water table, create a situation that increases the likelihood of ground-water contamination. Deeper aquifers usually are protected by upward pressure gradients under predevelopment or moderate development conditions and by overlying confining units of clay or shale.

The major land use in the State is agriculture. Although ground-water contamination from nonpoint sources has not been documented as a problem, the current trend toward the increased

use of fertilizers and pesticides may degrade or contaminate ground water in some areas. The Oakwood Lake-Poinsett Rural Clean Water Program is a current (1986) ground-water-monitoring project designed to determine the effects of fertilizers and pesticides on receiving ground water as a result of land-use management practices. Contamination of ground water by point sources, such as accidental spills and feedlots, is expected to continue. However, only local areas are expected to be affected by such contamination.

It is estimated that South Dakota has more than 10,000 buried tanks containing petroleum products (Jeanne Goodman, South Dakota Department of Water and Natural Resources, 1980). Because many of the tanks have been buried for a long time, it is expected that isolated instances of ground-water contamination will occur because of petroleum products leaking from the tanks.

The potential for ground-water contamination will probably increase in the Black Hills along with the recent increase in gold-mining activities. Cyanide heap leaching (the leaching of gold from crushed ore using a cyanide solution) is being used at one mining operation and has been proposed for use at two other mining operations. These renewed activities will increase the potential for cyanide and arsenic contamination of local aquifers. However, ground-water-monitoring systems required by the State should detect any aquifer contamination caused by the leaching process.

GROUND-WATER-QUALITY MANAGEMENT

Ground-water management and implementation of the ground-water-quality strategy for prevention, control, and abatement of ground-water contamination are functions of the South Dakota Department of Water and Natural Resources (DWNR). The various aspects of ground-water policies are the responsibility of divisions within that department.

The Division of Water Quality (DWQ) has the primary responsibility in dealing with ground-water contamination and is responsible for development of ground-water-quality strategy. Through this office, Federal Construction Grants, National Pollution Discharge Elimination Systems, and Underground Injection Control permits are reviewed, although U.S. Environmental Protection Agency maintains primacy in some cases. The RCRA Subtitle I-Underground Storage Tanks and remedial action also are administered by this office.

The Division of Drinking Water (DDW) monitors public drinking-water supplies under the Federal Safe Drinking Water Act. Suspected domestic-well contamination may be investigated by this division.

The Division of Environmental Quality (DEQ) coordinates activities to protect ground-water quality. The Division's Office of Air Quality and Solid Waste is responsible for the management of solid and hazardous wastes in the State. This includes administering the majority of the Federal RCRA regulations within the State in addition to issuing disposal-permit applications and conducting some ground-water monitoring. State hazardous-waste regulations are based on RCRA requirements.

The State Division of Water Rights (DWR) regulates water use, well construction, and well-driller licensing. Approval of water-use permits is the responsibility of a seven-member Water Management Board appointed by the Governor. The Board's duties include establishment of general well-construction standards and water-quality functions, which were revised in 1985.

The Division of the Geological Survey (DGS) conducts ground-water investigations involving quality, quantity, and contamination of ground water. Some investigations are conducted in cooperation with the U.S. Geological Survey.

Various divisions within DWNR are taking remedial actions to abate or eliminate reported ground-water contamination. Information on ground-water quality collected through the existing programs does not indicate widespread ground-water contamination; however, background water-quality data are needed for some areas.

The initiation of elements necessary for establishing a State ground-water quality strategy date back to 1979 when the Big Sioux Aquifer Water Quality Study began. A network of monitoring wells was established by the U.S. Geological Survey in cooperation with DGS (Leibbrand, 1985). Monitoring wells were installed in areas of large nitrate concentrations around landfills, in areas of petroleum spills, and around a municipal wastewater-treatment lagoon. Water samples from a group of municipal wells and numerous domestic wells were analyzed for contaminants on the EPA's priority pollutant list (U.S. Environmental Protection Agency, 1986a). A nitrogen-isotope study also was conducted in an attempt to identify sources of nitrate contamination.

DWNR, in cooperation with the U.S. Army Corps of Engineers, is evaluating selected aspects of ground-water resources in eastern and western South Dakota. Among the information compiled under this effort are: (1) A comprehensive bibliography of ground-water-related references; (2) characterization of water-quality suitability by aquifer for specific uses; (3) estimates of recharge rates; (4) compilation and computerization of available water-quality, well-construction, and aquifer data; (5) preparation of ground-water-quality maps and charts; and (6) determination of water use by aquifer.

SELECTED REFERENCES

Bardwell, Lawrence, 1984, Water quality of South Dakota's glacial aquifers: South Dakota Department of Water and Natural Resources, 52 p.

Ellis, M.J., and Adolphson, D.G., 1971, Hydrology of the Pine Ridge Indian Reservation, South Dakota: U.S. Geological Survey Hydrologic Investigations Atlas HA-357, scale 1:125,000, 2 sheets.

Hamilton, L.J., 1982, Geology and water resources of McPherson, Edmunds, and Faulk Counties, South Dakota—part 2, Water resources: South Dakota Geological Survey Bulletin 26, 60 p.

_____ 1985, Water resources of Aurora and Jerauld Counties, South Dakota: U.S. Geological Survey Water-Resources Investigations Report 84-4030, 58 p.

Hansen, D.S., 1983, Water resources of Hanson and Davison Counties, South Dakota: U.S. Geological Survey Water-Resources Investigations Report 83-4108, 55 p.

_____ 1986, Water resources of Lake and Moody Counties, South Dakota: U.S. Geological Survey Water-Resources Investigations Report 84-4209, 51 p.

Howells, L.W., 1979, Geohydrology of the Cheyenne River Indian Reservation, South Dakota: U.S. Geological Survey Hydrologic Investigations Atlas HA-585, scales 1:250,000 and 1:500,000, 3 sheets.

Jorgensen, D.G., 1971, Geology and water resources of Bon Homme County, South Dakota—part 2, Water resources: South Dakota Geological Survey Bulletin 21, 61 p.

Koch, N.C., 1975, Geology and water resources of Marshall County, South Dakota: South Dakota Geological Survey Bulletin 23, 76 p.

Koch, N.C., and Bradford, Wendell, 1976, Geology and water resources of Brown County, South Dakota—part 2, Water resources: South Dakota Geological Survey Bulletin 25, 53 p.

Kume, Jack, 1976, Geology and water resources of Charles Mix and Douglas Counties, South Dakota—part 2, Water resources: South Dakota Geological Survey Bulletin 22, 31 p.

Leibbrand, N.F., 1985, Geochemical survey to determine water- quality characteristics of the Big Sioux aquifer in eastern South Dakota: U.S. Geological Survey Water-Resources Investigations Report 85-4069, 20 p.

Meyer, Michael, 1984a, Evaluation of the groundwater resources of western South Dakota, Task 5—Water quality suitability by aquifer for drinking, irrigation, livestock watering and industrial use: South Dakota Department of Water and Natural Resources, v. 1, 200 p.

_____ 1984b, Evaluation of the groundwater resources of western South Dakota, Task 5—Water quality suitability by aquifer for drinking, irrigation, livestock watering and industrial use: South Dakota Department of Water and Natural Resources, v. 2, appendices to v. 1.

Meyer, Michael, and Bardwell, Lawrence, 1983a, Evaluation of ground-water resources of eastern South Dakota and upper Big Sioux River, South Dakota and Iowa, Task 5—Water quality suitability by aquifer for drinking, irrigation, livestock watering and industrial uses: South Dakota Department of Water and Natural Resources, v. 1, 249 p.

_____ 1983b, Evaluation of ground-water resources of eastern South Dakota and upper Big Sioux River, South Dakota and Iowa, Task 5—Water quality suitability by aquifer for drinking, irrigation, livestock watering and industrial uses: South Dakota Department of Water and Natural Resources, v. 2, appendices to v. 1.

Peter, K.D., 1985, Availability and quality of water from the bedrock aquifers in the Rapid City area, South Dakota: U.S. Geological Survey Water-Resources Investigations Report 85-4022, 34 p.

South Dakota Department of Water and Natural Resources, 1984, South Dakota water quality, water years 1982-1983: Report to Congress of the United States by the South Dakota Department of Water and Natural Resources pursuant to Section 305(b) of the Federal Water Pollution Control Act, 149 p.

Swenson, F.A., 1968, New theory of recharge in the artesian basin of the Dakotas: Geological Society of America Bulletin, v. 79, p. 163-182.

Thorstenson, D.C., Fisher, D.W., and Croft, M.G., 1979, The geochemistry of the Fox Hills-Basal Hell Creek aquifer in southwestern North Dakota and northwestern South Dakota: Water Resources Research, v. 15, no. 6, p. 1479-1498.

U.S. Bureau of the Census, 1982, Census of the population, characteristics of the population, number of inhabitants—1980: Published separately by States, Puerto Rico, and outlying areas, PC80-1-A1 to A57a, and A57b.

U.S. Department of Defense, 1986, Status of the Department of Defense Installation Restoration Program—Information paper: Washington, D.C., U.S. Department of Defense, Office of the Assistant Secretary of Defense (Acquisition and Logistics), Environmental Policy Directorate, February, 35 p.

U.S. Environmental Protection Agency, 1986a, Amendment to National Oil and Hazardous Substances Contingency Plan; national priorities list, final rule and proposed rule: Federal Register, v. 51, no. 111, June 10, 1986, p. 21053-21112.

_____ 1986b, Maximum contaminant levels (subpart B of part 141, national interim primary drinking-water regulations): U.S. Code of Federal Regulations, Title 40, Parts 100 to 149, revised July 1, 1986, p. 524-528.

_____ 1986c, Secondary maximum contaminant levels (section 143.3 of part 143, national secondary drinking-water regulations): U.S. Code of Federal Regulations, Title 40, Parts 100 to 149, revised July 1, 1986, p. 587-590.

U.S. Geological Survey, 1985, National water summary 1984—Hydrologic events, selected water-quality trends, and ground-water resources: U.S. Geological Survey Water-Supply Paper 2275, 467 p.

U.S. Geological Survey and U.S. Bureau of Reclamation, 1975, Mineral and water resources of South Dakota: U.S. 94th Congress, 1st Session, Interior and Insular Affairs Committee Print, 313 p.

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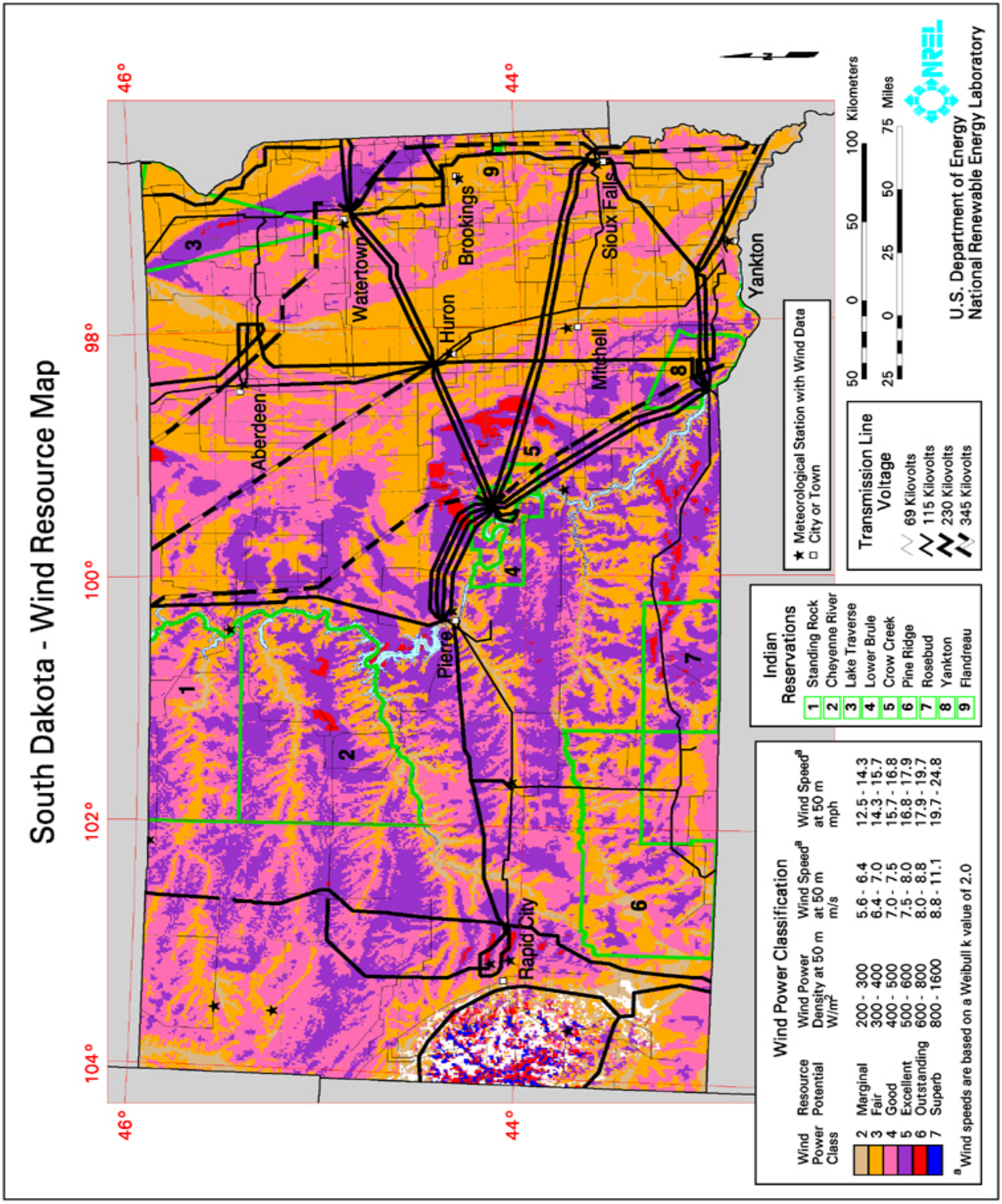
South Dakota - Wind Resource Map
104°
102°
100°
98°
46°
44°
Aberdeen
Watertown
Huron
Brookings
Sioux Falls
Mitchell
Yankton
Pierre
Rapid City
1
2
3
4
5
6
7
8
9
Meteorological Station with Wind Data
City or Town
Transmission Line Voltage
69 Kilovolts
115 Kilovolts
230 Kilovolts
345 Kilovolts
Kilometers
Miles
U.S. Department of Energy
National Renewable Energy Laboratory
Indian Reservations
1 Standing Rock
2 Cheyenne River
3 Lake Traverse
4 Lower Brule
5 Crow Creek
6 Pine Ridge
7 Rosebud
8 Yankton
9 Flandreau
Wind Power Classification
Wind Power Class
Resource Potential
Wind Power Density at 50 m W/m²
Wind Speed[a] at 50 m m/s
Wind Speed[a] at 50 m mph
2 Marginal 200 - 300 5.6 - 6.4 12.5 - 14.3
3 Fair 300 - 400 6.4 - 7.0 14.3 - 15.7
4 Good 400 - 500 7.0 - 7.5 15.7 - 16.8
5 Excellent 500 - 600 7.5 - 8.0 16.8 - 17.9
6 Outstanding 600 - 800 8.0 - 8.8 17.9 - 19.7
7 Superb 800 - 1600 8.8 - 11.1 19.7 - 24.8
[a] Wind speeds are based on a Weibull k value of 2.0

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FS 877P

Treatment Systems for Household Water Supplies

Identifying and Correcting Water Problems

by Tom Scherer, Extrension agricultural engineer, North Dakota Extension Service, and Russell Derickson, SDSU Extension associate in water & natural resources

Identifying Water Problems

Many people determine the quality of the water they consume by how it looks, smells, or tastes. Although these are important criteria, they are primarily aesthetic properties of the water. A glass of water may not look, smell, or taste good, but it could still be suitable to drink from a health standpoint.

The way water looks, smells, or taste can be used to help determine what type of treatment is necessary to improve the quality of the water. The following guidelines will help you determine if there are any problems with your water and what the most likely cause of those problems might be. All you need is a clear container to take a water sample, and then use your senses of sight, smell, and taste.

APPEARANCE

- **Water is clear** when first drawn from the raw water tap, then becomes yellow or reddish but clears upon standing for 24 hours.

  Dissolved iron present.

- **Water is yellow or reddish** when first drawn from the water tap but clears upon standing for 24 hours.

  Undissolved iron present.

- **Yellow or brownish cast to water** even after softening and/or filtering and does not clear up after standing for 24 hours.

  Tannin (humic acid) in water. Comes from water passing through peaty soils, decaying vegetation, and coal veins.

- **Black cast to water** that clears upon standing for 24 hours.

  Dissolved manganese present.

- **Milky water.**

  Excessive air in the water caused by the well pump sucking air (excessive drawdown) or a malfunctioning pressure tank. Also can be caused by high amounts of bicarbonate precipitates resulting from an increase in pH.

- **Blackening, tarnishing, or pitting** of metal sinks, utensils, pipes, etc.

  High amounts of salt (chlorides and sulfates) or hydrogen sulfide gas.

- **Green stains** on sinks and other porcelain bathroom fixtures. Blue-green cast to water.

  Acidic water (pH below 6.8) reacting with brass and copper pipes and fittings.

- **Suspended matter in water.**

  Caused by riled up water in a surface supply or by sand pumping from a well.

- **Soap curds and lime scum** in wash basins and bathtubs. Whitish scale deposits in tea kettle and one the ends of plumbing fixtures (faucet, shower head, etc.).

  Hard water caused by calcium and magnesium salts in the raw water supply.

- **Stained aluminum cookware.**

  High, dissolved-mineral content and high alkalinity in the raw water.

SMELL

- **Chlorine smell.**

  Normal chlorination of public or private well sources.

- **Fishy, musty, or earthy smell.**

  Generally harmless organic matter. Commonly associated with surface water supplies.

- **Rotten egg odor from the raw water tap** or directly from the well.

  Dissolved hydrogen sulfide gas in the raw water.

- **Rotten egg odor from the hot water tap.**

  Sulfates present in the raw water reacting with the magnesium anode which cause hydrogen sulfide gas. Can be corrected by removing the anode or replacing it with an aluminum anode.

- **Detergent odor and water foams** when drawn. Also septic odor.

  Leakage from a sewer/septic system is entering the water supply.

TASTE

- **Salty flavor** to the water that may have a laxative effect in some situations.

  High salt content (primarily sodium sulfate and magnesium sulfate).

- **Metallic taste.**

  High concentration of manganese or possibly other metals.

Correcting the Water Problem

When the cause of a water problem has been identified, then a method of treatment can be used to correct or minimize the problem. Before purchasing a treatment system, first have your water analyzed by a state certified laboratory to determine the quantity of foreign material in your water. These are the most common water tests:

- Coliform bacteria
- Nitrates
- pH
- Total dissolved solids
- Hardness
- Iron and manganese

After the water is analyzed, you can use Table 1. to determine what treatment methods are needed to correct the problem. You may have identified more than one problem. If this is the case, you may need more than one type of treatment. Many reputable water treatment companies have equipment that will treat more than one problem.

Table 1. Raw water problems and common treatment methods.

Raw water problem	Common treatment method
Bacterial contamination	Treat using chlorination or other forms of disinfection (boiling, iodine, etc.) until the source of contamination is found and corrected or removed.
Fine sand, clay, or other sediments	Remove using mechanical (fine screen) or sand filtration.
Odor and taste other than rotten egg smell	Correct with activated carbon filters.
Hydrogen sulfide gas (rotten egg smell)	Remove using chlorination followed by sedimentation or use an oxidation filter (sometimes called an aeration filter) followed by an activated carbon filter to remove excess chlorine.
Small amounts of dissolved iron and manganese	Remove with a common water softener. The water softener manufacturer should list a level of iron removal rating.
Higher amounts of dissolved iron and manganese	Remove using an oxidizing agent such as potassium permanganate or chlorine followed by a mechanical screen, or use a green sand filter.
Suspended iron and manganese particles	Remove using mechanical (fine screen) or sand filtration.
Hard water	Treat using a water softener.
Acid water (pH less than 5.0)	Treat with a neutralizing filter (adds calcium carbonate).
Alkaline water (pH greater than 9.0)	Treat by injecting a weak acid (acetic acid or white vinegar).
Tannin (humic acid)	Remove using chlorination with a detention tank or a special anion exchange unit.
Volatile organic[1] compounds, certain pesticides, trihalo-methanes, and radon	Remove using an activated carbon filter. Other treatment options include reverse osmosis or distillation.
Nitrates, heavy metals[1] (lead, copper, etc.), high total dissolved solids (TDS), sodium, sulfates.	Remove with reverse osmosis or by distillation. Nitrates can be removed with an anion exchange unit.

[1] These problems generally are not noticeable to human senses. Testing for these constituents should be performed by a trained professional familiar with the problems that can cause these forms of contamination.

Common Water Treatment Methods

Brief descriptions of the six most common types of household water treatment are given in Table 2. The list explains the main use for the treatment method and also, equally important, the major limitations of the method.

Table 2. Common home water treatment methods.

Treatment method	Main Use	Restrictions
Water softening	Reduces water hardness minerals (calcium and magnesium) by replacing them with sodium. Softened water requires less soap or detergent for washing and cleaning. Reduces scale formation in pipes, water heaters, and on faucets. Improves sudsing ability of soaps and detergents.	Replaces calcium and magnesium with sodium which can present a problem for people on low-sodium diets. Leave a kitchen faucet unsoftened for drinking purposes. Periodic backwashing and regeneration of the resin bed using salt brine is required.
Oxidative iron filtration	Reduces iron and manganese concentrations to levels where they don't stain clothes or plumbing fixtures. Prevents odors caused by hydrogen sulfide (rotten egg smell).	Periodic backwashing required. Periodic recharging with potassium permanganate is required. Install upstream from a water softener.
Activated carbon filtration	Removes general taste and odor problems including chlorine. Usually installed at the point-of-use for drinking and cooking.	Generally does not remove nitrates, sulfates, bacteria, or heavy metals. Periodic replacement of activated charcoal (usually in canisters) is required for continuous operation.
Reverse osmosis	Reduces heavy metals, most pesticides, and fluoride to acceptable levels. Used primarily for drinking and cooking.	Does not remove all organic chemicals such as chloroform. Does not remove 100% of most chemicals. Uses large amounts of water for flushing.
Distillation	Removal of dissolved minerals, trace amounts of heavy metals and many organic chemicals Used primarily for drinking and cooking.	Produces bland-tasting water. Requires significant energy, therefore small-capacity units are used.
Chlorination	Disinfection of biologically contaminated water supplies, "shock" treatment of wells and storage tanks. Aids in the removal of high levels of iron and manganese.	Not recommended as a continuous practice for the control of bacteria in private wells. A new, bacteria-free source of water should be found. Additional treatment is required to remove residual chlorine and chlorinated organics.

For Further Information

Contact your county Extension office or the state health department. Additional information can be found in other fact sheets in the *Treatment Systems for Household Water Supplies* series:

FS 877A Activated Carbon Filtration
FS 877C Chlorination
FS 877D Distillation
FS 887IM Iron and Manganese Removal
FS 877RO Reverse Osmosis
FS 877S Softening

COOPERATIVE EXTENSION SERVICE SDSU

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FS 877S

Treatment Systems for Household Water Supplies

Softening

by Russell Derickson, SDSU Extension associate in water & natural resources; Bruce Seelig, NDSU water quality specialist, North Dakota Extension Service; and Fred Bergsrud, UM Extension agricultural engineer and water quality coordinator, Minnesota Extension Service

What Impurities Will Softeners Remove?

Water softeners will remove calcium and magnesium from the water during the softening process. Softeners can remove up to 10 ppm of iron and magnesium. Water supplies with high levels of iron and manganese (greater than 10 ppm) may need pretreatment to prolong the life span of a water softener.

What Makes Water "Hard?"

Groundwater contains dissolved rocks and minerals. Dissolved calcium and manganese ions cause water to be hard. These dissolved minerals together with other impurities give hard water its characteristics.

How Is Hardness Measured?

Water hardness ordinarily is expressed in grains of hardness per gallon (gpg) of water. Water impurities also can be measured either in parts per million (ppm) or in milligrams per liter (mg/l). One gpg is equal to 17 ppm (or mg/l).

Figure 1. Classifications of water hardness according to concentration of hardness minerals.

Mineral grains per gallon (gpg)*	Level of hardness	Milligrams per liter (mg/l) or parts per million (ppm
below 1.0	soft	less than 17
1.0 to 3.5	sightly hard	17 to 60
3.5 to 7.0	moderately hard	61 to 120
7.0 to 10.5	hard	121 to 180
above 10.5	very hard	more than 180

* ASAE rating scale

Problems Caused By Hard Water

Hard water interferes with all types of cleaning tasks. Problems arise when the cleaning agents do not fully remove dirt and grime. Over time, clothes washed in hard water may look dingy and feel harsh and scratchy. White clothing continually washed in hard water gradually will show a grayish tinge. Dishes and glassware washed in dishwashers using hard water may be spotted when dry. Hard water causes films on glass shower doors, walls, and bathtubs. Hair washed in hard water may feel sticky and look dull.

Regular soaps used in hard water combine with the hardness minerals to form soap curds or soap scum. Soap scum is difficult to remove from sinks and appliances.

Household appliance performance may be affected by hard water use. When water is heated, calcium carbonate and magnesium carbonate are removed from the water and produce a scale buildup in the hot water heater. A large scale buildup slows the heating process and requires more energy to heat water. Water heaters with large accumulations of mineral buildup will have shorter life spans. Scale deposits also corrode and plug plumbing fixtures and accumulate in other appliances and affect their performance.

Newer cleaning products and detergents contain softening compounds that reduce the negative cleaning effects of hard water.

The Ion Exchange Process

Calcium and magnesium ions that cause water hardness can be removed easily by using an ion exchange procedure. Water softeners are cation exchange devices that replace the positively charged Ca^{++} and Mg^{++} with a non-hardness ion. Water softeners usually use sodium (Na^{+}) as the exchange cation. Sodium ions are supplied from dissolved sodium chloride salt, also called brine.

Figure 2.

During Softening:

NaZeolite + Ca^{++}	CaZeolite + Na^{+}
and	
NaZeolite + Mg^{++}	MgZeolite + Na^{+}

During Recharging:

NaCl + CaZeolite	NaZeolite + CaCl
and	
NaCl + MgZeolite	NaZeolite + MgCl

In the cation exchange process, sodium ions are used to coat thousands of resin beads that are inside the softener. The exchange media can be natural "zeolites" or synthetic resin beads that resemble wet sand.

As hard water passes through a softener, the calcium and magnesium trade places with sodium ions (Figures 2 and 3). Sodium ions are held loosely and exchange easily with calcium and magnesium ions which have a stronger attraction to the exchange media. During this process free sodium ions are released to the water.

After softening a large quantity of hard water, the exchange media becomes coated with calcium and magnesium ions. When this occurs, the exchange media must be recharged or regenerated. To recharge the softener with sodium ions, a softener is backflushed with a salt brine solution. During a backflush the brine solution replaces the calcium and magnesium ions on the exchange media with sodium ions from the salt solution (Figure 2).

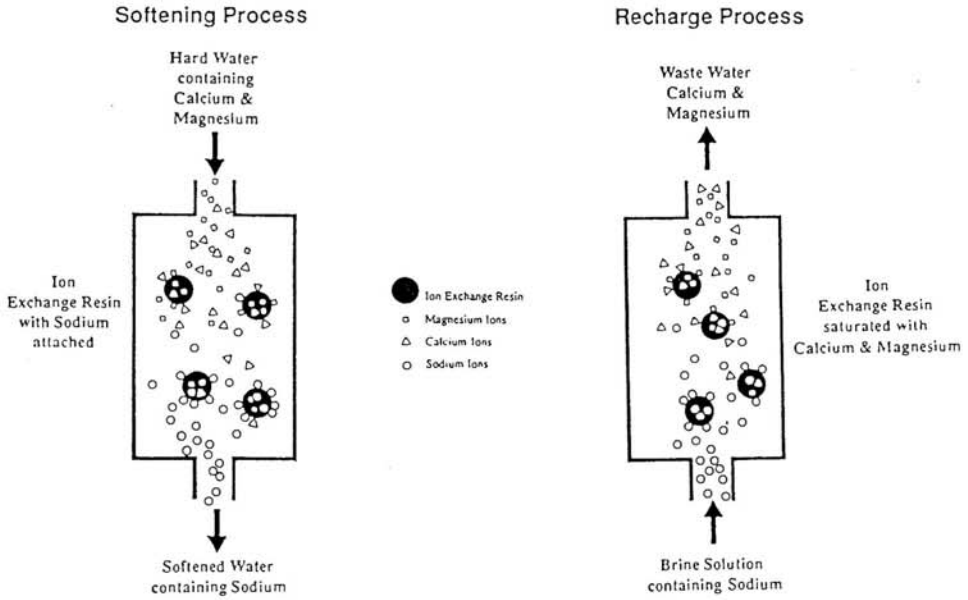
The time between recharging cycles depends on the hardness of the water, the amount of water used, the size of the unit, and the capacity of the exchange media to remove hardness.

Water Testing

Hardness is considered a nuisance water problem. Removing hardness is not necessary to protect your health, but water softening is popular because most people prefer soft water for bathing, cleaning, and washing.

Before buying any type of water softening or water treatment equipment, find out what impurities are in your water supply. A certified laboratory can determine the types and amounts of impurities in your water.

Figure 3. Resin beads with sodium, calcium, and magnesium.



The water test will help you determine if softening is needed. It also may reveal if any other contaminant is present at a level that may harm health and requires that the water be treated.

If you obtain water from a private water supply, water testing is your responsibility. Test water for nitrates and bacteria on a yearly basis. Test for hardness every 3 years. If a water quality problem is suspected, test more often.

Community water supplies are monitored and treated to protect users from health threatening water impurities. Ask your supplier for a copy of the latest water test results.

Health Risks Associated with Softened Water

During the softening process, sodium is released from the exchange media into the output water. For every grain of hardness removed from water, 8 mg/l (ppm) of sodium is added.

If you are on a restricted sodium intake diet, take the increased levels of sodium in softened water into account, and consult your physician. You can avoid sodium intake from softened water by leaving one kitchen tap unsoftened for drinking and cooking.

Types of Water Softening Equipment Available

There are five categories of water softeners: manual, semi-automatic, automatic, demand-initiated regeneration, and off-site regeneration.

Manual -- There are several types. The operator opens and closes valves to control the frequency, rate, and time length of backflushing or recharging.

Semi-automatic -- The operator initiates only the recharging cycle. A button is pushed when the softener needs recharging, and the unit will control and complete the recharging process.

Automatic -- The automatic softener usually is equipped with a timer that automatically initiates the recharging cycle and every step in the process. The operator needs only to set the timer and add salt when needed. It is the most popular softener used.

Demand-initiated Regeneration (DIR) -- All operations are initiated and performed automatically in response to the water-use demand for softened water. DIR systems generally have two softening tanks and a brine tank. While one tank is softening the other tank is recharging.

Off-site regeneration -- These generally are rental units. A used softening tank is physically replaced with a recharged tank. Spent softening tanks are then recharged at a central location.

The automatic softener or demand-initiated regeneration softener probably are the best two choices for household use. DIR softeners do not require electricity for operation but cost more because of the two softening tanks used.

The basic softener unit and the installation of the water softener is illustrated in Figure 4.

Operation and maintenance

Maintenance of water softening units is largely confined to restocking the salt supply for the brine solution. With manual and semiautomatic models, the owner will have to start the recharging cycle. Salt can be purchased in the form of pellets, granules, or blocks.

The brine tank may require periodic cleaning. The frequency of cleaning depends on the amount and purity of the salt used in the softening process. The brine valve and float assembly need to be checked and cleaned periodically.

The presence of excess iron, magnesium, or hydrogen sulfide can inhibit the effectiveness of a water softening unit. Proper presoftening treatment equipment may be required. (See FS 877IM *Treatment Systems for Household Water Supplies: Iron and Manganese Removal.*) Water test results can help you make that determination. More frequent backflushing or reversing the normal flow of water through the treatment unit may be required to remove iron and/or magnesium buildup.

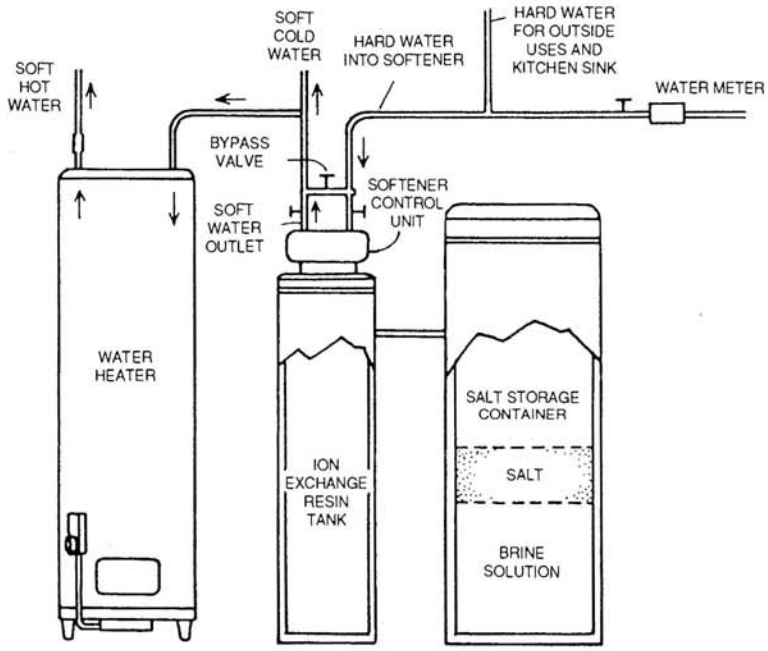
Disconnecting the power to the softener will save electricity and salt costs when leaving home for extended time periods, like vacations.

Cost of Water Softeners and Supplies

Retail prices for home water softeners may range from approximately $400 to $1200 depending on the size and type of softener. Softeners are rated by the total number of grains the unit can remove before being recharged.

Cost of salt is approximately $3-7 per 40 or 50 pound bag depending on the form of salt purchased.

Figure 4. Typical installation of a water softener.



Advantages of Water Softeners

Water treated through a softener offers cleaner, softer-feeling clothes. It also extends the life of appliances including washing machines, dishwashers, and water heaters. You are likely to use less of household cleaning products, such as detergents, and personal cleanliness products, like shampoo. Softened water reduces water spotting.

Disadvantages of Water Softeners

Softened water is not recommended for watering house plants, lawns, and gardens because of its sodium content.

There may be health risks from sodium intake.

Softened water is not recommended for steam irons or evaporative coolers; the best choice for such appliances is distilled water or water from a reverse osmosis unit.

When water used in recharging a water softener is discharged into a small septic system, the drain field may experience hydraulic overload and the surface may become soggy.

Alternatives to Ion Exchange Units

Additives

Hard water problems can be reduced by using detergents that include water softening chemicals in their formulation.

Chemicals can be added to hard water to reduce the negative effect from calcium and magnesium, but chemical treatment for household water softening is recommended only for low levels of hardness.

There are two forms of water softening additives, precipitating and non-precipitating.

Precipitating types (Sal Soda, Borax) combine with calcium and magnesium to form solid particles. These particles settle out with dirt during washing. Washing machine action keeps the solid particles in suspension, the water becomes cloudy, and solid particles may cling to fabrics.

Non-precipitating types (Calgon, blu white) combine with calcium and magnesium and form compounds that stay in solution. These additives have a negative environmental effect, however, because of their high phosphate content.

FS 877S

Magnetic Conditioning

Permanent magnetic water conditioning devices have been marketed based on a variety of claims regarding their effect on water hardness and related scale formation. Tests conducted at Purdue University and reported by the Water Quality Association* found ". . . no significant, beneficial variations in the physical or chemical water quality parameters measured."

Considerations When Purchasing an Ion Exchange Water Softener

- Test your water to determine the hardness and identify other impurities that may need to be removed.
- How much softened water will your household need per day and per year?
- What type and size of softener will fit your situation?
- How easy is the softener to clean and/or repair?
- Will the dealer provide service?
- What type of convenience level should a softener offer (manual or automatic operation)?
- Will pretreatment be needed for iron and manganese?
- Will sodium intake be a health problem?
- Investigate equipment before purchasing or renting. Don't rush a purchase.
- Purchase price does not directly indicate a softener's performance. A moderately priced unit might work as well as an expensive unit.
- When buying or renting, are the installation costs included in the price?
- Don't by more equipment than you need. Other removal systems might be better suited for the removal of certain impurities.
- Choose a reputable dealer. Get guarantees in writing and read them thoroughly.
- Beware of manufacturer's advertising that is too good to be true.
- Equipment should carry UL and NSF or AWQA approval.

*Research reports -- *Quantitative Assessment of the Effectiveness of Permanent Magnetic Water Conditioning Devices.* Water Quality Association. 1985.

Further Information

Contact your county Extension Office, the state water resources department, the state health department, or a commercial water treatment equipment dealer. Additional information can be found in other fact sheets in the *Treatment Systems for Household Water Supplies* series:

FS 877A Activated Carbon Filtration
FS 877C Chlorination
FS 877D Distillation
FS 877IM Iron and Manganese Removal
FS 877RO Reverse Osmosis
FS 877P Identifying and Correcting Water Problems

References

MWPS-14. Private Water Systems. Midwest Plan Service.

MF-848. *Hard water: To Soften or Not to Soften.* Kansas.

WQFS-22. *Ion Exchange*(water softening). New Hampshire.

WR-19. *Using Ion Exchange Units to Soften Your Well Water.* Maryland.

G89-946. *Water Treatment Equipment: Water Softeners.* Nebraska.

WQFS-33. *Questions to Ask When Purchasing Water Treatment Equipment.* New Hampshire.

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FS 877IM

Treatment Systems for Household Water Supplies

Iron and Manganese Removal

by Bruce Seelig, NDSU water quality specialist, North Dakota Extension Service;
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Problems Caused by Iron and Manganese in Household Water

Neither iron nor manganese in water present a health hazard. However, their presence in water may cause taste, staining, and accumulation problems.

Because iron and manganese are chemically similar, they cause similar problems. Iron will cause reddish-brown staining of laundry, porcelain, dishes, utensils, and even glassware. Manganese acts in a similar way but causes a brownish-black stain. Soaps and detergents do not remove these stains, and the use of chlorine bleach and alkaline builders (such as sodium carbonate) actually can intensify the stains.

Iron and manganese deposits will build up in pipelines, pressure tanks, water heaters, and water softeners. This reduces the available quantity and pressure of the water supply. Iron and manganese accumulations become an economic problem when water supply or softening equipment must be replaced. There also are associated increased energy costs, like pumping water through constricted pipes or heating water with heating rods coated with iron or manganese mineral deposits.

Sources of Iron and Manganese in Household Water

Iron and manganese are concentrated in water by contact with rocks and minerals, and occasionally manmade materials like iron and steel pipes. It usually is groundwater supplies that may require treatment for high levels of iron and manganese. Generally , few surface water supplies have high enough levels of either to cause problems. Occasionally discharge of acid industrial wastes or mine drainage may increase iron or manganese to problem levels in surface water.

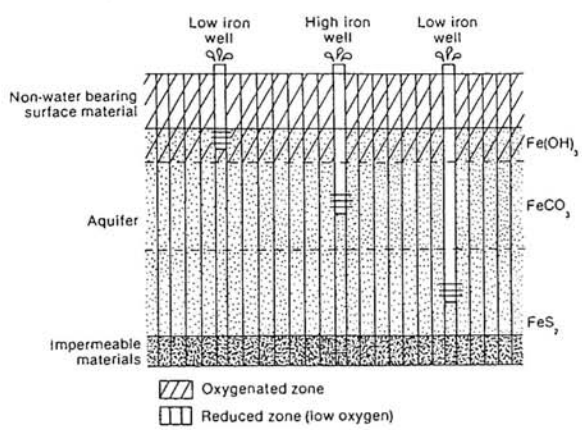
Iron and Manganese Solubility

Iron and manganese exist in many different chemical forms. The presence of a given form of iron or manganese in geologic materials or water depends on many different environmental factors. Iron and manganese problems in water often can be anticipated by observing a few general principles that affect water chemistry.

An important principle to remember about chemical reactions is that, if allowed enough time, they will reach an equilibrium with the surrounding environment. When the conditions of that environment are changed, such as pumping water from an underground acquifer, the chemical equilibrium is upset. This will lead either to solution of certain elements such as iron and manganese or to their precipitation.

Oxygenated water generally will have only low levels of iron and manganese. That's because both iron and manganese react with oxygen to form compounds that do not stay dissolved in water. Surface water and shallow groundwater (Fig. 1) usually have enough dissolved oxygen to maintain iron and manganese in

Figure 1. The amount of iron and manganese dissolved in water often follows a trend of low to high, back to low again as depth of the well increases. (Snoeyink, V.L. and D. Jenkins. 1980.)



an undissolved state. In surface water, iron and manganese are most likely to be trapped within suspended organic matter particles. Waters that do not have regular contact with the atmosphere tend to be low in oxygen (oxygen poor). Iron and manganese carbonates in an oxygen-poor environment are relatively soluble and can cause high levels of dissolved iron and manganese. However, if iron is associated with sulfur as iron sulfide rather than iron carbonate, dissolved iron remains low. Dissolved oxygen generally decreases with depth, so these types of conditions are more likely to occur in deep wells.

Sometimes oxygen poor conditions also can occur in relatively shallow wells that have stagnant water with slow turnover. Iron and manganese problems then are most likely to develop in water from wells with high carbonate and low oxygen as shown in the middle well in Figure 1. Problems occur when this type of water is pumped to the surface. The chemical equilibrium is changed upon exposure to the atmosphere. The end result is precipitation of iron and manganese compounds in plumbing, on fixtures, and on clothing, dishes, and utensils.

Iron and Manganese Bacteria

Some types of bacteria derive their energy by reacting with soluble forms of iron and manganese. These organisms usually are found in waters that have high levels of iron and manganese in solution. The reaction changes the iron and manganese from a soluble form into a less soluble form, thus causing precipitation and accumulation of black or reddish brown gelatinous material (slime). Masses of mucous, iron, and/or manganese can clog plumbing and water treatment equipment. They also slough off in globs that become iron or manganese stains on laundry.

Bacterial reactions with iron and manganese do not cause any additional precipitation compared to normal exposure to oxygen. However, precipitation caused by bacteria occurs faster and tends to concentrate staining, thus making it more apparent.

Water System Pipelines

An additional source for dissolved iron may be the pipelines through which water flows. Water with high salinity or acidity from dissolved carbon dioxide or other acids will be corrosive to metal pipes. In order to establish equilibrium, iron and other metals will be dissolved from the pipelines.

If household pipes are being attacked by corrosive water and cause problem levels of metals such as iron, copper, and lead, the water can be treated to reduce corrosivity and the level of dissolved metals. Acidity can be reduced either by adding alkaline materials such as sodium carbonate or by passing water through filters made of alkaline material. Salinity can be treated either by distillation or by reverse osmosis.

Because different metals are more or less corrodible, a solution to the problem may be to use a more resistant metal. Consult a plumber regarding materials best suited to local water conditions.

How Much Is Too Much?

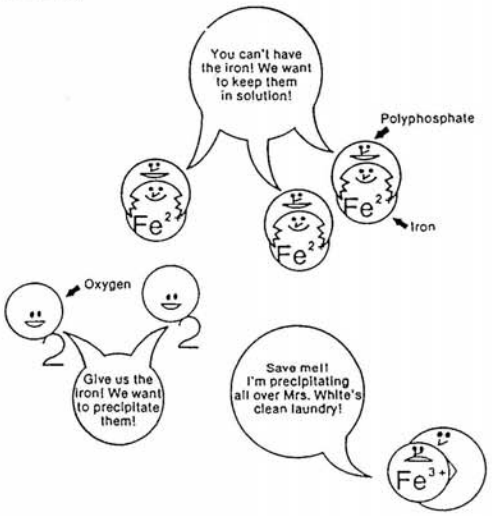
How much iron or manganese in the water is needed to cause these sorts of problems? There is no pat answer to this question, because it varies with each household situation. Standards for iron and manganese are based on levels that cause taste and staining problems and are set under EPA Secondary Drinking Water Standards. For most individuals 0.3 parts per million (ppm) of iron and 0.05 ppm of manganese is objectionable. Usually, iron and manganese do not exceed 10 ppm and 2 ppm, respectively, in natural waters. Iron and manganese are found at higher concentrations; however, that condition is rare.

Waster Testing for Iron and Manganese

The need to test for iron and manganese in water is not as critical as it is for other types of contaminants that can cause health problems. Iron and manganese are not a problem in household water until they become detectable by the senses. Consequently, elaborate laboratory analyses are not required to determine if iron or manganese are a problem. Laboratory analyses for iron and manganese are needed to quantify the problem.

Exposure of the sample to air will cause precipitation of iron and manganese. To get an estimate of the amount of iron and manganese originally dissolved in the well water, precipitation must be prevented or the precipitated material must be redissolved. Before sampling for iron and manganese, a certified laboratory should be consulted. They will recommend a sampling procedure that will provide an accurate estimate of dissolved iron and manganese in the source water.

Figure 2. Polyphosphates protect dissolved iron and manganese from reacting with oxygen and precipitating on household appliances, bath/plumbing fixtures, and laundry.



Water Treatment to Remove Iron and Manganese

Polyphosphate Treatment

Polyphosphates react with dissolved iron and manganese by trapping them in a complex molecule that is soluble in water (Fig. 2). As a result , the iron and manganese are not available to react with oxygen and precipitate. Polyphosphates can be fed into the water system with controlled injection equipment. Polyphosphates are not stable at high temperatures. If water is treated prior to heating in a water heater, the polyphosphates will release iron and manganese in the heater as they break down. The released iron and manganese will then react with oxygen and precipitate.

Polyphosphate treatment is a relatively cheap way to treat water for low levels of iron and manganese. Depending on the type of polyphosphate used, water with 1 to 3 ppm of iron can be treated adequately.

Ion Exchange

Iron and manganese dissolved in water can be exchanged for sodium on an exchange resin or zeolite (Fig. 3). This process of iron and manganese removal is the very same ion exchange process that removes hardness or calcium and magnesium. (Refer to FS 877S *Treatment Systems for Household Water Supplies: Softening.*)

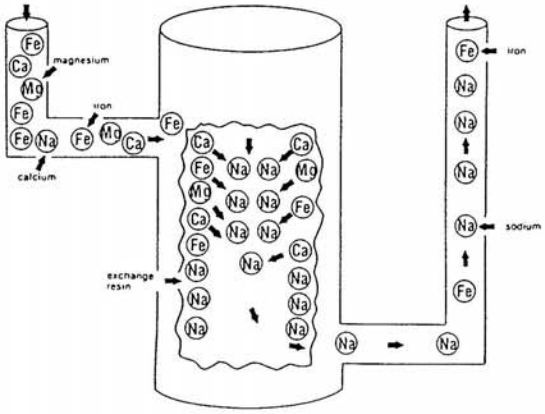
Iron and manganese are removed during normal operation of the water softener. They are later removed from the exchange medium along with calcium and magnesium during regeneration and backwashing.

Some water softeners can adequately treat water having iron up to 10 ppm. However, others are limited to treating water with iron no greater than 1 ppm. If iron and manganese removal is desired in addition to hardness, check the manufacturer's recommendations.

One of the disadvantages of depending on ion exchange for iron and manganese removal is precipitation by oxygen. Some of the precipitate becomes tightly bound to the exchange resin and over time reduces the exchange capacity by plugging pores and blocking exchange sites. If iron bacteria are present, the problem is even worse. Also, if suspended particles of insoluble forms of iron or manganese are present in the water prior to softening, they will be filtered out on the resin and cause plugging. Suspended iron and manganese need to be filtered out before water enters the softener.

A clogged water softener can be cleaned by acid regeneration if the unit is made to withstand acid corrosion. Consult the manufacturer before this is attempted. The problem with iron bacteria can be eliminated by chlorinating and filtering the water at some point before it reaches the softener. (Refer to FS 877C *Treatment Systems for Household Water Supplies: Chlorination.*) As long as levels of iron and

Figure 3. Household water softening units will remove some iron and manganese from water. Most units, however, are not designed to handle very large amount of iron and manganese and may become plugged when concentrations are too high.



manganese in the water do not exceed the manufacturer's recommendations, iron and manganese clogging should not be a significant problem. When iron and manganese levels are higher than recommended by the manufacturer, iron and manganese removal will be necessary prior to softening.

Greensand (Adsorptive/Oxidative) Filtration

One of the first types of filters to be used to treat water was the greensand filter. The active material in greensand is glauconite, a green clay mineral that contains iron and has ion exchange properties. Glauconite often occurs mixed with other material as small pellets, thus the name greensand. The glauconite is mined, washed, screened, and treated with various chemicals to produce a durable greenish-black product that has properties that allow it to adsorb soluble iron and manganese.

As water is passed through the filter, soluble iron and manganese are pulled from solution and later react to form insoluble iron and manganese. Insoluble iron and manganese will build up in the greensand filter and must be removed by backwashing. Backwashing should be done regularly twice a week or as recommended by the manufacturer.

Eventually, the greensand also must be regenerated by washing with a permanganate solution. Regeneration will leave the greensand grains coated once again with a manganese material that adsorbs soluble iron and manganese. Frequency of regeneration will depend on the level of iron, manganese, and oxygen in the water and the size of the filter. Follow the manufacturer's recommendations.

Most greensand filters are rated to be effective treating water with iron concentrations up to 10 ppm. Because some greensand filters are not rated this high, always check the manufacturer's recommendations. The acidity or pH of the water will influence the ability of the filter to remove both iron and manganese. If the pH of the water is lower than 6.8, the greensand probably will not adequately filter out the iron and manganese. The pH can be raised above 7.0 by running the water through a calcite filter.

Regular backwashing is essential for effective filter performance and requires flow rates that often are three to four times the normal household useage rate. A backwash rate of about eight ppm/square foot of filter bed is recommended. If the household system cannot support the needed flowrate for adequate backwashing, poor filter performance and failure are likely.

Chlorination (Oxidation) Plus Filtration

Chemical oxidation followed by filtration is the accepted way to remove iron and manganese when concentrations are greater than 10 ppm. A number of strong oxidants have been used in this procedure; however, chlorine generally is used in household systems. (Refer to FS 877C *Treatment Systems for Household Water Supplies: Chlorination.*)

A chlorine solution is injected with a chemical feed pump ahead of a sand filter. Soluble iron and manganese begin to precipitate almost immediately after contact with the chlorine solution. However, approximately 20 minutes of contact time is needed for the precipitate to form particles that can be filtered.

The standard 42-gallon pressure tank used on many household systems often will provide the needed contact time if water is forced through the tank. A simple T-connection from the pipeline to the pressure tank will not work, since much of the water bypasses the tank. Additional contact time can be provided by connecting another tank in series or using a plastic pipe coil.

This type of system will remove both soluble and suspended particles of insoluble iron and manganese from the source water. Backwashing the sand filter to remove precipitated iron and manganese is an important part of continued filtration. As with the greensand filter, check the system flow rate to make sure it can provide the needed rates for backwashing.

An additional advantage of the chlorination system is its bacteriacidal effect. Iron and manganese bacteria, along with other bacteria, are destroyed. Potential clogging problems in the sand filter are eliminated.

Chlorination does produce trihalomethanes (THM) when organic matter is present in the water. THMs are considered to be carcinogenic (maximum contaminant level permissible in public water systems is 0.1 parts per million) and, if necessary, can be filtered out with an activated charcoal filter. (Refer to FS 877A *Treatment Systems for Household Water Supplies: Activated Charcoal Filtration*).

The optimum rate of oxidation of iron and manganese by chlorination is at a pH of about 8.0 and 8.5, respectively. Soda ash injected with the chlorine will increase the pH to optimum levels. Adjusting the pH to alkaline levels also reduces the corrosivity of the water to pipes and plumbing.

Table 1. Summary of Iron Treatment Methods

Treatment Method	Range of Soluble Iron Removed (parts per million)
Polyphosphate	0-3
Iron Exchange (softener)	*0-10
Greensand Filter	0-10**
Chlorination and Filtration	0- >10@

*Most softeners are rated for use at the lower end of the range. Check with the manufacturer.

**Most greensand filters are rated for use at the upper end of the range. Check with the manufacturer. If water pH is less than 6.8, greensand filters will not perform as rated.

@ Chlorination and filtration will work at all levels of soluble iron; however, it is recommended only for levels above 10 ppm of soluble iron.

Standards for Equipment to Remove Iron and Manganese

The Water Quality Association (WQA) has set voluntary performance standards for oxidative filtration methods. "An oxidizing filter shall reduce 10.0 ppm plus or minus 1.0 ppm soluble iron to not more than 0.2 ppm and 2.0 ppm plus or minus 0.2 ppm soluble manganese to not more than 0.05 ppm." A directory of validated equipment that meet these standards is available from WQA, National Headquarters and Laboratory, 4151 Naperville Road, Lisle, IL 60532 (708/505-0160).

WQA also recognizes the following water treatment methods to meet EPA's Secondary Drinking Water Standards for both soluble iron and manganese:

- Oxidizing filters.
- Cation exchange.
- Chlorination - precipitation/filtration.

Polyphosphate treatment does not meet the drinking water standards, because it ties up iron and manganese but does not remove it. Reverse osmosis, distillation, and pressure aeration/filtration also are recognized by WQA as water treatment methods that can be used to meet the iron and manganese drinking water standards. (Refer to FS 877RO *Treatment Systems for Household Water Supplies: Reverse Osmosis* and FS 877D *Treatment Systems for Household Water Supplies: Distillation.*)

Different water treatment systems vary considerably in their ability to treat a specific contaminant. Select water treatment equipment only after careful consideration of the water problem. As a part of the installation procedure, use water analysis to test the performance of the equipment. Use periodic water analysis to check for continued equipment performance.

Further Information

Contact your county Extension office or the State Health Department. Additional information can be found in other fact sheets in the *Treatment Systems for Household Water Supplies* series:

FS 877A Activated Carbon Filtration
FS 877C Chlorination
FS 877D Distillation
FS 877RO Reverse Osmosis
FS 877S Softening
FS 887P Identifying and Correcting Water Problems

References

Hem, J. D. Equilibrium chemistry of iron in groundwater. In S. D. Faust and J. V. Hunter (ed.) *Principles and Applications of Water Chemistry.* John Wiley and Sons, Inc., New York. 1967. p. 625-643.

Machmeier, R. E. *Iron in Drinking Water,* AFO-1318. Minnesota Extension Service, University of Minnesota, Agriculture. Reviewed 1990. p. 380-396.

O'Connor, J. T. Iron and Manganese. In M. E. Flentje and R. J. Faust (ed.). *Water Quality and Treatment -- A Handbook of Public Water Supplies, 3rd Edition.* Prepared by The American Water Works Association, Inc. McGraw-Hill Book Co., New York. 1971.

Snoeyink, V. L. and D. Jenkins. *Water Chemistry.* John Wiley and Sons, Inc., New York. 1980.

Water Quality Association. *Recommended Industry Standards for Household and Commercial Water Filters -- A Voluntary Industry Standard,* S-200. National Headquarters and Laboratory, Lisle, Il. 1988.

Water Quality Association. *Recognized Treatment Techniques for Meeting the National Secondary Drinking Water Regulations with the Application of Point-of-Use Systems,* R28. National Headquarters and Laboratory, Lisle, Ill. 1989.

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FS 877A

Treatment Systems for Household Water Supplies

Activated Carbon Filtration

by Bruce Seelig, NDSU water quality specialist, North Dakota Extension Service;
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Russell Derickson, SDSU Extension associate in water & natural resources.

Water Contaminants Removed by Activated Carbon Filters

Activated carbon (AC) filtration is most effective in removing organic contaminants from water. Organic substances are composed of two basic elements, carbon and hydrogen. Because organic chemicals are often responsible for taste, odor, and color problems, AC filtration can generally be used to improve aesthetically objectional water. AC filtration will also remove chlorine. AC filtration is recognized by the Water Quality Association as an acceptable method to maintain certain drinking water contaminants within the limits of the EPA National Drinking Water Standards (Table 1).

AC filtration does remove some organic chemicals that can be harmful if present in quantities above the EPA Health Advisory Level (HAL). Included in this category are trihalomethanes (THM), pesticides, industrial solvents (halogenated hydrocarbons), polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs).

THMs are a byproduct of the chlorination process that most public drinking water systems use for disinfection. Chloroform is the primary THM of concern. EPA does not allow public systems to have more than 100 parts per billion (ppb) of THMs in their treated water. Some municipal systems have had difficulty in meeting this standard.

The Safe Drinking Water Act mandates EPA to strictly regulate contaminants in community drinking water systems. As a result, organic chemical contamination of municipal drinking water is not likely to be a health problem. Contamination is more likely to go undetected and untreated in unregulated private water systems. AC filtration is a viable alternative to protect private drinking water systems from organic chemical contamination.

Radon gas also can be removed from water by AC filtration, but actual removal rates of radon for different AC filtering equipment have not been established.

Table 1. Water contaminants that can be reduced to acceptable standards by activated carbon filtration. (Water Quality Association, 1989.)

PRIMARY DRINKING WATER STANDARDS

Contaminant	* MCL, mg / L
Inorganic Contaminants	
Organic arsenic complexes	0.05
Organic chromium complexes	0.05
Mercury (Hg+2) inorganic	0.05
Organic mercury complexes	0.002
Organic Contaminants	
Benzene	0.005
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
1, 2-dichlorothene	0.005
1, 1-dichloroethylene	0.007
1, 1, 1-trichloroethane	0.200
Total trihalomethanes (TTHMs)	0.10
Toxaphene	0.005
Trichloroethylene	0.005
2, 4-D	0.1
2, 4, 5-TP (Silvex)	0.1
Para-dichlorobenzene	0.075

SECONDARY DRINKING WATER STANDARDS

Contaminant	**SMCL
Color	15 color units
Foaming agents (MBAS)	0.5 mg/L
Odor	3 threshold odor number

*Maximum contaminant level
**Secondary maximum contaminant level

Water Contaminants Not Removed by AC Filtration

Similar to other types of water treatment, AC filtration is effective for some contaminants and not effective for others. AC filtration does not remove microbes, sodium, nitrates, fluoride, and hardness. Lead and other heavy metals are removed only by a very specific type of AC filter. Unless the manufacturer states that its product will remove heavy metals, the consumer should assume that the AC filter is not effective in removing them. Refer to the other fact sheets in this series for information on systems that do remove the contaminants listed above.

Water Testing

Regular water testing is recommended to reduce the risk of consuming contaminated water. Many contaminants are not detected by the senses. Even if contamination can be detected by color, smell, or taste, only a laboratory test can tell you the quantity of contaminant actually present.

Always have water testing done by a reputable or certified laboratory. Prior to sending in your water sample, determine what you want your water tested for. Contact the laboratory to find out how to take a proper water sample. Remember, there are thousands of substances that can contaminate your water, and they all have slightly different chemical behavior. Proper sampling and handling for one type of contaminant may cause erroneous results for other types of contaminants.

Once you have the laboratory results in hand, make sure you understand the numbers. If you don't fully understand the results, don't assume anything. The testing laboratory will be able to answer any questions you may have about the test results. Understanding the laboratory results will help you select the best and most economical water treatment system. Sometimes just a single piece of equipment, such as an AC filter, is all that is necessary to treat the problem. Other times you may need completely different equipment or possibly a combination of equipment. It depends on the type and amount of contaminants present in your water supply.

The Activated Carbon Filtration Process

AC works by attracting and holding certain chemicals as water passes through it. AC is a highly porous material; therefore, it has an extremely high surface area for contaminant adsorption. The equivalent surface area of 1 pound of AC ranges from 60 to 150 acres.

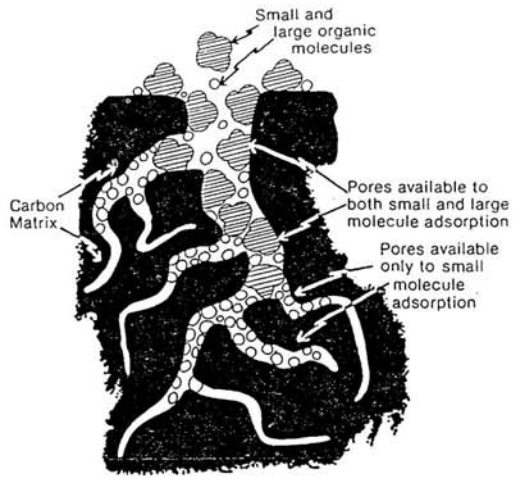


Figure 1. Molecular screening in the micropores of an activated carbon filter.

AC is made of tiny clusters of carbon atoms stacked upon one another. The carbon source is a variety of materials, such as peanut shells or coal. The raw carbon source is slowly heated in the absence of air to produce a high-carbon material. The carbon is activated by passing oxidizing gases through the material at extremely high temperatures. The activation process produces the pores that result in such high adsorptive properties.

The adsorption process depends on the following factors:

- Physical properties of the AC, such as pore size distribution and surface area.
- Chemical nature of the carbon source or the amount of oxygen and hydrogen associated with it.
- Chemical composition and concentration of the contaminant.
- Temperature and pH of the water.
- Flow rate or time exposure of water to AC.

Physical Properties

Forces of physical attraction or adsorption of contaminants to the pore walls is the most important AC filtration process. The amount and distribution of pores play key roles in determining how well contaminants are filtered. The best filtration occurs when pores are barely large enough to admit the contaminant molecule (Figure 1).

Because contaminants come in all different sizes, they are attracted differently depending on pore size of the filter. In general, AC filters with relatively large molecules (most organic chemicals) are most effective in removing contaminants. Type of raw carbon material and its method of activation will affect types of contaminants adsorbed. This is due largely to the influence of raw material and activation on pore size and distribution.

Chemical Properties

Processes other than physical attraction also affect AC filtration. The filter surface actually may interact chemically with organic molecules. Electrical forces between the AC surface and some contaminants also may result in adsorption or ion exchange. Adsorption, then, also is affected by the chemical properties of the adsorbing surface which are determined to a large extent by the activation process. AC materials formed from different activation processes will have chemical properties that make them more or less attractive to various contaminants. For example, chloroform is adsorbed best by an AC that has the least amount of oxygen associated with the pore surfaces.

The consumer can not determine the chemical nature of an AC filter. Different types of AC filters will have varying levels of effectiveness in treating different chemicals. Consult the manufacturer to determine if its filter will adequately treat your specific water problem.

Contaminant Properties

Large organic molecules are adsorbed most effectively by AC. A general rule of thumb is that similar materials tend to associate. Organic molecules and activated carbon are similar materials; therefore, most organic chemicals have a strong tendency to associate with the activated carbon in the filter rather than staying dissolved in a dissimilar material like water. Generally, the least soluble organic molecules are most strongly adsorbed. The smaller organic molecules often are held the tightest, because they fit into the smaller pores.

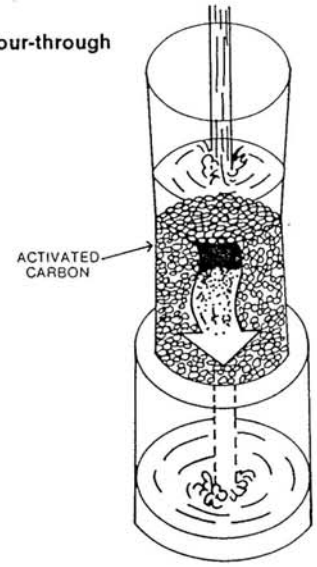
Concentration of organic contaminants can affect the adsorption process. A given AC filter may be more effective than another type of AC filter at low contaminant concentrations, but may be less effective than the other filter at high concentrations. This behavior has been observed with chloroform removal. Consult the filter manufacturer to determine how the filter will perform for specific chemicals at different levels of contamination.

Water Temperature and pH

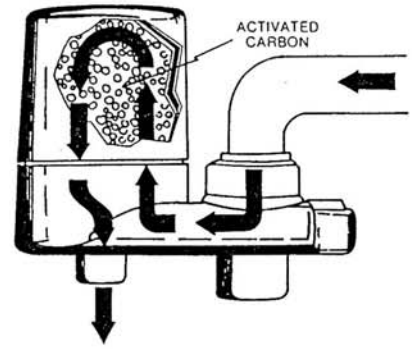
Adsorption usually increases as pH and temperature decrease. Chemical reactions and forms of chemicals

Figure 2. Three types of activated carbon filtration units.

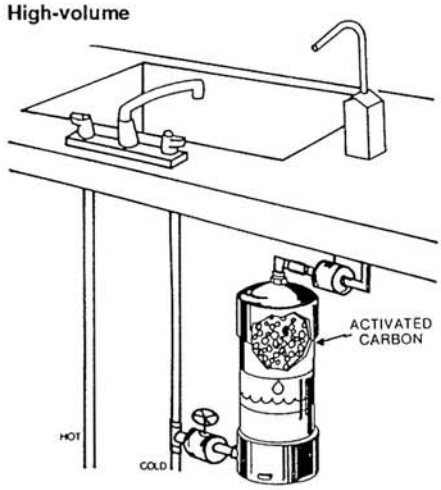
A -- Pour-through



B -- Faucet-mounted



C -- High-volume



are related closely to pH and temperature. When pH and temperature are lowered, many organic chemicals are in a more adsorbable form.

Exposure Time

The process of adsorption also is influenced by the length of time the AC is in contact with the contaminant in the water. Increasing contact time allows greater amounts of contaminant to be removed. Contact is improved by increasing the amount of AC in the filter and reducing the flow rate of water through the filter.

Activated Carbon Filtration Equipment

There are three categories of AC filters: pour-through, faucet-mounted, and high-volume (Figure 2).

Pour-through AC filters are the simplest. They work like a drip coffee maker. Water is poured in the top and, by gravity, filters through to the bottom. They are quite slow and handle only small volumes of water.

Faucet-mounted AC filters are small units attached on the end of a standard kitchen faucet. They are convenient to use but, because of their size, require frequent change. Some unitshave bypass valves, so that just water for cooking and drinking is filtered.

High-volume AC filters contain much more activated carbon than either the pour-through or faucet-mounted models. High-volume units are designed to be installed in-line, generally under the sink. They are installed on the cold water line, and some units are installed with a bypass to separate cooking and drinking water from other uses.

Under exceptional circumstances all water may need to be treated by AC filtration. In that case, a high-volume unit may be installed at the point of entry to the house.

Results of Activated Carbon Filter Testing

Several independent laboratories have tested AC filtration equipment for effectiveness in contaminant removal. Organizations involved in AC testing Gulf South Research Institute; National Sanitation Foundation; Canadian Bureau of Health; Consumer Reports; and Rodale Press Product Testing Department.

Based on the testing results of these organizations, general recommendations can be made regarding AC filtration. Use high-volume AC units if removal of health-threatening contaminants is your concern. Pour-through and faucet-mounted units do not provide the contact time required for significant removal of contaminants. If you are concerned only with taste, odor, or color, pour-through and faucet-mounted units will probably do the job. However, they still will require changing much more often than high-volume AC filters.

Efficiency of contaminant removal and equipment operation vary even among the high volume AC units (Table 2). The most efficient unit is not always the most expensive one.

Table 2. Comparison of activated carbon filtration units.
(Consumer Reports, 1990.)

Brand & Model	Price $	Cartridge Cost $	Chloroform Removal %
High-volume filters			
Ametek CCF-201	158	20 (2)	100
Ecowater Water Master	250	33 (2)	100
Amway E-9230	276	69	100
Hurley II	375	--	100
Filtrate CF 10	85	8	90
Cuno AquaPure AP-CRF	155	15	90
Kinetico MAC	275	32	90
Culligan SuperGard THM	349	37	90
Teledyne Instapure IF-10	50	12	80
Omni UC-2	99	20 (2)	80
NSA Bacyteriostatic 50C	179	--	80
(The following two models were downrated because they clogged after filtering only 300 gallons.)			
Bionaire H20 BT850	199	100	100
Everpure H200	298	90	100
Faucet-mount filters			
Cuno Purity PP01105	30	6	60
Teledyne Instapure F-2C	24	5	45
Pollenex WP90K	22	5	30
Pour-through filters			
Brita	30	8	50
Innova	7	5	45
Glacier Pure	13	5	40

FS 877A

Eventually, the AC filter loses its ability to remove contaminants, because it becomes clogged with material. In the case of taste and odor, the time to change the filter is easy to detect. However, in the case of other contaminants, it is more difficult to determine when the filter is no longer performing at an adequate level. Most manufacturers recommend a filter change after a certain volume of water has passed through the filter. Some AC units actually meter the water and automatically shut down after a specific quantity of water has passed through the filter. A general rule of thumb for high-volume AC filters is to change the filter after six months of use or 1000 gallons of filtered water.

Tests done by Rodale Press Product Testing Department indicated that filtering performance was reduced dramatically after 75 percent of the manufacturer's recommended life time. These results suggest that filters should be changed more often than suggested by the manufacturer. Some AC filters are claimed to last for five years, because they are rechargeable with hot water (145 degrees F). The heat is supposed to release adsorbed organic chemicals. Little information is available on the prolonged effectiveness of rechargeable AC units.

General recommendations are somewhat useful guidelines, but there is no guarantee that they apply to any specific situation. Remember, the only certain way to know whether contaminant levels are acceptable or not is to have your water tested.

A sediment filter installed ahead of any AC filter will prolong the life of the AC unit. Sediment can easily clog the pores of an AC filter within a short period of time.

The Bacteria Issue

AC filters can be a breeding ground for microorganisms. The organic chemicals that are adsorbed to the AC are a source of food for various bacteria. Pathogenic bacteria are those that cause human diseases such as typhoid, cholera, and dysentery. Public water systems must treat for disease-causing bacteria; therefore, the likelihood of disease-causing bacteria being introduced to an AC filter from public drinking water is remote. Only use AC filtration on water that has been tested and found to be bacteria free or effectively treated for pathogenic bacteria.

Other types of non-pathogenic bacteria that do not cause diseases have been found regularly in AC filters. There are times when high amounts of bacteria (non-pathogenic) are found in water filtered through an AC unit. Research by R. L. Caldron and E. W. Mood (1987) shows little risk to healthy people who consume high amounts of non-pathogenic bacteria. Humans regularly take in millions of bacteria every day from other sources. There is some concern for certain segments of the population, however, such as the very young or old and people weakened by illness. Some types of non-pathogenic bacteria can cause illness in those whose natural defenses are weak.

Bacteria that have built up in the filter can be flushed out by running water through an AC filter for about 30 seconds prior to use. Water filtered after the initial flushing will have much lower levels of bacteria, and ingestion of a high concentration of bacteria will have been avoided. The flushing procedure is most important in the morning or any other time of day when the filter has not been used for several hours.

Some compounds of silver have been used as disinfectants in certain AC filters as a solution to the bacteria problem. Unfortunately, product testing has not shown silver impregnated AC to be much more effective in controlling bacteria than normal AC filters. Only in the first month of operation did there appear to be any advantage to using an AC filter that contained silver.

EPA requires registration of all types of water treatment equipment that contain an active ingredient for the purpose of inhibiting the growth of microorganisms. Registration does not guarantee that the product is effective. It only guarantees that the active ingredient will not leach from the filter at levels that would be a health hazard.

Further Information

Contact your county Extension Office or the State Health Department. Ask for other publications in the *Treatment Systems for Household Water Supplies* fact sheet series:

- FS 877C Chlorination
- FS 877D Distillation
- FS 887IM Iron and Manganese Removal
- FS 88RO Reverse Osmosis
- FS 887S Softening
- FS 877P Identifying and Correcting Water Problems

References

Recognized treatment techniques for meeting the National Primary Drinking Water Regulations with the application of point-of-use systems. Water Quality Association, Lisle, Il. 1989.

Recognized treatment techniques for meeting the National Secondary Drinking Water Regulations with the application of point-of-use systems. Water Quality Association, Lisle, Il. 1989.

Fit to drink? Consumer Reports. January 1990. pp. 27-43.

Caldron, R. L., and E. W. Mood. Bacteria colonizing point-of-use, granular activated carbon filters and their relationship to human health. Research Project CR-811904-01-0, Health Effects Research Lab., U.S. EPA, Cincinnati, Ohio. 1987. Reprinted by the Water Quality Association, Lisle, Ill.

Culp, G. L. and R. L. Culp. New concepts in water purification. Van Nostrand Reinhold Co. New York. 1974.

Ishizake, C., I. Marti, and M. Ruiz. Effect of surface characteristics of activated carbon on the adsorption of chloroform from aqueous solution. In M. J. McGuire and I. H. Suffet (ed.). Treatment of water by granular activated carbon. Advances in Chemistry Series. American Chemical Society, Washington, D.C. 1983. pp. 95-106.

Rodale Press Product Testing Department Staff. Water treatment handbook -- A homeowners guide to safer drinking water. Rodale Press Inc., Emmaus, Pa. 1985.

Taraba, J. L., L. M. Heaton, and T. W. Ilvento. Using activated carbon filters to treat home drinking water, IP-6. University of Kentucky Cooperative Extension Service, Lexington, Ky. 1990.

Temple, Barker, and Sloan Inc. Staff. Point-of-use treatment for compliance with drinking water standards. Reprinted by the Water Quality Association, Lisle, Ill. 1983.

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FS 877RO

Treatment Systems for Household Water Supplies

Reverse Osmosis

by Fred Bergsrud, UM Extension agricultural engineer and water quality coordinator, Minnesota Extension Service;
Bruce Seelig, NDSU water quality specialist, North Dakota Extension Service; and
Russell Derickson, SDSU Extension associate in water & natural resources

Impurities Removed by Reverse Osmosis

Reverse osmosis (RO) has become a common method for the treatment of household drinking water supplies. Effectiveness of RO units depends on initial levels of contamination and water pressure.

RO treatment may be used to reduce the levels of:

- Naturally occurring substances that cause water supplies to be unhealthy or unappealing (foul tastes, smells or colors).
- Substances that have contaminated the water supply resulting in possible adverse health effects or decreased desirability.

RO systems typically are used to reduce the levels of total dissolved solids and suspended matter. In South Dakota, the principle uses of reverse osmosis are for the reduction of high levels of nitrate, sulfate, sodium and total dissolved solids.

RO units with carbon filters also may reduce the level of some man-made chemicals like pesticides, dioxins and VOCs (volatile organic compounds like chloroform and petrochemicals). An RO unit alone may not be the best solution for these types of contaminants, but installing a properly designed RO unit to reduce the levels of other contaminants may provide a reduction in SOCs and VOCs.

How to Test Your Water

Before installing any water treatment system, be sure to have the water tested. The test will identify the bacteria and level of minerals present. Interpretation of the test results will help determine whether treatment is needed and what type of system or systems to consider. The intended use of the water (drinking only, drinking and cooking, laundry, or all household uses) also helps determine the type and extent of treatment needed and the type of system to select.

Note: RO systems normally are used to treat only drinking and cooking water supplies so may not be preferred where larger quantities are being treated. RO systems are not appropriate for treating water supplies that are contaminated by coliform bacteria.

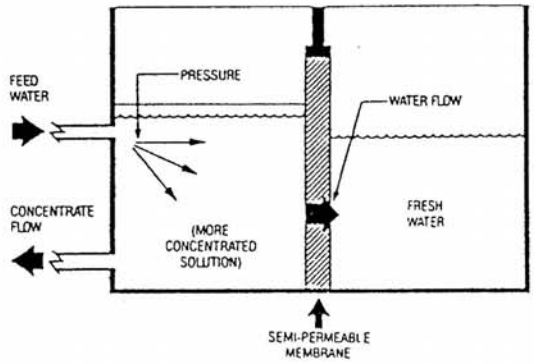
The water test analysis and interpretation will provide information about both naturally-occurring substances and those resulting from human activity.

Treatment of contaminated water supplies should be considered only as a temporary solution. The best solution is to remove the source(s) of contamination and/or obtain a new water supply.

How Reverse Osmosis Works

RO sometimes is referred to as ultrafiltration because it involves the movement of water through a membrane (Figure 1). The membrane has microscopic openings that allow water molecules, but not larger compounds, to pass through. Some RO membranes also have an electrical charge that helps reject some chemicals at the membrane surface. Proper maintenance is essential to retain effectiveness over time. Some units are equipped with automatic membrane flushing systems to clean the membrane.

Figure 1. Dynamic cross-section of a reverse osmosis unit.



Measuring RO Effectiveness

The effectiveness of RO units is characterized by the rejection rate or rejection percentage. The rejection rate is the percent of a contaminant that does not move through, or is rejected by, the membrane. Some typical rejection rates for common contaminants are shown in Table 1. These rejection rates are for single contaminants under design conditions.

Where water contains more than one contaminant, the rejection rate for each contaminant may be reduced or one of the contaminants may be reduced in preference to the other contaminant. For example, cases have been reported where water supplies containing either high TDS levels or high sulfates in combination with nitrates show no decrease in nitrates after treatment. (Nitrates as used in this publication refers to nitrate-nitrogen or NO_3^-N.)

Rejection rates need to be high enough to reduce the contaminant level in the untreated water to a safe level. To determine the needed rejection rate, it is necessary to consider the initial concentration. For example, if a water supply contains nitrates at a concentration of 20 milligrams per liter (mg/l), an RO unit rejecting at a rate of 85 percent, which means 15 percent remaining, would reduce the level to 3 mg/l (20 times 0.15 = 3).

Water with very high levels of nitrates (such as 100 mg/l) would remain near or above health standard levels even after treatment. Nitrate levels this high are not expected in this region and indicate unusual problems that require special investigation and handling. The National Sanitation Foundation (NSF) recommends that special designs be used for RO units where the NO_3^-N level exceeds 40 mg/l.

Table 1. Typical rejection rates for common contaminants.

Contaminant	Rejection Rate Range*	
	Laboratory Tests	Field Tests
Nitrates	83 - 92 %	** - 92 %
Total dissolved solids	95 - 99 %	60 - 99 %
Sulfates	90 - 98 %	60 - 98 %
Sodium	87 - 93 %	60 - 93 %

* These values are for properly maintained units. Poorly maintained units will not be as effective at removing contaminants and, in the worst care, may not be removing any contaminants.

Disadvantages of Reverse Osmosis Units

RO units use a lot of water. They recover only 5 to 15 percent of the water entering the system. The remainder is discharged as waste water. Because waste water carries with it the rejected contaminants, methods to recover this water are not practical for household systems. Waste water typically is connected to the house drains and will add to the load on the household septic system. An RO unit delivering 5 gallons of treated water per day may discharge 40 to 90 gallons of waste water per day to the septic system.

Equipment in an RO System

A typical home reverse osmosis treatment system is shown in Figure 2. The system normally is located beneath the kitchen sink since it is used to treat water for drinking and cooking purposes. RO systems consist of the prefilter, RO membrane unit, a pressurized storage tank for the treated water, a post-filter, and a separate delivery tap for the treated water supply.

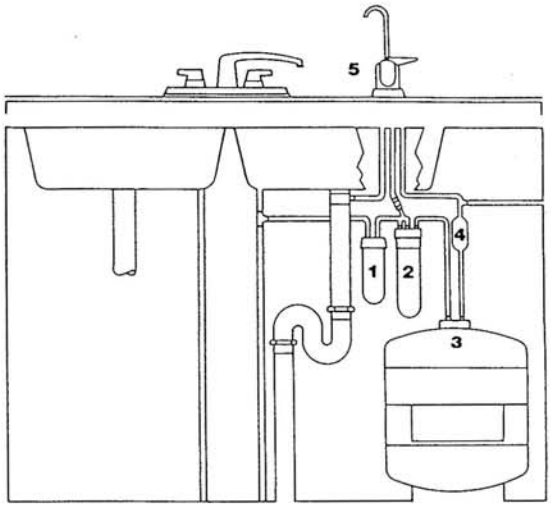
The water supply entering the RO unit should be bacteriologically safe. RO units will remove virtually all microorganisms, but they are not recommended for that use because of the possibility of contamination pinhole leaks or deterioration due to bacterial growth.

Prefilter: The prefilter is sometimes referred to as a sediment filter. It removes small suspended particles to extend the life of the membrane. Some membrane units are damaged by chlorine and others by bacterial growth. An inline activated carbon prefilter is recommended when chlorine is present.

RO Membrane: Several kinds of reverse osmosis membranes are available. The most common materials are cellulose acetate or polyamide resins. Mixtures or variations of these materials also are used. Each product has certain advantages and limitations and these need to be considered carefully. Investigate these factors:

- The contaminant(s) involved and their initial concentration(s).
- The water supply rate or whether the system will deliver enough water to meet normal, daily drinking and cooking requirements.
- The rejection rate, or the percentage of contaminants to be removed by the membrane.

Figure 2. A typical home RO system includes: (1) particle filter, (2) reverse osmosis membrane unit, (3) pressurized treated-water storage, (4) carbon adsorption post-filter, and (5) separate treated-water tap.



- The water pressure required to meet the supply and rejection rates. That is, can this unit be operated on the normal operating pressure of a home water system or will a booster pump be required?
- How can the system's performance be monitored? That is, how can leaks or other problems be detected or how is the time for servicing or replacement determined? Some systems have built-in monitors, but many do not. Conductivity meters, pressure gauges, and other devices can be used to detect problems where monitors are not included. Where coliform bacteria or other special contaminants are a known or suspected problem, periodic testing is recommended.

Storage Tank: Most RO units supply treated water at very low rates so a storage tank of 2 to 5 gallons is used to provide a suitable supply. These units are pressurized to produce an adequate flow when the tap is open. Under-sink storage requires minimum pressure to deliver water. Other locations may require increased delivery pressure which may reduce membrane performance.

Post-Filter: The main reason for postfiltration is to remove any residual organics from the treated water. Usually, a carbon filter is used for this purpose. Where a carbon filter is used as a part of the prefiltration step, postfiltration is normally eliminated.

Delivery Tap: A separate delivery tap for the treated water is used so that both treated and untreated water are available.

Other: No special controls are required on most systems since they operate by the use of pressure-sensitive switches, check valves, or flexible bladders. Shut-off valves are important to conserve water during low use periods. Monitoring gauges or servicing lights are becoming increasingly common and assist greatly in knowing whether the system is or isn't working.

Cost of an RO System

When deciding on a water treatment system, be sure to investigate all options and all costs. To compare purchase to lease or rent options, consider the following:

Initial costs of the system: Be sure that all parts are included, especially when comparisons are being made. RO units range in cost from $300 to $3000 and vary in quality and effectiveness. Replacement membranes cost $100 to $200 and filter cartridges around $50.

Installation costs: These costs are generally the responsibility of the purchaser, but who pays installation fees when renting or leasing? Is there enough space to accommodate the system being considered or will some modifications of space be needed?

Operating and maintenance costs: Electricity to pump the water is the only significant operating cost. Filter cleaning and/or replacement (both pre- and post-filters) and RO membrane replacement need to be estimated. Whether routine maintenance can be done by the owner or requires special service is important information when purchasing a system. When renting or leasing, how and when servicing is to be done and who pays for the supplies and service needs to be clearly stated. For example, is the service done on a schedule or an as needed basis?

Summary

Reverse osmosis is a proven technology that has been used successfully on a commercial basis. Household RO units typically deliver small amounts (2 to 10 gallons per day) of treated water and waste 3 to 20 times the amount of water treated.

Reverse osmosis units remove many inorganic contaminants from household drinking water supplies. The removal effectiveness depends on the contaminant and its concentration, the membrane selected, the water

pressure, and proper installation. RO units require regular maintenance and monitoring to perform satisfactorily over an extended period of time.

Before purchasing an RO unit or any other water treatment equipment, test your water to be certain that treatment is needed and that the equipment being selected is appropriate to the problem requiring treatment.

Consider all costs when comparing competitive systems and when making purchase or rental decisions.

Further Information

Contact your local county Extension Office or state health department. Additional information is available in other publications in the *Treatment Systems for Household Water Supplies* fact sheet series:

FS 877A Activated Carbon Filtration
FS 877C Chlorination
FS 877D Distillation
FS 877IM Iron and ManganeseRemoval
FS 877S Softening
FS 877P Identifying and Correcting Water Problems

References

MF-884 *Reverse Osmosis.* Cooperative Extension Service, Kansas State University, Manhattan, Kan.

Fact Sheet 4 *Water Treatment Notes: Reverse Osmosis Treatment of Drinking Water.* Cornell Cooperative Extension, New York State College of Human Ecology.

Vol. 9, No. 2, *Water Review: Residential Reverse Osmosis.* 1991. Water Quality Research Council.

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FS 877D

Treatment Systems for Household Water Supplies

Distillation

by Russell Derickson, SDSU Extension associate in water & natural resources; Bruce Seelig, NDSU water quality specialist, North Dakota Extension Service; and Fred Bergsrud, UM Extension agricultural engineer and water quality coordinator, Minnesota Extension Service

What Impurities Will Distillers Remove?

Distillation removes about 99.5% of impurities from water. Distillers commonly are used for removing nitrate, bacteria, sodium, hardness (dissolved solids), most organic compounds, heavy metals, and radionucleides from water.

What Impurities Will Distillers Not Remove?

Distillers can allow 0.3% to 0.5% of water impurities to exist in the storage container after distilling.

Some volatile organic contaminants (VOCs)(certain pesticides and volatile solvents) boil at temperatures very close to water (207-218°F.) so these types of contaminants will not be substantially reduced in concentration. Properly equipped distillers can reduce VOC concentrations effectively. Bacteria can accumulate in a distiller's cooling coils when it has been inactive.

Water Testing

Before you buy any water treatment unit, find out the types and amounts of impurities in your water supply. Have the water tested/analyzed by a certified lab. The results of the water test will help determine the best water treatment system to use.

If you obtain water from a private water supply (you supply your own water), you are responsible for water testing. Test on a regular basis. If a problem is suspected, test the water more often.

Community water supplies are monitored and treated to protect users from health-threatening water impurities. Ask your water supplier for a copy of the latest water test results.

The Distillation Process

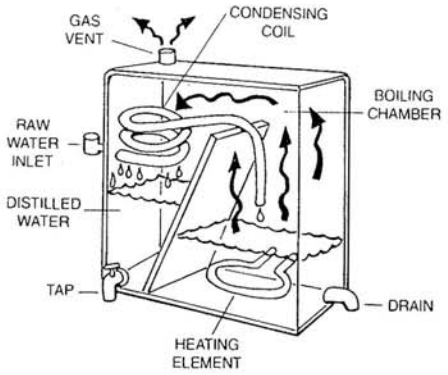
Distillers use heat to boil water into steam which is condensed back into water and collected in a purer form. When water boils, it leaves impurities behind in the boiling chamber. The rising steam passes into a cooling section and condenses back into a liquid. The condensed liquid (water) then flows into a storage container (Figure 1).

Distillers remove almost all of the impurities from water supplies used for drinking purposes in the Dakotas and Minnesota. As water is heated, the impurities in the boiling chamber increase in concentration. The water left behind in the boiling chamber is discarded and the process is started over.

Distilled water has a bland taste because the dissolved minerals that give water a pleasing taste have been removed. Store distilled water under sanitary conditions in plastic, glass, or stainless steel containers.

Household distillers are designed to provide water for drinking and cooking. It is not necessary to distill water for other uses like flushing toilets, bathing, washing clothes, and cleaning.

Figure 1. Distillers boil water into steam and condense it back into purer water.



Types of Distillation Equipment

Distillers commonly are made of stainless steel, aluminum, and plastic. These materials do not absorb impurities from water and they are easy to clean.

There are two types of distillers: batch units and continuous flow units (Figures 2 and 3).

Batch Distillers: Water is poured directly into the boiling chamber. The unit is turned on and the water is heated to boiling. When all the water in the boiling chamber is evaporated, the unit shuts off. Distilled water is removed from the storage container for household use.

Batch units can range from 1 gallon, counter-top units to 10 gallon, floor units. Batch distillers produce from 3 to 10 gallons of distilled water per day. The smallest distillers are about the same size as a coffee maker.

Continuous flow units: This is an automatic units connected to the water supply line. The water level in the boiling chamber is maintained by a float valve connected to the water supply. As distilled water is removed from the storage tank, the unit turns itself on and starts to produce more distilled water. A discharge line periodically removes the concentrated impurities from the boiling chamber. Distilled water is either stored in a container or is piped to the use area.

Distiller accessories: Additional storage containers, transfer pumps and special kitchen taps can be installed adjacent to a distiller. Increased storage capacity only will be an advantage for continuous flow units.

Figure 2. Batch distiller.

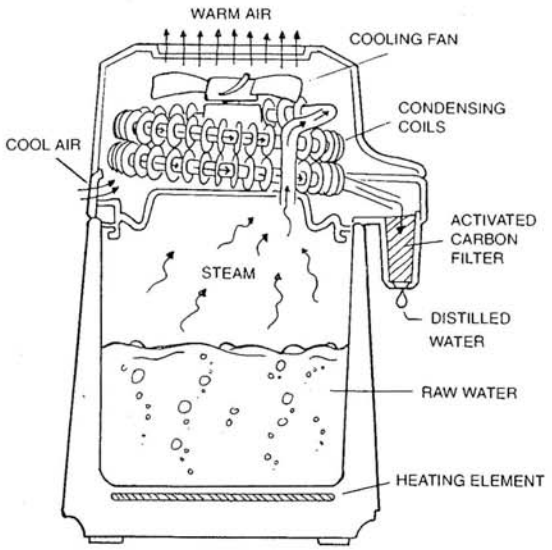


Figure 3. Continuous-flow distiller.

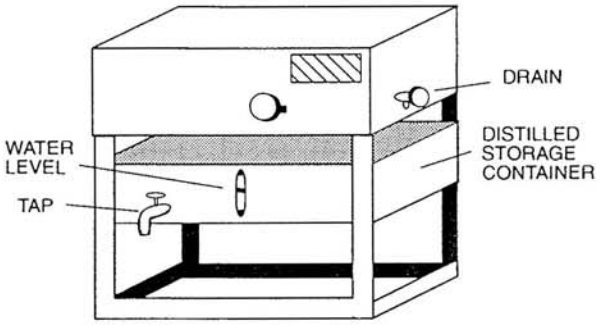
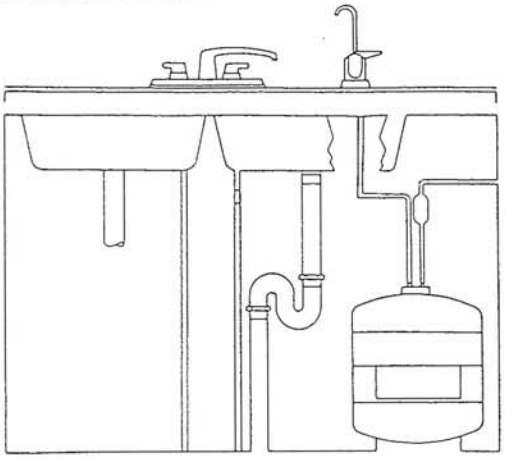


Figure 4. Under-the-sink distiller.

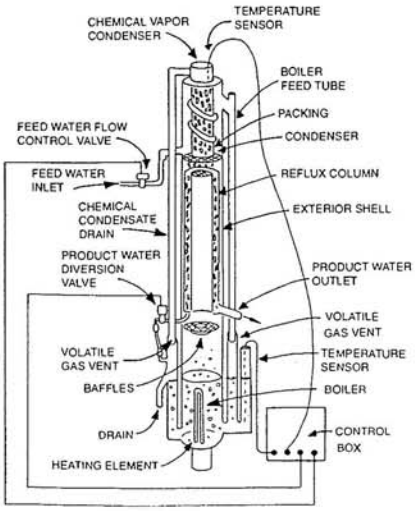


For example, you can install an under-the-sink reserve tank that has a level switch to turn on a small transfer pump (Figure 4). This pump transfers water from the distiller to a storage container located under the sink. When the under-the-sink reserve tank empties, it turns on the transfer pump to refill the reserve tank. When the distiller's storage tank empties, it turns itself on and fills the storage containers. Capacity is increased by increasing the total amount of distilled water available to the user.

How are Volatile Organic Compounds (VOC) removed?

Distillers can remove VOCs by three methods: gas vents; fractional columns; and activated carbon filters (ACF). Distillers that use a combination of VOC removal methods are more efficient than a single method.

Figure 5. Fractional column distiller.



Gas vents are small holes drilled into the passage leading to the cooling coils. Gas vents allow VOCs to escape the distiller before they enter the cooling section coils. These holes (one or two) are usually from .045 inches to .065 inches in diameter.

Fractional column distillers use differential cooling to remove VOCs (Figure 5). VOCs are removed when they condense in a different section of the fractional column than where water does. Fractional distillers usually cost more than distillers with gas vents or ACF cartridges.

Activated carbon filters (ACF) trap VOCs in millions of small pores. ACFs need periodic replacement. The life span of an ACF depends on the concentration of VOCs in the water. The ACF units normally are located at the end of the cooling coils and remove the VOCs prior to entering the distilled water storage container. ACF's also can be placed in the water supply line to reduce VOC's entering a distiller.

Removal of VOCs in distillers without gas vents, fractional columns, or ACF's also can be accomplished with some success by discarding the first pint (liter) of distilled water in the storage container.

Proper Distiller Maintenance

Minerals and other residues accumulate in the distiller's boiling chamber as water is boiled away. These minerals and compounds need to be removed occasionally. Empty the boiling chamber about once a week. If used constantly, empty the boiling chamber more often. If scale and sediment are not removed periodically, a distiller becomes inefficient. Mineral scale buildup from hard water can be difficult to remove without the use of an acid-type cleaner.

Commercial cleaning agents are available to remove the scale buildup in distillers. The cleaners usually contain sulfamic acid or other organic acids. DO NOT use strong mineral acids like hydrochloric, sulfuric, nitric, etc. to clean distillers. These strong mineral acids tarnish and can damage stainless steel and aluminum. Check the owners manual or consult your local distiller dealer for the appropriate cleaner to use.

To remove the scale buildup from a distiller, mix an acid cleaner to the correct concentration as indicated by the cleaner's label. Fill the distiller with the acid mix to approximately 1/2 inch above the mineral line. Let the organic acid solution sit for the indicated labeled time.

An alternative cleaning agent is vinegar because it contains acetic acid, a weak organic acid. Pour a 50% solution of vinegar into the distiller to about 1/2 inch above the top of the mineral line, and let the unit sit over night. Empty the distiller and rinse with water. If mineral scale is still present, increase the vinegar concentration and/or cleaning time.

Replace the ACF cartridge (if equipped) as needed, or make sure the gas vent holes are free of mineral deposits.

Routine maintenance and cleaning will increase the lifespan of a distiller.

The lifespan of any distiller depends on the levels of impurities in the raw water supply, how often the distillers operates, and how often the distiller is cleaned. A good distiller should last 10 to 15 years with proper maintenance and routine cleaning. The most common repair for distillers is replacing a heating element or a cooling fan.

Cost of Distillation Equipment

Distillers cost from $200 to 1500 for home use models. Counter top distillers will range from $200 to $500 and automatic models from $600 to $1500.

Examples of purchase cost:
For under $200, you can purchase a 5-quart batch unit (about the same size as a coffee maker). Five quarts of raw water are poured into the boiling chamber, the unit is plugged in, and distillation begins. Distilled water is stored in an external plastic container. The unit shuts

off automatically when the boiling chamber is empty. It has a 4-gallon per day maximum output.

For about $1200, you can purchase a 10-gallon per day continuous flow unit with a 4-gallon storage container. When water is removed from the storage container, the unit refills the boiling chamber and begins distilling. The unit shuts off when the storage container is filled. Typical dimensions of this system are about 3 feet high x 2 feet wide x 1.5 feet deep.

Operation Costs

In addition to the purchase cost of the distiller, there are yearly operating costs. These include electricity, chemical cleaners, and replacement ACF units (if equipped).

Yearly operation costs depend on how often a distiller is used. Distiller operation costs are directly related to the amount of distilled water you will use daily.

The largest operation cost is electricity. Small batch distillers range from .25 to .30 gallons per Kilowatt-hour (gal/KWH) and larger automatic continuous flow distillers range from .30 to .34 (gal/KWH). The electrical cost is easy to calculate:

$$\text{Cost} = 0.024 \times \frac{\text{Wattage of unit}}{\text{Production (gal/day)}} \times \text{cost of electricity (\$/KWH)}$$

or

$$\text{Cost} = \frac{\text{Wattage of unit}}{1000} \times \text{time to distill 1 gal (hrs)} \times \text{Cost of electricity (\$/KWH)}$$

For example, a 1100 watt distiller produces 8 gal/day (3hr/gal) and electricity costs $0.10/KWH

$$\text{Cost} = 0.024 \times \frac{1100}{8} \times 0.10 = \$0.33/\text{gal or (33 cents/gal)}$$

-or-

$$\text{cost} = \frac{1100}{1000} \times 3 \times 0.10 = \$0.33/\text{gal}$$

Typical electrical cost for a family of four will range from $275 to $400 per year (or $22 to $34 per month) because the average family of four uses 3 gal/day (1100 gal/year) of water for drinking and cooking.

Consult the owners manual or check with a dealer for the cost of a ACF cartridge replacement for a particular distiller.

Cleaning cost increases with increased distiller operation.

Total Cost Over the Life Span of a Distiller

Total cost of running a distiller includes the purchase price (or rental cost/year), cost of operation (electricity & ACF (if used)) and maintenance cost. Typical operational costs range from $0.35 per gal to $0.50 per gallon. Bottled distilled water, in comparison, costs from $0.30 to $1.50.

Based on the example below, it will cost an average family of four $38.60 per month for distilled water or $456.50 per year.

Example of total cost of distilled water per gallon:
For $800, you could purchase a 1100-watt distiller that would last 10 years at full production of 8 gal/day. Electricity costs $0.10/KWH. How much will a gallon of distilled water cost?

Cost assumptions --
- electricity = $0.10 / KWH
- repairs & cleaning = 10% of purchase price/year; 10-year life span
- 1100-watt unit produces 8 gal/day; purchase price = $800

Total cost per gallon over ten years --
- purchase price, $800/8 (gal/day)/365 (days/year) /10 years(based on continuous operation) = $0.027/gal
- electricity, 1100wt/1000 (wt/KWH) x 3 (hr/gal) x $0.10KWH = $0.33 /gal
- repairs and cleaning, $800 x 0.10/8 (gal/day)/365 (days/year); annual cost = 10% of purchase price) = $0.027/gal

TOTAL $0.384/gal (38.4 cents/gal)

A typical distiller might realistically only run 60 to 70 percent of the time. The above total cost per gallon was figured at full production. If the distiller ran 70% of the time, the cost per gallon would increase by $0.0314 per gallon for a total of $0.415/gal. Distiller idle time varies with how much distilled water is needed by the user. Based on the example above, it will cost a typical family of $38.60 per month ($456.50 per year) for distilled water.

Advantages of Distillers

Distillers remove almost all of the impurities found in water, produce sodium free water if needed for health reasons, and are relatively easy to maintain. Most distillers are mechanically simple.

Disadvantages of Distillers

Distillers have small capacities and use considerable energy to process water. Because of their small capacities, distillers are limited to point-of-use systems. Distillers without gas vents, fractional columns, or ACF units may not remove compounds (volatile liquids) that have boiling temperatures close to water. Heat generated by a distiller must be dissipated into the surrounding environment.

Considerations When Purchasing a Distiller

- Test your water for impurities. A distiller might not be the best treatment alternative.
- How much distilled water does your household need? (per day, per year)
- What type of distillers will fit into your needs?
- How easy is the distiller to clean and/or repair?
- What convenience level should a distiller offer (manual or automatic operation)?
- What will you do with the by-products of distillers - waste water, wasteheat, old ACF cartridges?
- Is it designed to remove VOCs? Distillers should be operated with activated carbon filters if volatile organic compounds are present.
- What is the cost of replacement parts and ACF cartridges (if equipped).
- Investigate equipment before purchasing or renting. Don't rush a purchase.
- Purchase price does not directly indicate a distiller's performance. A moderately priced unit might work as well as expensive units. Consider convenience along with performance.
- Don't buy more equipment than you need.
- Choose a reputable dealer. Get guarantees in writing and read them thoroughly.
- Beware of advertising that is too good to be true.
- Equipment should carry UL and NSF or AWQA approval.

For Further Information

Contact your county Extension office or the state health department. Additional information can be found in other fact sheets in the *Treatment Systems for Household Water Supplies* series:

FS 877A Activated Carbon Filtration
FS 877C Chlorination
FS 887IM Iron and Manganese Removal
FS 877RO Reverse Osmosis
FS 877S Softening
FS 877P Identifying and Correcting Water Problems

References

MWPS-14 *Private Water Systems.* Midwest Plan Service.

HE-430 *Household Water Treatment.* NDSU Extension Service.

FS-5 *Drinking Water: Treatment Guidelines.* University of Maryland Extension Service.

Water Treatment Handbook. Rodale Testing. Emmaus, Pa.

9.729 *Drinking Water Treatment Devices: Distillers.* Colorado State University Extension Service.

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FS 877C

Treatment Systems for Household Water Supplies

Chlorination

by Fred Bergsrud, UM Extension agricultural engineer and water quality coordinator, Minnesota Extension Service;
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Water Impurities Removed by Chlorination

Chlorination is a water treatment that destroys disease-causing bacteria, nuisance bacteria, parasites, and other organisms. Chlorination also removes soluble iron, manganese, and hydrogen sulfide from water.

Disease-causing bacteria can infect humans and animals in several ways. Fecal waste from an infected host frequently carries organisms which cause diseases such as typhoid fever, paratyphoid fever, bacillary dysentary, infectious hepatitis, and others. Disease-causing organisms are transmitted from host to host in many ways including through a contaminated water supply. Human and/or livestock populations concentrated together with improperly located or constructed wells may result in contamination of water supplies by sewage or fecal wastes.

There is no substitute for a safe and sanitary water supply. If your water supply becomes contaminated, elimination of the source of contamination is the most permanent solution. Continuous chlorination to kill disease-causing bacteria in a contaminated water source should be a temporary measure used only until you can develop a new, sanitary water supply.

How to Test Your Water

Most water testing for chlorination purposes is done to detect the presence of coliform bacteria. Coliform bacteria testing is used as an indicator of the possible presence of disease-causing bacteria. Tests for the presence of coliform bacteria may be made by the most probable number (MPN) method or the membrane filter (MF) method. If no coliform bacteria are detected in a test, the MPN will be reported as **less than 2.2** and the MF as **zero**. If any bacteria are present, the number will be stated.

If coliform bacteria are present, thoroughly shock chlorinate your water supply and system. After chlorinating, wait 2 to 7 days after all chlorine has been removed from the system, and then collect a sample for retesting. If this retest does not detect the presence of coliform bacteria, it is likely that the bacteria are not entering on a continuous basis. However, some authorities suggest that at least 3 consecutive tests spaced 3 to 6 months apart should report no bacteria presence before you resume normal testing intervals. If repeated tests show the presence of bacteria, you may have a continuous source of contamination.

Detergents, nitrates, and coliform bacteria are all indicators of well contamination. None of these indicators are necessarily harmful, but they do suggest that disease may occur if conditions are favorable. If a test indicates that your water is contaminated, locate the source of pollution, and eliminate it from your water supply.

Advantages of Chlorination

Controls disease-causing bacteria: Disease-causing bacteria may enter your well during construction, repair, flooding, or as a result of improper construction. Proper chlorination will kill these bacteria. If disease-causing bacteria enter your water supply on a continuous basis, you must eliminate the source or construct a new water supply.

Controls nuisance organisms: Chlorine treatment will control nuisance organisms such as iron, slime, and sulfate-reducing bacteria. Iron bacteria feed on the iron in the water. They may appear as a slimy, dark-red mass in the toilet tank, but microscopic examination is needed to confirm their presence. Iron bacteria colonies may break loose from the inside of pipes and flow through faucets to cause stains in laundry, plumbing

fixtures, etc. A thorough shock chlorination of the well and water system may destroy all iron bacteria colonies. However, iron bacteria that have penetrated the water-bearing formation will be difficult to eliminate and will likely re-infest the system. In this situation, you will need to repeat chlorination treatment periodically.

Other nuisance organisms include slime bacteria and sulfate-reducing bacteria which produce a rotten-egg odor. Chlorination will kill or control these bacteria. Nuisance bacteria **do not** cause disease.

Mineral removal: You can remove large amounts of iron from water by adding chlorine to oxidize the clear soluble iron into the filterable, reddish, insoluble form. Chlorine helps remove manganese and hydrogen sulfide in the same way. For a complete discussion of iron and manganese removal, see South Dakota Extension Service publication, FS 877IM *Treatment Systems for Household Water Supplies: Iron and Manganese Removal.*

Disadvantages of Chlorination

No nitrate removal: The claims of some water treatment firms imply that nitrates can be removed by chlorination. This is not true. Adding chlorine may prevent nitrates from being reduced to the toxic nitrite form; however, **nitrates are not removed from water by chlorination.**

Causes smell and bad taste: Chlorine in water is not poisonous to humans or animals. However, if the concentration is great enough, the water will taste bad so consumption may be reduced.

Some people object to the smell and/or taste of even very small amounts of chlorine. In those cases an activated carbon or charcoal filter may be used to remove the chlorine from the drinking water.

Trihalomethanes (THMs) are organic chemicals that may form when chlorine is used to treat water supplies that contain humic compounds. Humic compounds form as a part of the decomposition of organic materials such as leaves, grass, wood, or animal wastes. Because THMs are very seldom associated with groundwater, they are primarily a concern where surface water supplies are used.

Lifetime consumption of water supplies with THMs at a level greater than 0.10 milligrams per liter is considered by the Environmental Protection Agency to be a potential cause of cancer. THMs can be removed from drinking water through use of an activated carbon filter.

The Chlorination Process

To chlorinate a water supply properly, it is necessary to understand chlorine demand, free available chlorine residual, and contact time.

Chlorine demand is the amount of chlorine required to kill bacteria, oxidize iron or other elements in the water, and oxidize any organic matter that may be present. There is no easy way to determine the amount of chlorine required -- chlorine is added until the chlorine odor persists.

Free available chlorine residual is the amount of chlorine remaining in the water after the chlorine demand has been met. If the chlorine demand is greater than the amount of chlorine introduced, there will be no free available chlorine residual. Unless a chlorine residual is present, adequate amounts of chlorine have not been added to the water.

You can determine free available chlorine residual by using a test kit which sells for $15 to $50. Swimming pool owners use these kits to test the chlorine level of their pool water. Kits are available from local plumbing or water supply equipment dealers.

Contact time is the amount of time that the chlorine is present in the water. The combination of chlorine residual and contact time determines the effectiveness of the chlorination treatment. The bacterial "kill factor" is defined as the product of free available chlorine residual and contact time. Thus, the greater the chlorine residual, the shorter the required contact time for bacterial kill.

Do not use either shock or continuous chlorination as a substitute for a safe water supply. Locate and construct wells in accordance with existing state well codes and accepted sanitary standards. The water system also must be constructed properly to prevent bacterial contamination between the well and the point of use.

Chlorination Methods

There are two methods for chlorinating water. **Shock chlorination**, required for new wells or after well repairs (your well driller or repair person should perform this

chlorination), is recommended to treat non-recurring bacterial contamination. **Continuous chlorination** is used to treat recurring bacterial contamination problems. This process is similar to that used in municipal water supplies as a preventive measure.

Shock chlorination procedures

For shock chlorination, an initial chlorine concentration of 50 to 100 parts per million (ppm) with a contact time of at least 6 hours is recommended. To obtain a concentration of 100 ppm, you need to know (or estimate) the diameter of your well and the depth of water in the well.

Note: Do not use the total depth of the well. The depth of water is the distance from the water surface to the bottom of the well. Your well driller may have this information or you can determine it yourself by lowering a weighted string to the bottom of the well.

Table 1 shows the amounts of chlorine bleach to add for an initial concentration of about 100 ppm.

Any type of laundry bleach containing 5.25% hypochlorite solution will work. Because bleach is corrosive to metals, dilute it in the ratio of 12 parts of water to 1 part bleach prior to adding to the well water. These corrosive properties also mean that you take care to avoid contact with skin and especially eyes. Rubber gloves and goggles are recommended when handling chlorine solutions. If you are exposed, flush repeatedly with clean water. Do this immediately after exposure.

To properly shock chlorinate your well, follow these steps:

Step 1. Determine the amount of bleach and dilution water to use (Table 1). For example, if you have a 4-inch diameter well with 40 feet of water, Table 1 recommends using 1/4 quart of bleach. To dilute, use 3 quarts of water (12 times 1/4 quart).

Step 2. Remove the cap from your well. There are many types of well caps. If you have questions or need instructions to remove the cap, contact your well driller.

Step 3. Pour the mixture of chlorine and water down the well. Try to coat the casing (sides of the well) as you pour. To get good distribution in the well, attach a hose to a nearby hydrant or faucet and put the discharge end of the hose in the well. Then start the pump to recirculate chlorinated water back into the well. The recirculating water should have a strong odor of chlorine if the chlorine demand has been met.

Table 1. Chlorine bleach additive quantities.

Well Diameter (inches)	Depth of Water in Well (feet) less than 50	100	150	200
	Quarts of Laundry Bleach (5.25%)			
2	1/4	1/4	1/4	1/4
4	1/4	1/2	3/4	1
6	1/2	1	1.5	2
8	1	2	2	3
10	1.5	3	3	3
12	2	3	4	4

Step 4. Run water through the service lines in the house until you detect the odor of chlorine at each tap. Make sure you run the chlorinated water through every line in the system. You also may want to flush toilets.

Note: If you have an activated carbon filter in the system, temporarily remove the cartridge or bypass the filter completely.

Step 5. Let the chlorinated water stand in the system for at least 6 hours, preferably 8 to 12 hours.

Step 6. Flush out the system beginning with the well. Use a hose connected to an outside hydrant, and discharge the water to an appropriate waste system.

Note: Do not discharge this large volume of chlorinated water into a septic system or onto delicate plants or lawns.

After water from the well is free from chlorine odor, flush the rest of the piping system. Draining this volume of water into your septic system should be acceptable.

Single-pipe, packer jet water systems

If your well has a single-pipe, packer jet water system, you can disinfect it thoroughly only by removing the drop pipe from the well. Add the chlorine solution into the jet pump by disconnecting the tube at the air charging device and placing it in the chlorine solution (Figure 1). The solution will be drawn through the pump, the jet fittings, the upper portion of the well, the drop pipe, and the distribution system.

Because there is a foot valve at the bottom of the drop pipe, very little, if any, chlorine solution can enter the well below the packer leathers (Figure 2). Therefore, you must pull the drop pipe to disinfect the well

thoroughly. With a packer jet water pump, chlorinate the water system before you remove the jet fitting from the well.

If your hot water smells worse than the cold, you may want to add a small amount of bleach directly to the hot water heater or drain the hot water heater before chlorinating. Turn off the hot water heater first -- chlorine is not as effective in hot water, and always turn off the heater before draining the tank.

Depending on the age and condition of your well, you may want to shock chlorinate the well up to 10 times before abandoning the well. If you must use the present contaminated water supply until the new supply can be developed, be sure to follow a process of continuous chlorination.

Figure 1. Tube from air-charging device is used to introduce chlorine solution into water system. (Note: This process does not adequately disinfect the well.)

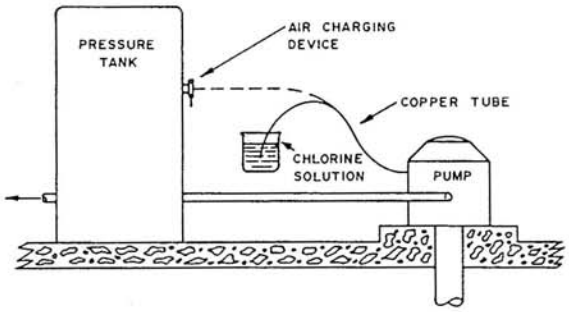
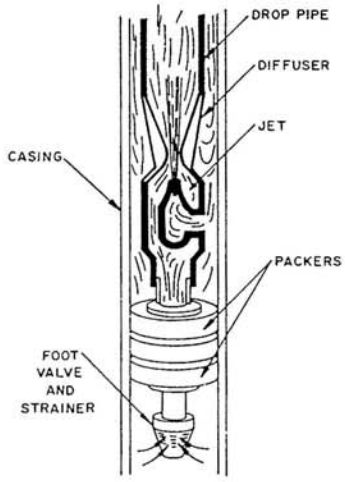


Figure 2. Packer type jet used for small wells (2-4 inch).



Continuous chlorination procedures

Continuous chlorination is a necessity for surface water supplies such as ponds, springs, lakes or cisterns, and groundwater sources which are contaminated with bacteria.

You can use chemical feed pumps to inject chlorine into your system. Wire the feed pump to the water pump pressure switch so that the pumps operate simultaneously. Other proportioning devices are available to feed chemicals into the water. If you are chlorinating to control disease-causing bacteria, you will need an alarm device that indicates when the chlorine solution supply needs replenishing.

Because effective organism kill is a function of contact time, inject the chlorine solution into the water as close to the source as possible. Adequate contact time for disease-causing bacterial kill depends on free chlorine residual, water temperature, water pH (acidity), and the specific organism. Continuous chlorination typically uses a chlorine residual of 3 to 5 ppm. This level is considerably higher than that of municipalities (0.2 to 0.5 ppm) where the large distribution system provides a long contact time. This level of residual chlorine may cause a taste and/or odor that is objectionable.

At the 3 to 5 ppm level, adequate contact time for surface water supplies is in the range of 2 to 7 minutes to develop the proper bacterial kill factor. For well water, a contact time of 2 to 3 minutes is normally sufficient. In any case, where disease-causing bacteria are involved, conduct tests after installation and continue on a regular basis to insure a safe water supply.

Research has shown that there is no dependable contact time calculation to test the pressure tank of the water system. The piping in home water systems usually provides little contact time. The time between the pump and the nearest faucet is usually one minute or less.

A coil of plastic pipe can be used to increase contact time. The length of pipe required depends on the pipe diameter and the flow rate. For example, to achieve a 4-minute contact time with a 10 gallon per minute flow rate, you would need 128 feet of 3 inch nominal diameter pipe or 480 feet of 1.5 inch nominal diameter pipe. Your pipe supplier should be able to assist you in selecting the proper size and length for your required contact time and flow rate.

Continuous chlorination is expensive and requires frequent and intelligent management. Do not consider it for disease-causing bacteria control until other alternatives have been explored fully.

Summary

Shock chlorination and/or continuous chlorination are useful and effective methods to destroy disease-causing bacteria and other nuisance organisms in water supplies. Chlorination is not a substitute for a safe pure water supply and should be used only when other options have been investigated thoroughly.

Further Information

Contact your local county Extension Office or state health department. Additional information is available in other fact sheets in the *Treatment Systems for Household Water Supplies* series:

FS 877A Activated Carbon Filtration
FS 877C Chlorination
FS 877D Distillation
FS 877IM Iron and Manganese Removal
FS 877RO Reverse Osmosis
FS 877S Softening
FS 877P Identifying and Correcting Water Problems

References

MWPS-14. Private Water Systems Handbook. Midwest Plan Service.

AG-FO-1319. Chlorination of Private Water Supplies, University of Minnesota Agricultural Extension Service.

NRAES-47. Private Drinking Water Supplies: Quality, Testing, and Options for Problem Waters, Northeast Regional Agricultural Engineering Service, Cooperative Extension.

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Nitrates in South Dakota Drinking Water

By
F. F. Kerr, Water Resources Specialist, Cooperative Extension Service, South Dakota State University, and **John Hatch,** Chief, Water Sanitation Section, Division of Sanitary Engineering, South Dakota Department of Health, Pierre.

South Dakota citizens are becoming increasingly aware of and concerned with nitrate in household drinking water. Also, concern is expressed about the danger to livestock from the use of high nitrate water. *This publication deals with the nitrate problem as it pertains to drinking water used for human consumption.* A companion publication, Fact Sheet Number 603 "Nitrates in Livestock Waters," deals with nitrates in livestock water.

Laboratories frequently report the nitrate content of water in various expressions of measurement. Since this is often confusing, this publication attempts to define and equate these measurement expressions. The scope and sources of the nitrate problem are discussed and toxicity levels given. Proper sample taking techniques are explained and control actions recommended.

Laboratory Expressions Clarified

The *presence* of nitrates in water is usually expressed in two ways: nitrate-nitrogen (NO_3-N) or nitrate (NO_3).

The *quantity* present may be expressed in either parts per million (p.p.m.) or in milligrams per liter (mg/l).

The conversion numbers for these expressions are:

1. **To change nitrate-nitrogen (NO_3-N) to nitrate (NO_3), multiply by 4.43.**
2. **To change nitrates (NO_3) to nitrate-nitrogen (NO_3-N), multiply by 0.23.**
3. **Parts per million (p.p.m.) and milligrams per liter (mg/l) are both used when reporting laboratory results. For practical purposes 1 p.p.m.=1 mg/l. One p.p.m. may be expressed in terms of one pound per million pounds of water, one drop per million drops of water, or similar common measurements.**

The terms nitrite-nitrogen (NO_2-N) and nitrites (NO_2) are sometimes referred to in literature, but are seldom used in laboratory reports. Nitrites are much more harmful than nitrates, but only small amounts are ever found in the water itself. The changing of nitrates to nitrites in the digestive tract is what causes the health hazard and will be explained later. When using the conversion numbers above do not confuse nitrates with nitrites.

Maximum Limits

Before stating the permissable levels of nitrates in drinking water as recommended by the 1962 U. S. Public Health Service Drinking Water Standards, a brief discussion of how nitrates poison may be helpful.

Nitrates as such, are not very harmful; however, when they are acted on by microorganisms in the digestive tract, they tend to change from the nitrate form to the nitrite form and become much more toxic. They are toxic because after being absorbed into the blood they make the hemoglobin, or red oxygen-carrying blood pigment, incapable of carrying oxygen and symptoms of asphyxiation (lack of oxygen) appear. The change in the blood is described as a change from hemoglobin to methemoglobin. This term is the origin of the condition called methemoglobinemia, commonly referred to as "blue babies" when it occurs in infants.

The body blood does not give up the struggle easily, however, because the blood also contains an enzyme capable of changing the blood back to hemoglobin. However, infants seem to be less capable of making this reversal of the blood condition. Therefore there is a lower toxicity level for infants.

The Public Health

Nitrates above the level listed on the next page are considered to be of health significance; amounts above 10 p.p.m. as nitrate-nitrogen have caused methemoglobinemia which can cause death of an infant under 6 months of age. Nitrate levels above 115 p.p.m. nitrate-nitrogen have caused irritation of the mucous linings of the gastrointestinal tract and bladder, with symptoms of diarrhea and diuresis in adults. The values given above allow for a reasonable margin of safety.

Maximum Limits		
Persons affected	Expressed as Nitrate Nitrogen (NO_3-N)	Expressed as Nitrates (NO_3)
For infants under 6 months of age	10 p.p.m.	45 p.p.m.
For older children and adults	115 p.p.m.	500 p.p.m.

Scope of the Nitrate Problem

There were 1,949 private water samples from farms, ranches, and rural homes tested for nitrate-nitrogen during calendar year 1972 by the South Dakota Department of Health Laboratory. Of these samples, 259 (13.3%) contained nitrate-nitrogen above 10 p.p.m. and 34 (1.7%) contained nitrate-nitrogen above 115 p.p.m. All samples submitted for bacteriological analysis from private water supplies are tested for nitrate-nitrogen. All reports from the State Department of Health Laboratory are in terms of nitrate-nitrogen.

The table summarizing water supply samples from private sources illustrates the extent of the nitrate-nitrogen problem by counties.

Source of Nitrate Contamination

Nitrates occur in the soil, animal excreta, crop residues, human wastes, some industrial wastes and nitrogen fertilizers. All are possible sources of nitrate contamination of both surface and groundwaters. Nitrates are soluble and will move with water.

Groundwater is the dominant source of drinking water in South Dakota. Its protection from contamination is, therefore, very important. Protection of water supplies by proper construction and location of wells as shown on pages 11 through 13 in Extension Circular 671, "Safe Rural Water Supplies," is an important first step. Sealing of abandoned wells is also important, since the groundwater does move, although quite slowly in most cases.

Shallow wells are more likely to contain nitrates than deep wells, since they are more susceptible to the effects of leaching, especially in sandy or light soils. Having a deep well, however, is no guarantee against

Summary of water supply samples from private sources tested by the South Dakota Department of Health between January 1, 1971 and August 18, 1972 that were higher than 10 p.p.m. of nitrate-nitrogen.

	parts per million			
Counties	10-50	51-114	115-450	450+
Beadle	1	1		
Brookings	11	9	3	1
Brown	4	3	1	
Charles Mix	1			
Clay		1		
Clark	3	3		
Codington	24	8	8	
Corson	1			
Custer	3			
Davison			1	
Day	7	3	1	
Deuel	8	6		
Dewey	2			
Edmunds		1	1	
Fall River	1			
Grant	2	3	2	
Gregory	16	5		
Haakon		1		
Hamlin	8	1	2	
Hand		1		
Hanson	2	1	1	
Harding	2			
Hughes	3	3		1
Jerauld	3	1		
Kingsbury			2	
Lake			2	
Lincoln	3	2	1	
Marshall	3			
McPherson	6	2	1	1
Meade	2			
Mellette	2			
Minnehaha	8			
Moody	4		1	
Pennington	2			
Perkins			1	
Potter		2		
Roberts	4	1		
Spink	2			
Sully		1		
Tripp	4	3	1	
Union	4			
Walworth	4	1	2	
Yankton	1	1		
Totals	151	64	31	3

entrance of contamination from surface sources, if the well is not properly constructed. If a properly constructed deep well does contain nitrates, the source of contamination may be a considerable distance away and therefore difficult or impossible to locate.

Surface waters used for drinking purposes are also susceptible to nitrate contamination, although locating the source is usually easier since water and possible nitrate sources can be seen quite easily.

Some ponds are used as a drinking water source in South Dakota. Their location is very important. Page 19 of Extension Circular 671 discusses pond location.

Water Testing and Sample Taking

Water samples for nitrate-nitrogen analysis should be collected in special bacteriological sample bottles obtained from the State Department of Health Laboratory in Pierre. Special sampling procedures are not necessary for nitrate samples; however, when testing for nitrate, bacteriological testing should also be done. The two forms of contamination are somewhat related and are often found together, although it is not unusual to have bacteriologically *safe* water and water with nitrate-nitrogen above 10 p.p.m., or bacteriologically *unsafe* water with *no nitrate-nitrogen.*

A bacteriological water sample should be collected from a single, cold hard water faucet and the faucet flamed with a propane torch prior to sampling. The water should also be permitted to run for about 5 minutes to assure that a fresh sample of water from the well is being collected.

Nitrate levels have been known to fluctuate, depending upon local conditions. When nitrate-nitrogen levels are above the recommended limits, additional sampling should be conducted at 2-month intervals before changing water supplies. Additional sampling is especially important when nitrate-nitrogen levels are above 115 p.p.m. Drinking water should be obtained from another source during this test period.

Recommended Control Actions

The level of nitrate in a water supply can be reduced by certain ion exchange resins, electrodialysis or reverse osmosis processes. The higher cost of reducing the nitrates must be weighed against the availability of another source of water, cost of hauling and amount needed. *Filtering does not remove nitrates. Allowing the water to stand does not remove them. Boiling makes the situation even* worse since nitrates are not destroyed, part of the water passes off as steam and the net result is more p.p.m. of nitrates than before boiling.

While chlorination is highly effective in removing bacteriological contamination from water, it is not effective in removing nitrates. See Fact Sheet 603, "Nitrates in Livestock Water" for further discussion.

Other alternatives to reducing nitrate-nitrogen are:

1. Locate the source of contamination and try to remove it. Adequate sealing of the well or establishing good drainage away from the well may solve the problem in the case of groundwater. Effectiveness of this procedure will depend upon the amount of nitrate-nitrogen contamination present. Controlling drainage into ponds is usually effective.

2. If the source cannot be located or controlled, establishment of a new water source is recommended. Seeking groundwater from a deeper source is often effective. Be sure the new well is properly sealed and located.

If Analysis Shows High Nitrates

1. Do not panic.
2. Arrange for drinking water from another source while you investigate your situation.
3. Have additional samples analyzed as recommended here.
4. Try to locate the source or cause of contamination and remove it.
5. If high analysis persists, weigh the cost of nitrate removal against the cost of establishing a new source.
6. Take appropriate action.

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APPENDIX B

PIPE DATA AND FRICTION LOSS

Pipe Data Tables		B-3 – B21
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Pipe Type -- Size in.	O.D. Inch	I.D. Inch	Wall Thickness	Area Sq. FT	SDR GA.	Press PSI	MAN "n"	Kp	Pipe Length	Lay Length	MATL Type	ASTM No.	Weight LBS/FT	Fittings Cus/Std	Coupler O.D.	Press Rated
PVC (IPS) Iron Pipe Size																
0.5	0.840	0.716	0.062	0.003	13.5	315	0.009	0.64327	20+/40+	20/40	1120	D2241	0.096	SOLV		YES
0.75	1.050	0.930	0.060	0.005	21	200	0.009	0.45391	20+/40+	20/40	1120	D2241	0.118	SOLV		YES
0.75	1.050	0.926	0.062	0.005	17	250	0.009	0.45653	20+/40+	20/40	1120	D2241	0.122	SOLV		YES
0.75	1.050	0.894	0.078	0.004	13.5	315	0.009	0.47844	20+/40+	20/40	1120	D2241	0.15	SOLV		YES
1	1.315	1.195	0.060	0.008	26	160	0.009	0.32493	20+/40+	20/40	1120	D2241	0.149	SOLV		YES
1	1.315	1.189	0.063	0.008	21	200	0.009	0.32712	20+/40+	20/40	1120	D2241	0.159	SOLV		YES
1	1.315	1.161	0.077	0.007	17	250	0.009	0.33768	20+/40+	20/40	1120	D2241	0.189	SOLV		YES
1	1.315	1.121	0.097	0.007	13.5	315	0.009	0.35384	20+/40+	20/40	1120	D2241	0.235	SOLV		YES
1.25	1.660	1.532	0.064	0.013	26	160	0.009	0.23331	20+/40+	20/40	1120	D2241	0.203	SOLV		YES
1.25	1.660	1.502	0.079	0.012	21	200	0.009	0.23955	20+/40+	20/40	1120	D2241	0.248	SOLV		YES
1.25	1.660	1.464	0.098	0.012	17	250	0.009	0.24787	20+/40+	20/40	1120	D2241	0.304	SOLV		YES
1.25	1.660	1.414	0.123	0.011	13.5	315	0.009	0.25963	20+/40+	20/40	1120	D2241	0.373	SOLV		YES
1.5	1.900	1.754	0.073	0.017	26	160	0.009	0.19479	20+/40+	20/40	1120	D2241	0.264	BELL/SOLVE		YES
1.5	1.900	1.720	0.090	0.016	21	200	0.009	0.19994	20+/40+	20/40	1120	D2241	0.322	BELL/SOLVE		YES
1.5	1.900	1.676	0.112	0.015	17	250	0.009	0.20697	20+/40+	20/40	1120	D2241	0.397	BELL/SOLVE		YES
1.5	1.900	1.618	0.141	0.014	13.5	315	0.009	0.21692	20+/40+	20/40	1120	D2241	0.489	BELL/SOLVE		YES
2	2.375	2.229	0.073	0.027	32.5	125	0.009	0.14151	20+/40+	20/40	1120	D2241	0.331	BELL/SOLVE		YES
2	2.375	2.193	0.091	0.026	26	160	0.009	0.14462	20+/40+	20/40	1120	D2241	0.41	BELL/SOLVE		YES
2	2.375	2.149	0.113	0.025	21	200	0.009	0.14858	20+/40+	20/40	1120	D2241	0.508	BELL/SOLVE		YES
2	2.375	2.095	0.140	0.024	17	250	0.009	0.15371	20+/40+	20/40	1120	D2241	0.618	BELL/SOLVE		YES
2	2.375	2.023	0.176	0.022	13.5	315	0.009	0.16105	20+/40+	20/40	1120	D2241	0.767	BELL/SOLVE		YES
2.5	2.875	2.699	0.088	0.040	32.5	125	0.009	0.10965	20+/40+	20/40	1120	D2241	0.484	BELL/SOLVE		YES
2.5	2.875	2.655	0.110	0.038	26	160	0.009	0.11208	20+/40+	20/40	1120	D2241	0.604	BELL/SOLVE		YES
2.5	2.875	2.601	0.137	0.037	21	200	0.009	0.11519	20+/40+	20/40	1120	D2241	0.742	BELL/SOLVE		YES
2.5	2.875	2.537	0.169	0.035	17	250	0.009	0.11908	20+/40+	20/40	1120	D2241	0.905	BELL/SOLVE		YES
2.5	2.875	2.449	0.213	0.033	13.5	315	0.009	0.12482	20+/40+	20/40	1120	D2241	1.122	BELL/SOLVE		YES
3	3.500	3.284	0.108	0.059	32.5	125	0.009	0.08441	20+/40+	20/40	1120	D2241	0.723	BELL/SOLVE		YES
3	3.500	3.230	0.135	0.057	26	160	0.009	0.08630	20+/40+	20/40	1120	D2241	0.9	BELL/SOLVE		YES
3	3.500	3.166	0.167	0.055	21	200	0.009	0.08863	20+/40+	20/40	1120	D2241	1.103	BELL/SOLVE		YES
3	3.500	3.088	0.206	0.052	17	250	0.009	0.09163	20+/40+	20/40	1120	D2241	1.341	BELL/SOLVE		YES
3	3.500	2.982	0.259	0.049	13.5	315	0.009	0.09600	20+/40+	20/40	1120	D2241	1.656	BELL/SOLVE		YES
3.5	4.000	3.754	0.123	0.077	32.5	125	0.009	0.07062	20+/40+	20/40	1120	D2241	0.944	BELL/SOLVE		YES
3.5	4.000	3.692	0.154	0.074	26	160	0.009	0.07221	20+/40+	20/40	1120	D2241	1.173	BELL/SOLVE		YES
4	4.500	4.280	0.110	0.100	41	100	0.009	0.05930	20+/40+	20/40	1120	D2241	0.962	BELL/SOLVE		YES
4	4.500	4.224	0.138	0.097	32.5	125	0.009	0.06035	20+/40+	20/40	1120	D2241	1.192	BELL/SOLVE		YES
4	4.500	4.154	0.173	0.094	26	160	0.009	0.06171	20+/40+	20/40	1120	D2241	1.477	BELL/SOLVE		YES
4	4.500	4.072	0.214	0.090	21	200	0.009	0.06337	20+/40+	20/40	1120	D2241	1.822	BELL/SOLVE		YES

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Pipe Type -- Size in.	O.D. Inch	I.D. Inch	Wall Thickness	Area Sq. FT	SDR GA.	Press PSI	MAN "n"	Kp	Pipe Length	Lay Length	MATL Type	ASTM No.	Weight LBS/FT	Fittings Cus/Std	Coupler O.D.	Press Rated
PVC (IPS) Iron Pipe Size																
4	4.500	3.972	0.264	0.086	17	250	0.009	0.06550	20+/40+	20/40	1120	D2241	2.222	BELL/SOLVE	—	YES
4	4.500	3.834	0.333	0.080	13.5	315	0.009	0.06867	20+/40+	20/40	1120	D2241	2.746	BELL/SOLVE	—	YES
5	5.563	5.291	0.136	0.153	41	100	0.009	0.04469	20+/40+	20/40	1120	D2241	1.463	BELL/SOLVE	—	YES
5	5.563	5.133	0.215	0.144	26	160	0.009	0.04654	20+/40+	20/40	1120	D2241	2.277	BELL/SOLVE	—	YES
5	5.563	5.033	0.265	0.138	21	200	0.009	0.04777	20+/40+	20/40	1120	D2241	2.788	BELL/SOLVE	—	YES
6	6.625	6.301	0.162	0.217	41	100	0.009	0.03541	20+/40+	20/40	1120	D2241	2.084	BELL/SOLVE	—	YES
6	6.625	6.217	0.204	0.211	32.5	125	0.009	0.03604	20+/40+	20/40	1120	D2241	2.594	BELL/SOLVE	—	YES
6	6.625	6.115	0.255	0.204	26	160	0.009	0.03685	20+/40+	20/40	1120	D2241	3.215	BELL/SOLVE	—	YES
6	6.625	5.993	0.316	0.196	21	200	0.009	0.03785	20+/40+	20/40	1120	D2241	3.947	BELL/SOLVE	—	YES
6	6.625	5.845	0.390	0.186	17	250	0.009	0.03914	20+/40+	20/40	1120	D2241	4.816	BELL/SOLVE	—	YES
6	6.625	5.643	0.491	0.174	32.5	315	0.009	0.04101	20+/40+	20/40	1120	D2241	5.948	BELL/SOLVE	—	YES
8	8.625	8.205	0.210	0.367	41	100	0.009	0.02490	20+/40+	20/40	1120	D2241	3.519	BELL/SOLVE	—	YES
8	8.625	8.095	0.265	0.357	32.5	125	0.009	0.02535	20+/40+	20/40	1120	D2241	4.402	BELL/SOLVE	—	YES
8	8.625	7.961	0.332	0.346	26	160	0.009	0.02592	20+/40+	20/40	1120	D2241	5.465	BELL/SOLVE	—	YES
8	8.625	7.805	0.410	0.332	21	200	0.009	0.02661	20+/40+	20/40	1120	D2241	6.679	BELL/SOLVE	—	YES
10	10.750	9.924	0.413	0.537	32.5	125	0.009	0.01932	20+/40+	20/40	1120	D2241	8.473	SOLV	—	YES
10	10.750	9.728	0.511	0.516	21	160	0.009	0.01984	20+/40+	20/40	1120	D2241	10.378	SOLV	—	YES
12	12.750	12.128	0.311	0.802	41	100	0.009	0.01479	Check	Available	1120	D2241	7.918	Check Available	—	YES
12	12.750	11.966	0.392	0.781	32.5	125	0.009	0.01506	Check	Available	1120	D2241	9.912	Check Available	—	YES
12	12.750	11.770	0.490	0.756	26	160	0.009	0.01539	Check	Available	1120	D2241	12.286	Check Available	—	YES
PVC (IPS) Iron Pipe Size																
Large Dia. 14	14.000	13.318	0.341	0.967	41	100	0.009	0.01305	20' 8.5"	20	1120	D2241	9.960	BELL/SOLVE	16.240	YES
14	14.000	13.150	0.425	0.943	32.5	125	0.009	0.01328	20' 8.5"	20	1120	D2241	12.300	BELL/SOLVE	16.420	YES
14	14.000	13.924	0.538	0.911	26	160	0.009	0.01230	20' 8.5"	20	1120	D2241	15.450	BELL/SOLVE	16.640	YES
16	16.000	15.220	0.390	1.263	41	100	0.009	0.01092	20' 10.5"	20	1120	D2241	13.090	BELL/SOLVE	18.380	YES
16	16.000	15.030	0.485	1.232	32.5	125	0.009	0.01111	20' 10.5"	20	1120	D2241	16.180	BELL/SOLVE	18.580	YES
16	16.000	14.770	0.615	1.190	26	100	0.009	0.01137	20' 10.5"	20	1120	D2241	20.300	BELL/SOLVE	18.830	YES
18	18.000	17.122	0.439	1.599	41	100	0.009	0.00934	20' 11"	20	1120	D2241	16.750	BELL/SOLVE	20.480	YES
18	18.000	16.892	0.554	1.556	32.5	125	0.009	0.00951	20' 11"	20	1120	D2241	20.880	BELL/SOLVE	20.710	YES
18	18.000	16.614	0.693	1.505	26	160	0.009	0.00972	20' 11"	20	1120	D2241	25.880	BELL/SOLVE	21.000	YES
20	20.000	19.022	0.489	1.974	41	100	0.009	0.00811	21'	20	1120	D2241	20.720	BELL/SOLVE	22.930	YES
20	20.000	18.770	0.615	1.922	32.5	125	0.009	0.00826	21'	20	1120	D2241	25.950	BELL/SOLVE	23.180	YES
20	20.000	18.460	0.770	1.859	26	160	0.009	0.00845	21'	20	1120	D2241	32.330	BELL/SOLVE	23.490	YES
24	24.000	22.830	0.585	2.843	41	100	0.009	0.00636	21' 1.5"	20	1120	D2241	29.820	BELL/SOLVE	27.440	YES
24	24.000	22.520	0.740	2.766	32.5	125	0.009	0.00648	21' 1.5"	20	1120	D2241	37.540	BELL/SOLVE	27.750	YES
24	24.000	22.152	0.924	2.676	26	160	0.009	0.00662	21' 1.5"	20	1120	D2241	46.750	BELL/SOLVE	28.120	YES

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Pipe Type -- Size in.	O.D. Inch	I.D. Inch	Wall Thickness	Area Sq. FT	SDR GA.	Press PSI	MAN "n"	Kp	Pipe Length	Lay Length	MATL Type	ASTM No.	Weight LBS/FT	Fittings Cus/Std	Coupler O.D.	Press Rated
PVC (PIP) Plastic Irrigation																
Pipe 4	4.130	3.928	0.101	0.084	41	100	0.009	0.06648	+40	40	1120	D2241	0.833	BELL/SOLVE		YES
6	6.140	5.988	0.076	0.196	81	50	0.009	0.03789	+40	40	1120	D2241	0.957	BELL/SOLVE	7.318	YES
6	6.140	5.900	0.120	0.190	51	80	0.009	0.03865	+40	40	1120	D2241	1.492	BELL/SOLVE	7.318	YES
6	6.140	5.840	0.150	0.186	41	100	0.009	0.03918	+40	40	1120	D2241	1.853	BELL/SOLVE	7.318	YES
6	6.140	5.762	0.189	0.181	32.5	125	0.009	0.03989	+40	40	1120	D2241	2.230	BELL/SOLVE	7.318	YES
6	6.140	5.668	0.236	0.175	26	160	0.009	0.04077	+40	40	1120	D2241	2.783	BELL/SOLVE	7.318	YES
8	8.160	7.958	0.101	0.345	81	50	0.009	0.02593	+40	40	1120	D2241	1.691	BELL/SOLVE	9.647	YES
8	8.160	7.840	0.160	0.335	51	80	0.009	0.02646	+40	40	1120	D2241	2.645	BELL/SOLVE	9.647	YES
8	8.160	7.762	0.199	0.329	41	100	0.009	0.02681	+40	40	1120	D2241	3.269	BELL/SOLVE	9.647	YES
8	8.160	7.658	0.251	0.320	32.5	125	0.009	0.02730	+40	40	1120	D2241	3.936	BELL/SOLVE	9.647	YES
8	8.160	7.532	0.314	0.309	26	160	0.009	0.02791	+40	40	1120	D2241	4.923	BELL/SOLVE	9.647	YES
10	10.200	9.948	0.126	0.540	81	50	0.009	0.01926	+40	40	1120	D2241	2.637	BELL/SOLVE	11.828	YES
10	10.200	9.800	0.200	0.524	51	80	0.009	0.01965	+40	40	1120	D2241	4.132	BELL/SOLVE	11.828	YES
10	10.200	9.702	0.249	0.513	41	100	0.009	0.01991	+40	40	1120	D2241	5.109	BELL/SOLVE	11.828	YES
10	10.200	9.572	0.314	0.500	32.5	125	0.009	0.02027	+40	40	1120	D2241	6.350	BELL/SOLVE	11.828	YES
10	10.200	9.416	0.392	0.484	26	160	0.009	0.02072	+20	20	1120	D2241	7.584	BELL/SOLVE	11.828	YES
12	12.240	11.938	0.151	0.777	81	50	0.009	0.01510	+20	20	1120	D2241	3.851	BELL/SOLVE	13.954	YES
12	12.240	11.760	0.240	0.754	51	80	0.009	0.01541	+20	20	1120	D2241	6.009	BELL/SOLVE	13.954	YES
12	12.240	11.620	0.310	0.736	41	100	0.009	0.01566	+20	20	1120	D2241	7.420	BELL/SOLVE	13.954	YES
12	12.240	11.480	0.380	0.719	32.5	125	0.009	0.01591	+20	20	1120	D2241	9.148	BELL/SOLVE	13.954	YES
12	12.240	11.298	0.471	0.696	26	160	0.009	0.01625	+20	20	1120	D2241	11.008	BELL/SOLVE	13.954	YES
15	15.300	14.922	0.189	1.214	81	50	0.009	0.01122	+20	20	1120	D2241	6.060	BELL/SOLVE	17.212	YES
15	15.300	14.700	0.300	1.179	51	80	0.009	0.01144	+20	20	1120	D2241	9.423	BELL/SOLVE	17.212	YES
15	15.300	14.554	0.373	1.155	41	100	0.009	0.01160	+20	20	1120	D2241	11.605	BELL/SOLVE	17.212	YES
15	15.300	14.358	0.471	1.124	32.5	125	0.009	0.01181	+20	20	1120	D2241	14.287	BELL/SOLVE	17.212	YES
18	18.701	18.240	0.231	1.815	81	50	0.009	0.00858	21	20	1120	D2241	8.403	BELL	21.900	YES
18	18.701	17.969	0.366	1.761	51	80	0.009	0.00875	21	20	1120	D2241	13.305	BELL	21.900	YES
18	18.701	17.789	0.456	1.726	41	100	0.009	0.00887	21	20	1120	D2241	16.495	BELL	21.900	YES
18	18.701	17.551	0.575	1.680	32.5	125	0.009	0.00903	21	20	1120	D2241	20.664	BELL	21.900	YES
18	18.701	17.263	0.719	1.625	26	160	0.009	0.00924	21	20	1120	D2241	25.633	BELL	21.900	YES
21	22.047	21.500	0.272	2.521	81	50	0.009	0.00689	20.75	19.5	1120	D2241	15.074	BELL	25.810	YES
21	22.047	21.183	0.432	2.447	51	80	0.009	0.00703	20.75	19.5	1120	D2241	23.603	BELL	25.810	YES
21	22.047	20.971	0.538	2.399	41	100	0.009	0.00713	20.75	19.5	1120	D2241	29.250	BELL	25.810	YES
21	22.047	20.691	0.678	2.335	32.5	125	0.009	0.00725	20.75	19.5	1120	D2241	36.621	BELL	25.810	YES
21	22.047	20.351	0.848	2.259	26	160	0.009	0.00742	20.75	19.5	1120	D2241	45.439	BELL	25.810	YES
24	24.803	24.190	0.306	3.192	81	50	0.009	0.00589	20.75	19.5	1120	D2241	18.924	BELL	28.780	YES
24	24.803	23.831	0.486	3.098	51	80	0.009	0.00601	20.75	19.5	1120	D2241	29.872	BELL	28.780	YES
24	24.803	23.593	0.605	3.036	41	100	0.009	0.00609	20.75	19.5	1120	D2241	37.005	BELL	28.780	YES
24	24.803	23.277	0.763	2.955	32.5	125	0.009	0.00620	20.75	19.5	1120	D2241	46.364	BELL	28.780	YES
24	24.803	22.895	0.954	2.859	26	160	0.009	0.00634	20.75	19.5	1120	D2241	57.509	BELL	28.780	YES
27	27.953	26.857	0.548	3.934	51	80	0.009	0.00512	21	19.5	1120	D2241	37.960	BELL	32.220	YES
27	27.953	26.589	0.682	3.856	41	100	0.009	0.00519	21	19.5	1120	D2241	47.012	BELL	32.220	YES
27	27.953	26.233	0.860	3.753	32.5	125	0.009	0.00529	21	19.5	1120	D2241	58.895	BELL	32.220	YES
Page 3 27	27.953	25.803	1.075	3.631	26	160	0.009	0.00540	21	19.5	1120	D2241	73.034	BELL	32.220	YES

Pipe Type -- Size in.	O.D. Inch	I.D. Inch	Wall Thickness	Area Sq. FT	SDR GA.	Press PSI	MAN "n"	Kp	Pipe Length	Lay Length	MATL Type	ASTM No.	Weight LBS/FT	Fittings Cus/Std	Cost Price/Ft	Press Rated
PVC Schedule 40,80,120																
0.5	0.840	0.622	0.109	0.002	SCH 40	600	0.009	0.77605	20+/40+	20/40	1120	D1785	0.157	SOLV	$0.00	YES
0.5	0.840	0.546	0.147	0.002	SCH 80	850	0.009	0.92333	20+/40+	20/40	1120	D1785	0.200	SOLV	$0.00	YES
0.5	0.840	0.500	0.170	0.001	SCH 120	1010	0.009	1.03829	20+/40+	20/40	1120	D1785	0.226	SOLV	$0.00	YES
0.75	1.050	0.824	0.113	0.004	SCH 40	480	0.009	0.53339	20+/40+	20/40	1120	D1785	0.210	SOLV	$0.00	YES
0.75	1.050	0.742	0.154	0.003	SCH 80	690	0.009	0.61340	20+/40+	20/40	1120	D1785	0.270	SOLV	$0.00	YES
0.75	1.050	0.710	0.170	0.003	SCH 120	770	0.009	0.65053	20+/40+	20/40	1120	D1785	0.297	SOLV	$0.00	YES
1	1.315	1.049	0.133	0.006	SCH 40	450	0.009	0.38659	20+/40+	20/40	1120	D1785	0.311	SOLV	$0.00	YES
1	1.315	0.957	0.179	0.005	SCH 80	630	0.009	0.43692	20+/40+	20/40	1120	D1785	0.400	SOLV	$0.00	YES
1	1.315	0.915	0.200	0.005	SCH 120	720	0.009	0.46386	20+/40+	20/40	1120	D1785	0.442	SOLV	$0.00	YES
1.25	1.660	1.380	0.140	0.010	SCH 40	370	0.009	0.26819	20+/40+	20/40	1120	D1785	0.420	SOLV	$0.00	YES
1.25	1.660	1.278	0.191	0.009	SCH 80	520	0.009	0.29710	20+/40+	20/40	1120	D1785	0.552	SOLV	$0.00	YES
1.25	1.660	1.230	0.215	0.008	SCH 120	600	0.009	0.31266	20+/40+	20/40	1120	D1785	0.616	SOLV	$0.00	YES
1.5	1.900	1.610	0.145	0.014	SCH 40	330	0.009	0.21836	20+/40+	20/40	1120	D1785	0.504	SOLV	$0.00	YES
1.5	1.900	1.500	0.200	0.012	SCH 80	470	0.009	0.23997	20+/40+	20/40	1120	D1785	0.671	SOLV	$0.00	YES
1.5	1.900	1.450	0.225	0.011	SCH 120	540	0.009	0.25107	20+/40+	20/40	1120	D1785	0.747	SOLV	$0.00	YES
2	2.375	2.067	0.154	0.023	SCH 40	280	0.009	0.15649	20+/40+	20/40	1120	D1785	0.676	SOLV	$0.00	YES
2	2.375	1.939	0.218	0.021	SCH 80	400	0.009	0.17042	20+/40+	20/40	1120	D1785	0.929	SOLV	$0.00	YES
2	2.375	1.875	0.250	0.019	SCH 120	470	0.009	0.17822	20+/40+	20/40	1120	D1785	1.053	SOLV	$0.00	YES
2.5	2.875	2.469	0.203	0.033	SCH 40	300	0.009	0.12348	20+/40+	20/40	1120	D1785	1.073	SOLV	$0.00	YES
2.5	2.875	2.323	0.276	0.029	SCH 80	420	0.009	0.13393	20+/40+	20/40	1120	D1785	1.421	SOLV	$0.00	YES
2.5	2.875	2.275	0.300	0.028	SCH 120	470	0.009	0.13771	20+/40+	20/40	1120	D1785	1.532	SOLV	$0.00	YES
3	3.500	3.068	0.216	0.051	SCH 40	260	0.009	0.09243	20+/40+	20/40	1120	D1785	1.408	SOLV	$0.00	YES
3	3.500	2.900	0.300	0.046	SCH 80	370	0.009	0.09964	20+/40+	20/40	1120	D1785	1.890	SOLV	$0.00	YES
3	3.500	2.800	0.350	0.043	SCH 120	440	0.009	0.10441	20+/40+	20/40	1120	D1785	2.186	SOLV	$0.00	YES
3.5	4.000	3.548	0.226	0.069	SCH 40	240	0.009	0.07614	20+/40+	20/40	1120	D1785	1.691	SOLV	$0.00	YES
3.5	4.000	3.364	0.318	0.062	SCH 80	350	0.009	0.08175	20+/40+	20/40	1120	D1785	2.321	SOLV	$0.00	YES
3.5	4.000	3.300	0.350	0.059	SCH 120	380	0.009	0.08387	20+/40+	20/40	1120	D1785	2.533	SOLV	$0.00	YES
4	4.500	4.026	0.237	0.088	SCH 40	220	0.009	0.06434	20+/40+	20/40	1120	D1785	2.001	SOLV	$0.00	YES
4	4.500	3.826	0.337	0.080	SCH 80	320	0.009	0.06886	20+/40+	20/40	1120	D1785	2.774	SOLV	$0.00	YES
4	4.500	3.626	0.437	0.072	SCH 120	430	0.009	0.07397	20+/40+	20/40	1120	D1785	3.520	SOLV	$0.00	YES
5	5.563	5.047	0.258	0.139	SCH 40	190	0.009	0.04760	20+/40+	20/40	1120	D1785	2.714	SOLV	$0.00	YES
5	5.563	4.813	0.375	0.126	SCH 80	290	0.009	0.05071	20+/40+	20/40	1120	D1785	3.857	SOLV	$0.00	YES
5	5.563	4.563	0.500	0.114	SCH 120	400	0.009	0.05444	20+/40+	20/40	1120	D1785	5.019	SOLV	$0.00	YES
6	6.625	6.065	0.280	0.201	SCH 40	180	0.009	0.03725	20+/40+	20/40	1120	D1785	3.522	SOLV	$0.00	YES
6	6.625	5.761	0.432	0.181	SCH 80	280	0.009	0.03990	20+/40+	20/40	1120	D1785	3.519	SOLV	$0.00	YES
6	6.625	5.501	0.562	0.165	SCH 120	370	0.009	0.04243	20+/40+	20/40	1120	D1785	5.299	SOLV	$0.00	YES
8	8.625	7.981	0.322	0.347	SCH 40	160	0.009	0.02583	20+/40+	20/40	1120	D1785	5.301	SOLV	$0.00	YES
8	8.625	7.625	0.500	0.317	SCH 80	250	0.009	0.02746	20+/40+	20/40	1120	D1785	8.054	SOLV	$0.00	YES
8	8.625	7.189	0.718	0.282	SCH 120	380	0.009	0.02970	20+/40+	20/40	1120	D1785	11.256	SOLV	$0.00	YES
10	10.750	10.020	0.365	0.548	SCH 40	140	0.009	0.01907	20+/40+	20/40	1120	D1785	7.515	SOLV	$0.00	YES
10	10.750	9.564	0.593	0.499	SCH 80	230	0.009	0.02030	20+/40+	20/40	1120	D1785	11.941	SOLV	$0.00	YES
10	10.750	9.064	0.843	0.448	SCH 120	370	0.009	0.02180	20+/40+	20/40	1120	D1785	16.558	SOLV	$0.00	YES
12	12.750	11.938	0.406	0.777	SCH 40	130	0.009	0.01510	20+/40+	20/40	1120	D1785	9.936	SOLV	$0.00	YES
12	12.750	11.376	0.687	0.706	SCH 80	230	0.009	0.01611	20+/40+	20/40	1120	D1785	16.430	SOLV	$0.00	YES
12	12.750	10.750	1.000	0.630	SCH 120	340	0.009	0.01737	20+/40+	20/40	1120	D1785	23.296	SOLV	$0.00	YES

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Pipe Type -- Size in.	O.D. Inch	I.D. Inch	Wall Thickness	Area Sq. FT	SDR GA.	Press PSI	MAN "n"	Kp	Pipe Length	Lay Length	MATL Type	ASTM No.	Weight LBS/FT	Fittings Cus/Std	Coupler O.D.	Press Rated
PVC Sewer Pipe																
SMALL 4	4.215	3.975	0.012	0.086	SDR 35	—	0.009	0.06544	—	20/40	1120	D3033	0.974	BELL/SOLVE	—	NO
4	4.215	3.891	0.162	0.083	SDR 26	—	0.009	0.06733	—	20/40	1120	D3033	1.302	BELL/SOLVE	—	NO
4	4.215	3.859	0.178	0.081	SDR 23.5	—	0.009	0.06807	—	20/40	1120	D3033	1.425	BELL/SOLVE	—	NO
6	6.275	5.969	0.153	0.194	SDR 41	—	0.009	0.03806	—	20/40	1120	D3033	1.857	BELL/SOLVE	—	NO
6	6.275	5.915	0.180	0.191	SDR 35	—	0.009	0.03852	—	20/40	1120	D3033	2.175	BELL/SOLVE	—	NO
6	6.275	5.793	0.241	0.183	SDR 26	—	0.009	0.03960	—	20/40	1120	D3033	2.883	BELL/SOLVE	—	NO
6	6.275	5.745	0.265	0.180	SDR 23.5	—	0.009	0.04005	—	20/40	1120	D3033	3.158	BELL/SOLVE	—	NO
8	8.400	7.990	0.205	0.348	SDR 41	—	0.009	0.02580	—	20/40	1120	D3033	3.331	BELL/SOLVE	—	NO
8	8.400	7.920	0.240	0.342	SDR 35	—	0.009	0.02610	—	20/40	1120	D3033	3.883	BELL/SOLVE	—	NO
8	8.400	7.754	0.323	0.328	SDR 26	—	0.009	0.02685	—	20/40	1120	D3033	5.172	BELL/SOLVE	—	NO
9	9.440	8.980	0.230	0.440	SDR 41	—	0.009	0.02208	—	20/40	1120	D3033	4.200	BELL/SOLVE	—	NO
10	10.500	9.988	0.256	0.544	SDR 41	—	0.009	0.01916	—	20/40	1120	D3033	5.199	BELL/SOLVE	—	NO
10	10.500	9.900	0.300	0.535	SDR 35	—	0.009	0.01938	—	20/40	1120	D3033	6.067	BELL/SOLVE	—	NO
10	10.500	9.692	0.404	0.512	SDR 26	—	0.009	0.01994	—	20/40	1120	D3033	8.087	BELL/SOLVE	—	NO
12	12.500	11.890	0.305	0.771	SDR 41	—	0.009	0.01518	—	20/40	1120	D3033	7.374	BELL/SOLVE	—	NO
12	12.500	11.780	0.360	0.757	SDR 35	—	0.009	0.01537	—	20/40	1120	D3033	8.665	BELL/SOLVE	—	NO
12	12.500	11.538	0.481	0.726	SDR 26	—	0.009	0.01580	—	20/40	1120	D3033	11.462	BELL/SOLVE	—	NO
15	15.300	14.550	0.375	1.155	SDR 41	—	0.009	0.01160	—	20/40	1120	D3033	11.096	BELL/SOLVE	—	NO
15	15.300	14.426	0.437	1.135	SDR 35	—	0.009	0.01173	—	20/40	1120	D3033	12.877	BELL/SOLVE	—	NO
15	15.300	14.124	0.588	1.088	SDR 26	—	0.009	0.01207	—	20/40	1120	D3033	17.151	BELL/SOLVE	—	NO
LARGE 18	18.701	17.629	0.536	1.695	DR 35	—	0.009	0.00898	—	12.5 / 19.5	1220	F679	21.000	BELL & GAS	—	NO
21	22.047	20.783	0.632	2.356	DR 35	—	0.009	0.00721	—	12 / 19.5	1220	F679	29.600	BELL & GAS	—	NO
24	24.803	23.381	0.711	2.982	DR 35	—	0.009	0.00616	—	12 / 19.5	1220	F679	37.700	BELL & GAS	—	NO
27	27.953	26.351	0.801	3.787	DR 35	—	0.009	0.00525	—	11.5 / 19	1220	F679	48.700	BELL & GAS	—	NO

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Pipe Type -- Size in.	O.D. Inch	I.D. Inch	Wall Thickness	Area Sq. FT	SDR GA.	Press PSI	MAN "n"	Kp	Pipe Length	Lay Length	MATL Type	ASTM No.	Weight LBS/FT	Fittings Cus/Std	Coupler O.D.	Press Rated
PVC AWWA C900 (IPS)																
Iron Pipe Size 4	4.500	4.140	0.180	0.093	DR 25	100	0.009	0.06198	20+	20	1120	C900	1.637	BELL/SOLVE	—	YES
4	4.500	4.000	0.250	0.087	DR 18	150	0.009	0.06489	20+	20	1120	C900	2.237	BELL/SOLVE	—	YES
4	4.500	3.858	0.321	0.081	DR 14	200	0.009	0.06810	20+	20	1120	C900	2.824	BELL/SOLVE	—	YES
6	6.625	6.095	0.265	0.203	DR 25	100	0.009	0.03701	20+	20	1120	C900	3.548	BELL/SOLVE	—	YES
6	6.625	5.889	0.368	0.189	DR 18	150	0.009	0.03875	20+	20	1120	C900	4.847	BELL/SOLVE	—	YES
6	6.625	5.679	0.473	0.176	DR 14	200	0.009	0.04067	20+	20	1120	C900	6.126	BELL/SOLVE	—	YES
8	8.625	7.935	0.345	0.343	DR 25	100	0.009	0.02603	20+	20	1120	C900	6.013	BELL/SOLVE	—	YES
8	8.625	7.667	0.479	0.321	DR 18	150	0.009	0.02726	20+	20	1120	C900	8.214	BELL/SOLVE	—	YES
8	8.625	7.393	0.616	0.298	DR 14	200	0.009	0.02861	20+	20	1120	C900	10.385	BELL/SOLVE	—	YES
10	10.750	9.890	0.430	0.533	DR 25	100	0.009	0.01941	20+	20	1120	C900	9.341	BELL/SOLVE	—	YES
10	10.750	9.556	0.597	0.498	DR 18	150	0.009	0.02032	20+	20	1120	C900	12.76	BELL/SOLVE	—	YES
10	10.750	9.214	0.768	0.463	DR 14	200	0.009	0.02133	20+	20	1120	C900	16.138	BELL/SOLVE	—	YES
12	12.750	11.730	0.510	0.750	DR 25	100	0.009	0.01546	20+	20	1120	C900	13.141	BELL/SOLVE	—	YES
12	12.750	11.334	0.708	0.701	DR 18	150	0.009	0.01618	20+	20	1120	C900	17.947	BELL/SOLVE	—	YES
12	12.750	10.928	0.911	0.651	DR 14	200	0.009	0.01699	20+	20	1120	C900	22.704	BELL/SOLVE	—	YES
PVC AWWA C900 (CIP)																
Cast Iron Pipe Size 4	4.800	4.416	0.192	0.106	DR 25	100	0.009	0.05687	20+	20	1120	C900	1.862	BELL	—	YES
4	4.800	4.266	0.267	0.099	DR 18	150	0.009	0.05956	20+	20	1120	C900	2.548	BELL	6.500	YES
4	4.800	4.114	0.343	0.092	DR 14	200	0.009	0.06251	20+	20	1120	C900	3.218	BELL	—	YES
6	6.900	6.348	0.276	0.220	DR 25	100	0.009	0.03506	20+	20	1120	C900	3.849	BELL	—	YES
6	6.900	6.134	0.383	0.205	DR 18	150	0.009	0.03670	20+	20	1120	C900	5.254	BELL	9.000	YES
6	6.900	5.914	0.493	0.191	DR 14	200	0.009	0.03853	20+	20	1120	C900	6.649	BELL	—	YES
8	9.050	8.326	0.362	0.378	DR 25	100	0.009	0.02442	20+	20	1120	C900	6.621	BELL	—	YES
8	9.050	8.044	0.503	0.353	DR 18	150	0.009	0.02557	20+	20	1120	C900	9.050	BELL	11.600	YES
8	9.050	7.758	0.646	0.328	DR 14	200	0.009	0.02683	20+	20	1120	C900	11.428	BELL	—	YES
10	11.100	10.212	0.444	0.569	DR 25	100	0.009	0.01860	20+	20	1120	C900	9.960	BELL	—	YES
10	11.100	9.866	0.617	0.531	DR 18	150	0.009	0.01947	20+	20	1120	C900	13.616	BELL	14.100	YES
10	11.100	9.514	0.793	0.494	DR 14	200	0.009	0.02044	20+	20	1120	C900	17.206	BELL	—	YES
12	13.2	12.144	0.528	0.804	DR 25	100	0.009	0.01476	20+	20	1120	C900	14.085	BELL	—	YES
12	13.2	11.734	0.733	0.751	DR 18	150	0.009	0.01545	20+	20	1120	C900	19.237	BELL	16.700	YES
12	13.2	11.314	0.943	0.698	DR 14	200	0.009	0.01622	20+	20	1120	C900	24.331	BELL	—	YES

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Pipe Type -- Size in.	O.D. Inch	I.D. Inch	Wall Thickness	Area Sq. FT	SDR GA.	Press PSI	MAN "n"	Kp	Pipe Length	Lay Length	MATL Type	ASTM No.	Weight LBS/FT	Fittings Cus/Std	Coupler O.D.	Press Rated
PVC -Cast Iron OD Size																
Sceptor Brand 14	15.300	14.554	0.373	1.155	DR 41	100	0.009	0.01160	20' 8.5"	20	1120	C905	11.930	BELL/SOLVE	17.300	YES
14	15.300	14.076	0.612	1.081	DR 25	167	0.009	0.01212	20' 8.5"	20	1120	C905	19.240	GASKET	18.200	YES
14	15.300	13.600	0.850	1.009	DR 18	235	0.009	0.01269	20' 8.5"	20	1120	C905	26.240	GASKET	18.700	YES
16	17.400	16.552	0.424	1.494	DR 41	100	0.009	0.00977	20' 10.5"	20	1120	C905	15.480	GASKET	19.600	YES
16	17.400	16.008	0.696	1.398	DR 25	167	0.009	0.01021	20' 10.5"	20	1120	C905	24.950	GASKET	20.400	YES
16	17.400	15.466	0.967	1.305	DR 18	235	0.009	0.01069	20' 10.5"	20	1120	C905	34.190	GASKET	21.000	YES
18	19.500	18.550	0.475	1.877	DR 41	100	0.009	0.00839	20' 11"	20	1120	C905	19.540	GASKET	22.300	YES
18	19.500	17.940	0.780	1.755	DR 25	167	0.009	0.00877	20' 11"	20	1120	C905	31.520	GASKET	22.900	YES
18	19.500	17.334	1.083	1.639	DR 18	235	0.009	0.00919	20' 11"	20	1120	C905	43.080	GASKET	23.500	YES
20	21.600	20.546	0.527	2.302	DR 41	100	0.009	0.00732	21	20	1120	C905	24.220	GASKET	24.900	YES
20	21.600	19.872	0.864	2.154	DR 25	167	0.009	0.00766	21	20	1120	C905	39.170	GASKET	25.600	YES
20	21.600	19.200	1.200	2.011	DR 18	235	0.009	0.00801	21	20	1120	C905	53.920	GASKET	26.300	YES
24	25.800	24.542	0.629	3.285	DR 41	100	0.009	0.00578	21' 1.5"	20	1120	C905	34.690	GASKET	29.600	YES
24	25.800	23.736	1.032	3.073	DR 25	167	0.009	0.00604	21' 1.5"	20	1120	C905	56.050	GASKET	30.400	YES
24	25.800	22.934	1.433	2.869	DR 18	235	0.009	0.00632	21' 1.5"	20	1120	C905	77.017	GASKET	31.200	YES
30	32.000	30.746	0.627	5.156	DR 51	80	0.009	0.00428	21' 3"	20	1120	C905	43.387	CUSTOM	—	YES
30	32.000	30.440	0.780	5.054	DR 41	100	0.009	0.00434	21' 3"	20	1120	C905	53.711	CUSTOM	36.000	YES
30	32.000	30.030	0.985	4.919	DR 32.5	125	0.009	0.00441	21' 3"	20	1120	C905	67.382	CUSTOM	—	YES
30	32.000	29.440	1.280	4.727	DR 25	165	0.009	0.00453	21' 3"	20	1120	C905	86.730	CUSTOM	37.100	YES
36	38.300	36.798	0.751	7.385	DR 51	80	0.009	0.00337	20 +	20	1120	C905	62.198	CUSTOM	—	YES
36	38.300	36.432	0.934	7.239	DR 41	100	0.009	0.00341	20 +	20	1120	C905	76.977	CUSTOM	—	YES
36	38.300	35.944	1.178	7.047	DR 32.5	125	0.009	0.00347	20 +	20	1120	C905	96.453	CUSTOM	—	YES
36	38.300	35.240	1.530	6.773	DR 25	165	0.009	0.00357	20 +	20	1120	C905	124.086	CUSTOM	—	YES
PVC Ribbed Sewer Pipe																
8	8.800	7.890	0.455	0.340	—	—	0.009	0.02623	—	—	1120	F794	2.480	BELL / GAS	9.760	NO
10	11.000	9.860	0.570	0.530	—	—	0.009	0.01949	—	—	1120	F794	3.500	BELL / GAS	12.220	NO
12	13.100	11.740	0.680	0.752	—	—	0.009	0.01544	—	—	1120	F794	4.710	BELL / GAS	14.600	NO
15	16.070	14.370	0.850	1.126	—	—	0.009	0.01179	—	—	1120	F794	7.850	BELL / GAS	17.840	NO
18	19.760	17.650	1.055	1.699	—	—	0.009	0.00897	—	—	1120	F794	10.900	BELL / GAS	21.950	NO
21	22.990	20.750	1.120	2.348	—	—	0.009	0.00723	—	—	1120	F794	14.500	BELL / GAS	25.500	NO
24	25.970	23.500	1.235	3.012	—	—	0.009	0.00612	—	—	1120	F794	18.400	BELL / GAS	28.500	NO
27	29.450	26.500	1.475	3.830	—	—	0.009	0.00522	—	—	1120	F794	21.600	BELL / GAS	32.500	NO
30	32.700	29.500	1.600	4.746	—	—	0.009	0.00452	—	—	1120	F794	27.800	BELL / GAS	36.000	NO

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Pipe Type -- Size in.	O.D. Inch	I.D. Inch	Wall Thickness	Area Sq. FT	SDR GA.	Press PSI	MAN "n"	Kp	Pipe Length	Lay Length	MATL Type	ASTM No.	Weight LBS/FT	Fittings Cus/Std	Coupler O.D.	Press Rated
Fiberglass Reinforced Resin Pipe																
(PVC/GLASS) 2	2.500	—	—	—	—	350	—	—	—	20	PVC/GLASS	D2996	—	BELL / GAS	—	YES
3	3.960	—	—	—	—	350	—	—	—	20	PVC/GLASS	D2996	—	BELL / GAS	—	YES
4	4.800	4.500	0.150	0.110	—	350	0.009	0.05546	—	20	PVC/GLASS	D2996	—	BELL / GAS	6.010	YES
6	6.900	6.520	0.190	0.232	—	350	0.009	0.03383	—	20	PVC/GLASS	D2996	—	BELL / GAS	8.340	YES
8	9.050	8.560	0.245	0.400	—	350	0.009	0.02353	—	20	PVC/GLASS	D2996	—	BELL / GAS	10.810	YES
10	11.100	10.560	0.270	0.608	—	350	0.009	0.01779	—	20	PVC/GLASS	D2996	—	BELL / GAS	13.210	YES
12	13.200	12.550	0.325	0.859	—	350	0.009	0.01413	—	20	PVC/GLASS	D2996	—	BELL / GAS	15.640	YES
14	15.300	—	—	—	—	350	0.009	—	—	20	PVC/GLASS	D2996	—	BELL / GAS	—	YES
16	17.400	—	—	—	—	350	0.009	—	—	20	PVC/GLASS	D2996	—	BELL / GAS	—	YES
Polyethylene (PE)																
ID Controlled SDR Pipe PE 3408 High Density																
0.5	0.742	0.622	0.060	0.002	19	80	0.010	0.95809	ROLL	100, 400	PE 3408	D2239	—	INSERT	N/A	YES
0.5	0.742	0.622	0.060	0.002	15	100	0.010	0.95809	ROLL	100, 400	PE 3408	D2239	—	INSERT	N/A	YES
0.5	0.742	0.622	0.060	0.002	11.5	125	0.010	0.95809	ROLL	100, 400	PE 3408	D2239	—	INSERT	N/A	YES
0.5	0.760	0.622	0.069	0.002	9	160	0.010	0.95809	ROLL	100, 400	PE 3408	D2239	—	INSERT	N/A	YES
0.5	0.800	0.622	0.089	0.002	7	200	0.010	0.95809	ROLL	100, 400	PE 3408	D2239	—	INSERT	N/A	YES
0.5	0.856	0.622	0.117	0.002	5.3	250	0.010	0.95809	ROLL	100, 400	PE 3408	D2239	—	INSERT	N/A	YES
0.75	0.944	0.824	0.060	0.004	19	80	0.010	0.65850	ROLL	100, 400	PE 3408	D2239	—	INSERT	N/A	YES
0.75	0.944	0.824	0.060	0.004	15	100	0.010	0.65850	ROLL	100, 400	PE 3408	D2239	—	INSERT	N/A	YES
0.75	0.968	0.824	0.072	0.004	11.5	125	0.010	0.65850	ROLL	100, 400	PE 3408	D2239	—	INSERT	N/A	YES
0.75	1.008	0.824	0.092	0.004	9	160	0.010	0.65850	ROLL	100, 400	PE 3408	D2239	—	INSERT	N/A	YES
0.75	1.060	0.824	0.118	0.004	7	200	0.010	0.65850	ROLL	100, 400	PE 3408	D2239	—	INSERT	N/A	YES
0.75	1.134	0.824	0.155	0.004	5.3	250	0.010	0.65850	ROLL	100, 400	PE 3408	D2239	—	INSERT	N/A	YES
1	1.169	1.049	0.060	0.006	19	80	0.010	0.47727	ROLL	100, 300	PE 3408	D2239	—	INSERT	N/A	YES
1	1.189	1.049	0.070	0.006	15	100	0.010	0.47727	ROLL	100, 300	PE 3408	D2239	—	INSERT	N/A	YES
1	1.231	1.049	0.091	0.006	11.5	125	0.010	0.47727	ROLL	100, 300	PE 3408	D2239	—	INSERT	N/A	YES
1	1.283	1.049	0.117	0.006	9	160	0.010	0.47727	ROLL	100, 300	PE 3408	D2239	—	INSERT	N/A	YES
1	1.349	1.049	0.150	0.006	7	200	0.010	0.477267	ROLL	100, 300	PE 3408	D2239	—	INSERT	N/A	YES
1	1.445	1.049	0.198	0.006	5.3	250	0.010	0.477267	ROLL	100, 300	PE 3408	D2239	—	INSERT	N/A	YES
1.25	1.526	1.380	0.073	0.010	19	80	0.010	0.331098	ROLL	100, 300	PE 3408	D2239	—	INSERT	N/A	YES
1.25	1.564	1.380	0.092	0.010	15	100	0.010	0.331098	ROLL	100, 300	PE 3408	D2239	—	INSERT	N/A	YES
1.25	1.620	1.380	0.120	0.010	11.5	125	0.010	0.331098	ROLL	100, 300	PE 3408	D2239	—	INSERT	N/A	YES
1.25	1.686	1.380	0.153	0.010	9	160	0.010	0.331098	ROLL	100, 300	PE 3408	D2239	—	INSERT	N/A	YES
1.25	1.774	1.380	0.197	0.010	7	200	0.010	0.331098	ROLL	100, 300	PE 3408	D2239	—	INSERT	N/A	YES
1.25	1.900	1.380	0.260	0.010	5.3	250	0.010	0.331098	ROLL	100, 300	PE 3408	D2239	—	INSERT	N/A	YES
1.5	1.780	1.610	0.085	0.014	19	80	0.010	0.269584	ROLL	100, 250	PE 3408	D2239	—	INSERT	N/A	YES
1.5	1.824	1.610	0.107	0.014	15	100	0.010	0.269584	ROLL	100, 250	PE 3408	D2239	—	INSERT	N/A	YES
1.5	1.890	1.610	0.140	0.014	11.5	125	0.010	0.269584	ROLL	100, 250	PE 3408	D2239	—	INSERT	N/A	YES
1.5	1.968	1.610	0.179	0.014	9	160	0.010	0.269584	ROLL	100, 250	PE 3408	D2239	—	INSERT	N/A	YES
1.5	2.070	1.610	0.230	0.014	7	200	0.010	0.269584	ROLL	100, 250	PE 3408	D2239	—	INSERT	N/A	YES
1.5	2.218	1.610	0.304	0.014	5.3	250	0.010	0.269584	ROLL	100, 250	PE 3408	D2239	—	INSERT	N/A	YES

Pipe Type -- Size in.	O.D. Inch	I.D. Inch	Wall Thickness	Area Sq. FT	SDR GA.	Press PSI	MAN "n"	Kp	Pipe Length	Lay Length	MATL Type	ASTM No.	Weight LBS/FT	Fittings Cus/Std	Coupler O.D.	Press Rated
Polyethylene (PE)																
ID Controlled SDR Pipe PE 3408 High Density																
2	2.285	2.067	0.109	0.023	19	80	0.010	0.19320	ROLL	100, 200	PE 3408	D2239	—	INSERT	N/A	YES
2	2.343	2.067	0.138	0.023	15	100	0.010	0.19320	ROLL	100, 200	PE 3408	D2239	—	INSERT	N/A	YES
2	2.427	2.067	0.180	0.023	11.5	125	0.010	0.19320	ROLL	100, 200	PE 3408	D2239	—	INSERT	N/A	YES
2	2.527	2.067	0.230	0.023	9	160	0.010	0.19320	ROLL	100, 200	PE 3408	D2239	—	INSERT	N/A	YES
2	2.657	2.067	0.295	0.023	7	200	0.010	0.19320	ROLL	100, 200	PE 3408	D2239	—	INSERT	N/A	YES
2	2.847	2.067	0.390	0.023	5.3	250	0.010	0.19320	ROLL	100, 200	PE 3408	D2239	—	INSERT	N/A	YES
2.5	2.729	2.469	0.130	0.033	19	80	0.010	0.15244	—	—	PE 3408	D2239	—	INSERT	N/A	YES
2.5	2.799	2.469	0.165	0.033	15	100	0.010	0.15244	—	—	PE 3408	D2239	—	INSERT	N/A	YES
2.5	2.899	2.469	0.215	0.033	11.5	125	0.010	0.15244	—	—	PE 3408	D2239	—	INSERT	N/A	YES
3	3.390	3.068	0.161	0.051	19	80	0.010	0.11411	—	—	PE 3408	D2239	—	INSERT	N/A	YES
3	3.478	3.068	0.205	0.051	15	100	0.010	0.11411	—	—	PE 3408	D2239	—	INSERT	N/A	YES
3	3.602	3.068	0.267	0.051	11.5	125	0.010	0.11411	—	—	PE 3408	D2239	—	INSERT	N/A	YES
4	4.450	4.026	0.212	0.088	19	80	0.010	0.07943	—	—	PE 3408	D2239	—	INSERT	N/A	YES
4	4.562	4.026	0.268	0.088	15	100	0.010	0.07943	—	—	PE 3408	D2239	—	INSERT	N/A	YES
4	4.726	4.026	0.350	0.088	11.5	125	0.010	0.07943	—	—	PE 3408	D2239	—	INSERT	N/A	YES
6	6.703	6.065	0.319	0.201	19	80	0.010	0.045993	—	—	PE 3408	D2239	—	INSERT	N/A	YES
6	6.873	6.065	0.404	0.201	15	100	0.010	0.045993	—	—	PE 3408	D2239	—	INSERT	N/A	YES
6	7.119	6.065	0.527	0.201	11.5	125	0.010	0.045993	—	—	PE 3408	D2239	—	INSERT	N/A	YES
Polyethylene (PE)																
ID Controlled Pipe SCH 40																
0.5	0.840	0.622	0.109	0.002	SCH 40	190	0.010	0.958092	ROLL	100, 300	PE 3406	D2104	—	INSERT	N/A	YES
0.75	1.050	0.824	0.113	0.004	SCH 40	150	0.010	0.658504	ROLL	100, 250	PE 3406	D2104	—	INSERT	N/A	YES
1	1.315	1.049	0.133	0.006	SCH 40	140	0.010	0.477267	ROLL	100, 250	PE 3406	D2104	—	INSERT	N/A	YES
1.25	1.660	1.380	0.140	0.010	SCH 40	120	0.010	0.331098	ROLL	100, 250	PE 3406	D2104	—	INSERT	N/A	YES
1.5	1.900	1.610	0.145	0.014	SCH 40	100	0.010	0.269584	ROLL	100, 250	PE 3406	D2104	—	INSERT	N/A	YES
2	2.375	2.067	0.154	0.023	SCH 40	90	0.010	0.193201	ROLL	100, 250	PE 3406	D2104	—	INSERT	N/A	YES
2.5	2.875	2.469	0.203	0.033	SCH 40	100	0.010	0.152441	—	—	PE 3406	D2104	—	INSERT	N/A	YES
3	3.500	3.068	0.216	0.051	SCH 40	80	0.010	0.11411	—	—	PE 3406	D2104	—	INSERT	N/A	YES
4	4.500	4.026	0.237	0.088	SCH 40	70	0.010	0.079426	—	—	PE 3406	D2104	—	INSERT	N/A	YES
6	6.625	6.065	0.280	0.201	SCH 40	60	0.010	0.045993	—	—	PE 3406	D2104	—	INSERT	N/A	YES

Pipe Type -- Size in.	O.D. Inch	I.D. Inch	Wall Thickness	Area Sq. FT	SDR GA.	Press PSI	MAN "n"	Kp	Pipe Length	Lay Length	MATL Type	ASTM No.	Weight LBS/FT	Fittings Cus/Std	Coupler O.D.	Press Rated
Polyethylene (PE)																
ID Controlled SDR Pipe PE 3406																
0.5	0.742	0.622	0.060	0.002	15	80	0.010	0.95809	ROLL	100, 400	PE 3406	D2239	—	INSERT	N/A	YES
0.5	0.742	0.622	0.060	0.002	11.5	100	0.010	0.95809	ROLL	100, 400	PE 3406	D2239	—	INSERT	N/A	YES
0.5	0.760	0.622	0.069	0.002	9	125	0.010	0.95809	ROLL	100, 400	PE 3406	D2239	—	INSERT	N/A	YES
0.5	0.800	0.622	0.089	0.002	7	160	0.010	0.95809	ROLL	100, 400	PE 3406	D2239	—	INSERT	N/A	YES
0.5	0.856	0.622	0.117	0.002	5.3	200	0.010	0.95809	ROLL	100,400	PE 3406	D2239	—	INSERT	N/A	YES
0.75	0.944	0.824	0.060	0.004	15	80	0.010	0.65850	ROLL	100, 400	PE 3406	D2239	—	INSERT	N/A	YES
0.75	0.968	0.824	0.072	0.004	11.5	100	0.010	0.65850	ROLL	100, 400	PE 3406	D2239	—	INSERT	N/A	YES
0.75	1.008	0.824	0.092	0.004	9	125	0.010	0.65850	ROLL	100, 400	PE 3406	D2239	—	INSERT	N/A	YES
0.75	1.060	0.824	0.118	0.004	7	160	0.010	0.65850	ROLL	100, 400	PE 3406	D2239	—	INSERT	N/A	YES
0.75	1.134	0.824	0.155	0.004	5.3	200	0.010	0.65850	ROLL	100,400	PE 3406	D2239	—	INSERT	N/A	YES
1	1.189	1.049	0.070	0.006	15	80	0.010	0.47727	ROLL	100, 300	PE 3406	D2239	—	INSERT	N/A	YES
1	1.231	1.049	0.091	0.006	11.5	100	0.010	0.47727	ROLL	100, 300	PE 3406	D2239	—	INSERT	N/A	YES
1	1.283	1.049	0.117	0.006	9	125	0.010	0.47727	ROLL	100, 300	PE 3406	D2239	—	INSERT	N/A	YES
1	1.349	1.049	0.150	0.006	7	160	0.010	0.47727	ROLL	100, 300	PE 3406	D2239	—	INSERT	N/A	YES
1	1.445	1.049	0.198	0.006	5.3	200	0.010	0.47727	ROLL	100,300	PE 3406	D2239	—	INSERT	N/A	
1.25	1.564	1.380	0.092	0.010	15	80	0.010	0.33110	ROLL	100, 300	PE 3406	D2239	—	INSERT	N/A	YES
1.25	1.620	1.380	0.120	0.010	11.5	100	0.010	0.33110	ROLL	100, 300	PE 3406	D2239	—	INSERT	N/A	YES
1.25	1.686	1.380	0.153	0.010	9	125	0.010	0.33110	ROLL	100, 300	PE 3406	D2239	—	INSERT	N/A	YES
1.25	1.774	1.380	0.197	0.010	7	160	0.010	0.33110	ROLL	100, 300	PE 3406	D2239	—	INSERT	N/A	YES
1.25	1.900	1.380	0.260	0.010	5.3	200	0.010	0.33110	ROLL	100,300	PE 3406	D2239	—	INSERT	N/A	YES
1.5	1.824	1.610	0.107	0.014	15	80	0.010	0.26958	ROLL	100, 250	PE 3406	D2239	—	INSERT	N/A	YES
1.5	1.890	1.610	0.140	0.014	11.5	100	0.010	0.26958	ROLL	100, 250	PE 3406	D2239	—	INSERT	N/A	YES
1.5	1.968	1.610	0.179	0.014	9	125	0.010	0.26958	ROLL	100, 250	PE 3406	D2239	—	INSERT	N/A	YES
1.5	2.070	1.610	0.230	0.014	7	160	0.010	0.26958	ROLL	100, 250	PE 3406	D2239	—	INSERT	N/A	YES
1.5	2.218	1.610	0.304	0.014	5.3	200	0.010	0.26958	ROLL	100,250	PE 3406	D2239	—	INSERT	N/A	YES
2	2.343	2.067	0.138	0.023	15	80	0.010	0.19320	ROLL	100, 200	PE 3406	D2239	—	INSERT	N/A	YES
2	2.427	2.067	0.180	0.023	11.5	100	0.010	0.19320	ROLL	100, 200	PE 3406	D2239	—	INSERT	N/A	YES
2	2.527	2.067	0.230	0.023	9	125	0.010	0.19320	ROLL	100, 200	PE 3406	D2239	—	INSERT	N/A	YES
2	2.657	2.067	0.295	0.023	7	160	0.010	0.19320	ROLL	100, 200	PE 3406	D2239	—	INSERT	N/A	YES
2	2.847	2.067	0.390	0.023	5.3	200	0.010	0.19320	ROLL	100,200	PE 3406	D2239	—	INSERT	N/A	YES
2.5	2.799	2.469	0.165	0.033	15	80	0.010	0.15244	—	—	PE 3406	D2239	—	INSERT	N/A	YES
2.5	2.899	2.469	0.215	0.033	11.5	100	0.010	0.15244	—	—	PE 3406	D2239	—	INSERT	N/A	YES
3	3.478	3.068	0.205	0.051	15	80	0.010	0.11411	—	—	PE 3406	D2239	—	INSERT	N/A	YES
3	3.602	3.068	0.267	0.051	11.5	100	0.010	0.11411	—	—	PE 3406	D2239	—	INSERT	N/A	YES
4	4.562	4.026	0.268	0.088	15	80	0.010	0.07943	—	—	PE 3406	D2239	—	INSERT	N/A	YES
4	4.726	4.026	0.350	0.088	11.5	100	0.010	0.07943	—	—	PE 3406	D2239	—	INSERT	N/A	YES
6	6.873	6.065	0.404	0.201	15	80	0.010	0.045993	—	—	PE 3406	D2239	—	INSERT	N/A	YES
6	7.119	6.065	0.527	0.201	11.5	100	0.010	0.045993	—	—	PE 3406	D2239	—	INSERT	N/A	YES

Pipe Type -- Size in.	O.D. Inch	I.D. Inch	Wall Thickness	Area Sq. FT	SDR GA.	Press PSI	MAN "n"	Kp	Pipe Length	Lay Length	MATL Type	ASTM No.	Weight LBS/FT	Fittings Cus/Std	Coupler O.D.	Press Rated
Polyethylene (PE) High Molecular																
Butt Fusion O.D. Controlled																
Small 0.50	0.840	0.688	0.076	0.003	11	160	0.010	0.83755	—	—	PE3408	D3350		FUSION	—	YES
0.50	0.840	0.660	0.090	0.002	9.3	180	0.010	0.88526	—	—	PE3408	D3350		FUSION	—	YES
0.75	1.050	0.860	0.095	0.004	11	160	0.010	0.62201	—	—	PE3408	D3350		FUSION	—	YES
0.75	1.050	0.824	0.113	0.004	9.3	180	0.010	0.65850	—	—	PE3408	D3350		FUSION	—	YES
0.75	1.050	0.816	0.117	0.004	9	200	0.010	0.66713	—	—	PE3408	D3350		FUSION	—	YES
1.00	1.315	1.077	0.119	0.006	11	160	0.010	0.46079	—	—	PE3408	D3350		FUSION	—	YES
1.00	1.315	1.031	0.142	0.006	9.3	180	0.010	0.48841	—	—	PE3408	D3350		FUSION	—	YES
1.00	1.315	1.023	0.146	0.006	9	200	0.010	0.49351	—	—	PE3408	D3350		FUSION	—	YES
1.25	1.660	1.358	0.151	0.010	11	160	0.010	0.33827	—	—	PE3408	D3350		FUSION	—	YES
1.25	1.660	1.302	0.179	0.009	9.3	180	0.010	0.35781	—	—	PE3408	D3350		FUSION	—	YES
1.25	1.660	1.292	0.184	0.009	9	200	0.010	0.36150	—	—	PE3408	D3350		FUSION	—	YES
1.50	1.900	1.554	0.173	0.013	11	160	0.010	0.28261	—	—	PE3408	D3350		FUSION	—	YES
1.50	1.900	1.492	0.204	0.012	9.3	180	0.010	0.29838	—	—	PE3408	D3350		FUSION	—	YES
1.50	1.900	1.478	0.211	0.012	9	200	0.010	0.30215	—	—	PE3408	D3350		FUSION	—	YES
2.00	2.375	2.095	0.140	0.024	17	100	0.010	0.18977	—	—	PE3408	D3350	0.420	FUSION	—	YES
2.00	2.375	2.069	0.153	0.023	15.5	110	0.010	0.19295	—	—	PE3408	D3350	0.460	FUSION	—	YES
2.00	2.375	2.023	0.176	0.022	13.5	130	0.010	0.19882	—	—	PE3408	D3350	0.520	FUSION	—	YES
2.00	2.375	1.943	0.216	0.021	11	160	0.010	0.20981	—	—	PE3408	D3350	0.630	FUSION	—	YES
2.00	2.375	1.847	0.264	0.019	9	200	0.010	0.18977	—	—	PE3408	D3350	0.750	FUSION	—	YES
2.00	2.375	1.725	0.325	0.016	7.3	250	0.010	0.19882	—	—	PE3408	D3350	0.900	FUSION	—	YES
3.00	3.500	3.088	0.206	0.052	17	100	0.010	0.20981	—	—	PE3408	D3350	0.920	FUSION	—	YES
3.00	3.500	3.048	0.226	0.051	15.5	110	0.010	0.11511	—	—	PE3408	D3350	1.000	FUSION	—	YES
3.00	3.500	2.982	0.259	0.049	13.5	130	0.010	0.11852	—	—	PE3408	D3350	1.140	FUSION	—	YES
3.00	3.500	2.864	0.318	0.045	11	160	0.010	0.12507	—	—	PE3408	D3350	1.370	FUSION	—	YES
3.00	3.500	2.722	0.389	0.040	9	200	0.010	0.13385	—	—	PE3408	D3350	1.640	FUSION	—	YES
3.00	3.500	2.542	0.479	0.035	7.3	250	0.010	0.14663	—	—	PE3408	D3350	1.960	FUSION	—	YES
4.00	4.500	4.072	0.214	0.090	21	80	0.010	0.07823	—	—	PE3408	D3350	1.240	FUSION	—	YES
4.00	4.500	3.970	0.265	0.086	17	100	0.010	0.08092	—	—	PE3408	D3350	1.520	FUSION	—	YES
4.00	4.500	3.920	0.290	0.084	15.5	110	0.010	0.08230	—	—	PE3408	D3350	1.650	FUSION	—	YES
4.00	4.500	3.834	0.333	0.080	13.5	130	0.010	0.08477	—	—	PE3408	D3350	1.880	FUSION	—	YES
4.00	4.500	3.682	0.409	0.074	11	160	0.010	0.08947	—	—	PE3408	D3350	2.260	FUSION	—	YES
4.00	4.500	3.500	0.500	0.067	9	200	0.010	0.09573	—	—	PE3408	D3350	2.710	FUSION	—	YES
4.00	4.500	3.268	0.616	0.058	7.3	250	0.010	0.10489	—	—	PE3408	D3350	3.240	FUSION	—	YES

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Pipe Type -- Size in.	O.D. Inch	I.D. Inch	Wall Thickness	Area Sq. FT	SDR GA.	Press PSI	MAN "n"	Kp	Pipe Length	Lay Length	MATL Type	ASTM No.	Weight LBS/FT	Fittings Cus/Std	Coupler O.D.	Press Rated
Polyethylene (PE) High Molecular																
Butt Fusion O.D. Controlled																
Large 5	5.563	5.221	0.171	0.149	32.5	50	0.010	0.05616	—	—	PE3408	D3350	1.250	FUSION	—	YES
5	5.563	5.135	0.214	0.144	26	65	0.010	0.05742	—	—	PE3408	D3350	1.550	FUSION	—	YES
5	5.563	5.033	0.265	0.138	21	80	0.010	0.05898	—	—	PE3408	D3350	1.900	FUSION	—	YES
5	5.563	4.909	0.327	0.131	17	100	0.010	0.06097	—	—	PE3408	D3350	2.320	FUSION	—	YES
5	5.563	4.845	0.359	0.128	15.5	110	0.010	0.06205	—	—	PE3408	D3350	2.530	FUSION	—	YES
5	5.563	4.739	0.412	0.122	13.5	130	0.010	0.06391	—	—	PE3408	D3350	2.870	FUSION	—	YES
5	5.563	4.551	0.506	0.113	11	160	0.010	0.06745	—	—	PE3408	D3350	3.460	FUSION	—	YES
5	5.563	4.327	0.618	0.102	9	200	0.010	0.07215	—	—	PE3408	D3350	4.130	FUSION	—	YES
5	5.563	4.039	0.762	0.089	7.3	250	0.010	0.07909	—	—	PE3408	D3350	4.950	FUSION	—	YES
6	6.625	6.217	0.204	0.211	32.5	50	0.010	0.04450	—	—	PE3408	D3350	1.770	FUSION	—	YES
6	6.625	6.115	0.255	0.204	26	65	0.010	0.04549	—	—	PE3408	D3350	2.200	FUSION	—	YES
6	6.625	5.995	0.315	0.196	21	80	0.010	0.04671	—	—	PE3408	D3350	2.690	FUSION	—	YES
6	6.625	5.845	0.390	0.186	17	100	0.010	0.04832	—	—	PE3408	D3350	3.290	FUSION	—	YES
6	6.625	5.771	0.427	0.182	15.5	110	0.010	0.04914	—	—	PE3408	D3350	3.580	FUSION	—	YES
6	6.625	5.643	0.491	0.174	13.5	130	0.010	0.05064	—	—	PE3408	D3350	4.070	FUSION	—	YES
6	6.625	5.421	0.602	0.160	11	160	0.010	0.05342	—	—	PE3408	D3350	4.910	FUSION	—	YES
6	6.625	5.153	0.736	0.145	9	200	0.010	0.05715	—	—	PE3408	D3350	5.860	FUSION	—	YES
6	6.625	4.809	0.908	0.126	7.3	250	0.010	0.06267	—	—	PE3408	D3350	7.020	FUSION	—	YES
7	7.125	6.687	0.219	0.244	32.5	50	0.010	0.04038	—	—	PE3408	D3350	2.050	FUSION	—	YES
7	7.125	6.577	0.274	0.236	26	65	0.010	0.04128	—	—	PE3408	D3350	2.540	FUSION	—	YES
7	7.125	6.447	0.339	0.227	21	80	0.010	0.04240	—	—	PE3408	D3350	3.110	FUSION	—	YES
8	8.625	—	—	—	Check Availability for These Sizes SDR 32.5 to SDR 7.3	—	0.010	—	—	—	PE3408	D3350	—	FUSION	—	YES
10	10.750	—	—	—		—	0.010	—	—	—	PE3408	D3350	—	FUSION	—	YES
12	12.750	—	—	—		—	0.010	—	—	—	PE3408	D3350	—	FUSION	—	YES
13	13.380	—	—	—		—	0.010	—	—	—	PE3408	D3350	—	FUSION	—	YES
14	14.000	—	—	—		—	0.010	—	—	—	PE3408	D3350	—	FUSION	—	YES
16	16.000	—	—	—		—	0.010	—	—	—	PE3408	D3350	—	FUSION	—	YES
18	18.000	—	—	—		—	0.010	—	—	—	PE3408	D3350	—	FUSION	—	YES
20	20.000	—	—	—		—	0.010	—	—	—	PE3408	D3350	—	FUSION	—	YES
22	22.000	—	—	—		—	0.010	—	—	—	PE3408	D3350	—	FUSION	—	YES
24	24.000	—	—	—		—	0.010	—	—	—	PE3408	D3350	—	FUSION	—	YES
28	28.000	—	—	—		—	0.010	—	—	—	PE3408	D3350	—	FUSION	—	YES
30	30.000	—	—	—		—	0.010	—	—	—	PE3408	D3350	—	FUSION	—	YES
32	32.000	—	—	—		—	0.010	—	—	—	PE3408	D3350	—	FUSION	—	YES
36	36.000	—	—	—		—	0.010	—	—	—	PE3408	D3350	—	FUSION	—	YES
42	42.000	—	—	—		—	0.010	—	—	—	PE3408	D3350	—	FUSION	—	YES
48	48.000	—	—	—		—	0.010	—	—	—	PE3408	D3350	—	FUSION	—	YES

Pipe Type -- Size in.	O.D. Inch	I.D. Inch	Wall Thickness	Area Sq. FT	SDR GA.	Press PSI	MAN "n"	Kp	Pipe Length	Lay Length	MATL Type	ASTM No.	Weight LBS/FT	Fittings Cus/Std	Coupler O.D.	Press Rated
Polyethylene (PE) Double wall Corrugated Pipe																
Smooth Interior, Hancor HI-Q Sure Lock																
12.00	14.200	12.000	1.100	0.785	—	10.8	0.010	0.01852	20+	20	P33	F667	3.300	BELL/GAS	—	NO
15.00	17.700	15.000	1.350	1.227	—	10.8	0.010	0.01375	20+	20	P33	F667	4.700	CUSTOM	—	NO
18.00	21.500	18.000	1.750	1.767	—	10.8	0.010	0.01078	20+	20	P33	F667	6.700	ELBOWS	—	NO
24.00	28.400	24.000	2.200	3.142	—	10.8	0.010	0.00735	20+	20	P33	F667	12.000	AVAILABLE	—	NO
30.00	35.500	30.000	2.750	4.909	—	5	0.010	0.00546	20+	20	P33	F667	16.000	WATER TIGHT	—	NO
Polyethylene (PE) Double wall Corrugated Pipe																
Smooth Interior, Hancor HI-Q Gravity																
4.00	4.800	4.000	0.400	0.087	—	—	0.010	0.08012	20	20	P33	F667	0.400	BAND	—	NO
6.00	7.000	6.000	0.500	0.196	—	—	0.010	0.04666	20	20	P33	F667	1.000	BAND	—	NO
8.00	9.300	8.000	0.650	0.349	—	—	0.010	0.03179	20	20	P33	F667	1.500	BAND	—	NO
10.00	12.000	10.000	1.000	0.545	—	—	0.010	0.02361	20	20	P33	F667	2.000	BAND	—	NO
12.00	14.200	12.000	1.100	0.785	—	—	0.010	0.01852	20	20	P33	F667	3.300	BAND	—	NO
15.00	17.700	15.000	1.350	1.227	—	—	0.010	0.01375	20	20	P33	F667	4.200	BAND	—	NO
18.00	21.500	18.000	1.750	1.767	—	—	0.010	0.01078	20	20	P33	F667	6.300	BAND	—	NO
24.00	28.400	24.000	2.200	3.142	—	—	0.010	0.00735	20	20	P33	F667	11.100	BAND	—	NO
30.00	36.000	30.000	3.000	4.909	—	—	0.010	0.00546	20	20	P33	F667	16.000	BAND	—	NO
36.00	42.000	36.000	3.000	7.069	—	—	0.010	0.00428	20	20	P33	F667	17.500	BAND	—	NO
42.00	48.000	42.000	3.000	9.261	—	—	0.010	0.00348	20	20	P33	F667	22.000	BAND	—	NO
48.00	54.000	48.000	3.000	12.566	—	—	0.010	0.00292	20	20	P33	F667	26.000	BAND	—	NO
Polyethylene (PE) Corrugated Pipe																
Hancor AASHTO																
3.00	3.600	3.000	0.300	0.049	—	—	0.015	0.26454	20	20	P33	F667	0.200	BAND	—	NO
4.00	4.600	4.000	0.300	0.087	—	—	0.015	0.18026	20	20	P33	F667	0.300	BAND	—	NO
6.00	7.000	6.000	0.500	0.196	—	—	0.015	0.10498	20	20	P33	F667	0.700	BAND	—	NO
8.00	9.900	8.000	0.950	0.349	—	—	0.016	0.08139	20	20	P33	F667	1.200	BAND	—	NO
10.00	11.900	10.000	0.950	0.545	—	—	0.017	0.06824	20	20	P33	F667	1.600	BAND	—	NO
12.00	14.200	12.000	1.100	0.785	—	—	0.018	0.05999	20	20	P33	F667	2.800	BAND	—	NO
15.00	17.700	15.000	1.350	1.227	—	—	0.018	0.04455	20	20	P33	F667	3.900	BAND	—	NO
18.00	21.500	18.000	1.750	1.767	—	—	0.020	0.04313	20	20	P33	F667	6.100	BAND	—	NO
24.00	28.400	24.000	2.200	3.142	—	—	0.020	0.02939	20	20	P33	F667	10.000	BAND	—	NO
Polyethylene (PE) Corrugated Pipe																
Hancor Tubing																
3.00	3.600	3.000	0.300	0.049	—	—	0.015	0.26454	20	20	P33	F667	0.200	BAND	—	NO
4.00	4.600	4.000	0.300	0.087	—	—	0.015	0.18026	20	20	P33	F667	0.300	BAND	—	NO
6.00	7.000	6.000	0.500	0.196	—	—	0.015	0.10498	20	20	P33	F667	0.700	BAND	—	NO
8.00	9.900	8.000	0.950	0.349	—	—	0.016	0.08139	20	20	P33	F667	1.200	BAND	—	NO
10.00	11.900	10.000	0.950	0.545	—	—	0.017	0.06824	20	20	P33	F667	1.600	BAND	—	NO
12.00	14.200	12.000	1.100	0.785	—	—	0.018	0.05999	20	20	P33	F667	2.100	BAND	—	NO

Pipe Type -- Size in.	O.D. Inch	I.D. Inch	Wall Thickness	Area Sq. FT	SDR GA.	Press PSI	MAN "n"	Kp	Pipe Length	Lay Length	MATL Type	ASTM No.	Weight LBS/FT	Fittings Cus/Std	Coupler O.D.	Press Rated
Steel Pipe - Galv / Black																
SCH 40, 80																
0.50	0.840	0.622	0.109	0.002	SCH 40	700	0.016	2.45272	—	—	STEEL	A53	0.850	THREAD	1.063	**NO**
0.50	0.840	0.546	0.147	0.002	SCH 80	850	0.016	2.91817	—	—	STEEL	A53	1.090	THREAD	1.063	**NO**
0.75	1.050	0.824	0.113	0.004	SCH 40	700	0.016	1.68577	—	—	STEEL	A53	1.130	THREAD	1.313	**NO**
0.75	1.050	0.742	0.154	0.003	SCH 80	850	0.016	1.93864	—	—	STEEL	A53	1.470	THREAD	1.313	**NO**
1.00	1.315	1.049	0.133	0.006	SCH 40	700	0.016	1.22180	—	—	STEEL	A53	1.680	THREAD	1.576	**NO**
1.00	1.315	0.957	0.179	0.005	SCH 80	850	0.016	1.38087	—	—	STEEL	A53	2.170	THREAD	1.576	**NO**
1.25	1.660	1.380	0.140	0.010	SCH 40	1200	0.016	0.84761	—	—	STEEL	A53	2.270	THREAD	2.054	**NO**
1.25	1.660	1.278	0.191	0.009	SCH 80	1800	0.016	0.93899	—	—	STEEL	A53	3.000	THREAD	2.054	**NO**
1.50	1.900	1.610	0.145	0.014	SCH 40	1200	0.016	0.69014	—	—	STEEL	A53	2.720	THREAD	2.200	**NO**
1.50	1.900	1.500	0.200	0.012	SCH 80	1800	0.016	0.75843	—	—	STEEL	A53	3.630	THREAD	2.200	**NO**
2.00	2.375	2.067	0.154	0.023	SCH 40	2300	0.016	0.49459	—	—	STEEL	A53	3.650	THREAD	2.875	**NO**
2.00	2.375	1.939	0.218	0.021	SCH 80	2500	0.016	0.53860	—	—	STEEL	A53	5.020	THREAD	2.875	**NO**
2.50	2.875	2.469	0.203	0.033	SCH 40	2500	0.016	0.39025	—	—	STEEL	A53	5.790	THREAD	3.375	**NO**
2.50	2.875	2.323	0.276	0.029	SCH 80	2500	0.016	0.42329	—	—	STEEL	A53	7.660	THREAD	3.375	**NO**
3.00	3.500	2.868	0.316	0.045	SCH 40	2220	0.016	0.31959	—	—	STEEL	A53	7.580	THREAD	4.000	**NO**
3.00	3.500	2.900	0.300	0.046	SCH 80	2500	0.016	0.31490	—	—	STEEL	A53	10.250	THREAD	4.000	**NO**
3.50	4.000	3.548	0.226	0.069	SCH 40	2030	0.016	0.24065	—	—	STEEL	A53	9.110	THREAD	4.625	**NO**
3.50	4.000	3.364	0.318	0.062	SCH 80	2800	0.016	0.25836	—	—	STEEL	A53	12.510	THREAD	4.625	**NO**
4.00	4.500	4.026	0.237	0.088	SCH 40	1900	0.016	0.20333	—	—	STEEL	A53	10.790	THREAD	5.200	**NO**
4.00	4.500	3.826	0.337	0.080	SCH 80	2700	0.016	0.21763	—	—	STEEL	A53	14.980	THREAD	5.200	**NO**
5.00	5.563	5.047	0.258	0.139	SCH 40	1670	0.016	0.15043	—	—	STEEL	A53	14.620	THREAD	6.296	**NO**
5.00	5.563	4.813	0.375	0.126	SCH 80	2430	0.016	0.16026	—	—	STEEL	A53	20.780	THREAD	6.296	**NO**
6.00	6.625	6.065	0.280	0.201	SCH 40	1520	0.016	0.11774	—	—	STEEL	A53	18.970	THREAD	7.390	**NO**
6.00	6.625	5.761	0.434	0.181	SCH 80	2350	0.016	0.12610	—	—	STEEL	A53	28.570	THREAD	7.390	**NO**
8.00	8.625	7.981	0.322	0.347	SCH 40	1340	0.016	0.08165	—	—	STEEL	A53	28.550	THREAD	9.625	**NO**
8.00	8.625	7.625	0.500	0.317	SCH 80	2090	0.016	0.08677	—	—	STEEL	A53	43.390	THREAD	9.625	**NO**
10.00	10.750	10.020	0.365	0.548	SCH 40	1220	0.016	0.06029	—	—	STEEL	A53	40.480	THREAD	11.750	**NO**
10.00	10.750	9.562	0.594	0.449	SCH 80	1990	0.016	0.06417	—	—	STEEL	A53	64.430	THREAD	11.750	**NO**
12.00	12.750	11.938	0.406	0.777	SCH 40	1150	0.016	0.04773	—	—	STEEL	A53	53.520	THREAD	14.000	**NO**
12.00	12.750	11.374	0.688	0.706	SCH 80	1940	0.016	0.05091	—	—	STEEL	A53	88.630	THREAD	14.000	**NO**

Pressures listed are hydrostatic test pressures only, NOT PRESSURE RATING

Pipe Type -- Size in.	O.D. Inch	I.D. Inch	Wall Thickness	Area Sq. FT	SDR GA.	Press PSI	MAN "n"	Kp	Pipe Length	Lay Length	MATL Type	ASTM No.	Weight LBS/FT	Fittings Cus/Std	Coupler O.D.	Press Rated
Corrugated Steel Pipe 2-2/3 X 1/2" Corrugations																
Round Pipe																
8.00	—	8.00	0.064	0.349	16	—	0.025	0.19871	2' INCR	2' INCR	STEEL	WWP 405	7.300	BAND	N/A	NO
10.00	—	10.00	0.064	0.545	16	—	0.025	0.14757	2' INCR	2' INCR	STEEL	WWP 405	9.000	BAND	N/A	NO
12.00	—	12.00	0.064	0.785	16	—	0.025	0.11573	2' INCR	2' INCR	STEEL	WWP 405	10.500	BAND	N/A	NO
12.00	—	12.00	0.079	0.785	14	—	0.025	0.11573	2' INCR	2' INCR	STEEL	WWP 405	13.100	BAND	N/A	NO
15.00	—	15.00	0.064	1.227	16	—	0.025	0.08595	2' INCR	2' INCR	STEEL	WWP 405	12.900	BAND	N/A	NO
15.00	—	15.00	0.079	1.227	14	—	0.025	0.08595	2' INCR	2' INCR	STEEL	WWP 405	16.100	BAND	N/A	NO
15.00	—	15.00	0.108	1.227	12	—	0.025	0.08595	2' INCR	2' INCR	STEEL	WWP 405	22.300	BAND	N/A	NO
18.00	—	18.00	0.064	1.767	16	—	0.025	0.06740	2' INCR	2' INCR	STEEL	WWP 405	15.300	BAND	N/A	NO
18.00	—	18.00	0.079	1.767	14	—	0.025	0.06740	2' INCR	2' INCR	STEEL	WWP 405	19.100	BAND	N/A	NO
18.00	—	18.00	0.108	1.767	12	—	0.025	0.06740	2' INCR	2' INCR	STEEL	WWP 405	26.400	BAND	N/A	NO
21.00	—	21.00	0.064	2.405	16	—	0.025	0.05488	2' INCR	2' INCR	STEEL	WWP 405	17.700	BAND	N/A	NO
21.00	—	21.00	0.079	2.405	14	—	0.025	0.05488	2' INCR	2' INCR	STEEL	WWP 405	22.100	BAND	N/A	NO
21.00	—	21.00	0.108	2.405	12	—	0.025	0.05488	2' INCR	2' INCR	STEEL	WWP 405	30.600	BAND	N/A	NO
24.00	—	24.00	0.064	3.142	16	—	0.025	0.04593	2' INCR	2' INCR	STEEL	WWP 405	20.400	BAND	N/A	NO
24.00	—	24.00	0.079	3.142	14	—	0.025	0.04593	2' INCR	2' INCR	STEEL	WWP 405	25.200	BAND	N/A	NO
24.00	—	24.00	0.108	3.142	12	—	0.025	0.04593	2' INCR	2' INCR	STEEL	WWP 405	34.700	BAND	N/A	NO
30.00	—	30.00	0.064	4.909	16	—	0.025	0.03411	2' INCR	2' INCR	STEEL	WWP 405	25.500	BAND	N/A	NO
30.00	—	30.00	0.079	4.909	14	—	0.025	0.03411	2' INCR	2' INCR	STEEL	WWP 405	30.900	BAND	N/A	NO
30.00	—	30.00	0.108	4.909	12	—	0.025	0.03411	2' INCR	2' INCR	STEEL	WWP 405	43.000	BAND	N/A	NO
30.00	—	30.00	0.138	4.909	10	—	0.025	0.03411	2' INCR	2' INCR	STEEL	WWP 405	54.800	BAND	N/A	NO
30.00	—	30.00	0.168	4.909	8	—	0.025	0.03411	2' INCR	2' INCR	STEEL	WWP 405	66.700	BAND	N/A	NO
36.00	—	36.00	0.064	7.069	16	—	0.025	0.02675	2' INCR	2' INCR	STEEL	WWP 405	30.400	BAND	N/A	NO
36.00	—	36.00	0.079	7.069	14	—	0.025	0.02675	2' INCR	2' INCR	STEEL	WWP 405	37.100	BAND	N/A	NO
36.00	—	36.00	0.108	7.069	12	—	0.025	0.02675	2' INCR	2' INCR	STEEL	WWP 405	51.000	BAND	N/A	NO
36.00	—	36.00	0.138	7.069	10	—	0.025	0.02675	2' INCR	2' INCR	STEEL	WWP 405	65.400	BAND	N/A	NO
36.00	—	36.00	0.168	7.069	8	—	0.025	0.02675	2' INCR	2' INCR	STEEL	WWP 405	79.400	BAND	N/A	NO
42.00	—	42.00	0.064	9.621	16	—	0.025	0.02178	2' INCR	2' INCR	STEEL	WWP 405	35.600	BAND	N/A	NO
42.00	—	42.00	0.079	9.621	14	—	0.025	0.02178	2' INCR	2' INCR	STEEL	WWP 405	43.600	BAND	N/A	NO
42.00	—	42.00	0.108	9.621	12	—	0.025	0.02178	2' INCR	2' INCR	STEEL	WWP 405	59.500	BAND	N/A	NO
42.00	—	42.00	0.138	9.621	10	—	0.025	0.02178	2' INCR	2' INCR	STEEL	WWP 405	76.800	BAND	N/A	NO
42.00	—	42.00	0.168	9.621	8	—	0.025	0.02178	2' INCR	2' INCR	STEEL	WWP 405	93.200	BAND	N/A	NO
48.00	—	48.00	0.064	12.566	16	—	0.025	0.01823	2' INCR	2' INCR	STEEL	WWP 405	40.500	BAND	N/A	NO
48.00	—	48.00	0.079	12.566	14	—	0.025	0.01823	2' INCR	2' INCR	STEEL	WWP 405	49.700	BAND	N/A	NO
48.00	—	48.00	0.108	12.566	12	—	0.025	0.01823	2' INCR	2' INCR	STEEL	WWP 405	68.000	BAND	N/A	NO
48.00	—	48.00	0.138	12.566	10	—	0.025	0.01823	2' INCR	2' INCR	STEEL	WWP 405	87.400	BAND	N/A	NO
48.00	—	48.00	0.168	12.566	8	—	0.025	0.01823	2' INCR	2' INCR	STEEL	WWP 405	106.100	BAND	N/A	NO

Pipe Type -- Size in.	O.D. Inch	I.D. Inch	Wall Thickness	Area Sq. FT	SDR GA.	Press PSI	MAN "n"	Kp	Pipe Length	Lay Length	MATL Type	ASTM No.	Weight LBS/FT	Fittings Cus/Std	Coupler O.D.
Corrugated Steel Pipe 2-2/3 X 1/2" Corrugations															
Round Pipe															
54.00	—	54.00	0.079	15.904	14	—	0.025	0.01558	2' INCR	2' INCR	STEEL	WWP 405	56.000	BAND	N/A
54.00	—	54.00	0.108	15.904	12	—	0.025	0.01558	2' INCR	2' INCR	STEEL	WWP 405	77.800	BAND	N/A
54.00	—	54.00	0.138	15.904	10	—	0.025	0.01558	2' INCR	2' INCR	STEEL	WWP 405	99.400	BAND	N/A
54.00	—	54.00	0.168	15.904	8	—	0.025	0.01558	2' INCR	2' INCR	STEEL	WWP 405	120.700	BAND	N/A
60.00	—	60.00	0.108	19.635	12	—	0.025	0.01354	2' INCR	2' INCR	STEEL	WWP 405	86.200	BAND	N/A
60.00	—	60.00	0.138	19.635	10	—	0.025	0.01354	2' INCR	2' INCR	STEEL	WWP 405	108.900	BAND	N/A
60.00	—	60.00	0.168	19.635	8	—	0.025	0.01354	2' INCR	2' INCR	STEEL	WWP 405	133.500	BAND	N/A
66.00	—	66.00	0.108	23.758	12	—	0.025	0.01192	2' INCR	2' INCR	STEEL	WWP 405	94.600	BAND	N/A
66.00	—	66.00	0.138	23.758	10	—	0.025	0.01192	2' INCR	2' INCR	STEEL	WWP 405	120.600	BAND	N/A
66.00	—	66.00	0.168	23.758	8	—	0.025	0.01192	2' INCR	2' INCR	STEEL	WWP 405	146.600	BAND	N/A
72.00	—	72.00	0.108	28.274	12	—	0.025	0.01061	2' INCR	2' INCR	STEEL	WWP 405	102.800	BAND	N/A
72.00	—	72.00	0.138	28.274	10	—	0.025	0.01061	2' INCR	2' INCR	STEEL	WWP 405	130.400	BAND	N/A
72.00	—	72.00	0.168	28.274	8	—	0.025	0.01061	2' INCR	2' INCR	STEEL	WWP 405	159.300	BAND	N/A
78.00	—	78.00	0.108	33.183	12	—	0.025	0.00954	2' INCR	2' INCR	STEEL	WWP 405	111.400	BAND	N/A
78.00	—	78.00	0.138	33.183	10	—	0.025	0.00954	2' INCR	2' INCR	STEEL	WWP 405	142.400	BAND	N/A
78.00	—	78.00	0.168	33.183	8	—	0.025	0.00954	2' INCR	2' INCR	STEEL	WWP 405	172.800	BAND	N/A
84.00	—	84.00	0.138	38.485	10	—	0.025	0.00864	2' INCR	2' INCR	STEEL	WWP 405	153.700	BAND	N/A
84.00	—	84.00	0.168	38.485	8	—	0.025		2' INCR	2' INCR	STEEL	WWP 405	185.200	BAND	N/A
90.00	—	90.00	0.138	44.179	10	—	0.025		2' INCR	2' INCR	STEEL	WWP 405	164.700	BAND	N/A
90.00	—	90.00	0.168	44.179	8	—	0.025	0.00788	2' INCR	2' INCR	STEEL	WWP 405	198.400	BAND	N/A
96.00	—	96.00	0.138	50.265	10	—	0.025	0.00723	2' INCR	2' INCR	STEEL	WWP 405	175.600	BAND	N/A
96.00	—	96.00	0.168	50.265	8	—	0.025	0.00723	2' INCR	2' INCR	STEEL	WWP 405	212.000	BAND	N/A
Corrugated Steel Pipe 3" X 1" Corrugations															
Round Pipe															
36.00	—	36.00	—	7.069	16,14,12,10,8	—	0.028	0.03355	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A
42.00	—	42.00	—	9.621	16,14,12,10,8	—	0.028	0.02732	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A
48.00	—	48.00	—	12.566	16,14,12,10,8	—	0.028	0.02286	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A
54.00	—	54.00	—	15.904	16,14,12,10,8	—	0.028	0.01954	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A
60.00	—	60.00	—	19.635	16,14,12,10,8	—	0.028	0.01698	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A
66.00	—	66.00	—	23.758	16,14,12,10,8	—	0.028	0.01495	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A
72.00	—	72.00	—	28.274	16,14,12,10,8	—	0.028	0.01331	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A
78.00	—	78.00	—	33.183	16,14,12,10,8	—	0.028	0.01197	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A
84.00	—	84.00	—	38.485	16,14,12,10,8	—	0.028	0.01084	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A
90.00	—	90.00	—	44.179	16,14,12,10,8	—	0.028	0.00989	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A
96.00	—	96.00	—	50.265	16,14,12,10,8	—	0.028	0.00907	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A
102.00	—	102.00	—	56.745	16,14,12,10,8	—	0.028	0.00837	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A
108.00	—	108.00	—	63.617	16,14,12,10,8	—	0.028	0.00775	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A
114.00	—	114.00	—	70.882	16,14,12,10,8	—	0.028	0.00722	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A
120.00	—	120.00	—	78.540	16,14,12,10,8	—	0.028	0.00674	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A

Pipe Type -- Size in.	O.D. Inch	I.D. Inch	Wall Thickness	Area Sq. FT	SDR GA.	Press PSI	MAN "n"	Kp	Pipe Length	Lay Length	MATL Type	ASTM No.	Weight LBS/FT	Fittings Cus/Std	Coupler O.D.	Press Rated
Corrugated Steel Pipe 2-2/3 X 1/2"and 3" X 1"Corrugations																
Arch Pipe	Span	Rise	A/P													
18.0 X 11"	18.0	11.000	0.272	1.010	16,14,12,10,8	—	0.025	0.10326	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A	NO
22.0 X 13"	22.0	13.000	0.332	1.563	16,14,12,10,8	—	0.025	0.07928	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A	NO
25.0 X 16"	25.0	16.000	0.396	2.171	16,14,12,10,8	—	0.025	0.06267	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A	NO
29.0 X 18"	29.0	18.000	0.451	2.857	16,14,12,10,8	—	0.025	0.05269	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A	NO
36.0 X 22"	36.0	22.000	0.552	4.331	16,14,12,10,8	—	0.025	0.04025	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A	NO
43.0 X 27"	43.0	27.000	0.672	6.388	16,14,12,10,8	—	0.025	0.03096	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A	NO
50.0 X 31"	50.0	31.000	0.773	8.484	16,14,12,10,8	—	0.025	0.02569	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A	NO
58.0 X 36"	58.0	36.000	0.897	11.440	16,14,12,10,8	—	0.025	0.02107	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A	NO
65.0 X 40"	65.0	40.000	0.999	14.220	16,14,12,10,8	—	0.025	0.01825	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A	NO
72.0 X 44"	72.0	44.000	1.102	17.310	16,14,12,10,8	—	0.025	0.01601	2' INCR	2' INCR	STEEL	WWP 405	—	BAND	N/A	NO
Welded Steel Pipe																
						safe press										
8.00	8.000	7.851	0.075	0.336	14	308	0.014	0.06390	TO 40 FT	TO 40 FT	STEEL	AWWA	6.480	Flange Dresser Welded	—	YES
8.00	8.000	7.791	0.105	0.331	12	431	0.014	0.06455	TO 40 FT	TO 40 FT	STEEL	AWWA	9.040	Flange Dresser Welded	—	YES
8.00	8.000	7.731	0.135	0.326	10	555	0.014	0.06522	TO 40 FT	TO 40 FT	STEEL	AWWA	11.580	Flange Dresser Welded	—	YES
10.00	10.000	9.851	0.075	0.529	14	247	0.014	0.04722	TO 40 FT	TO 40 FT	STEEL	AWWA	8.120	Flange Dresser Welded	—	YES
10.00	10.000	9.791	0.105	0.523	12	345	0.014	0.04760	TO 40 FT	TO 40 FT	STEEL	AWWA	11.330	Flange Dresser Welded	—	YES
10.00	10.000	9.731	0.135	0.516	10	444	0.014	0.04799	TO 40 FT	TO 40 FT	STEEL	AWWA	14.530	Flange Dresser Welded	—	YES
12.00	12.000	11.851	0.075	0.766	14	208	0.014	0.03690	TO 40 FT	TO 40 FT	STEEL	AWWA	9.760	Flange Dresser Welded	—	YES
12.00	12.000	11.791	0.105	0.758	12	288	0.014	0.03715	TO 40 FT	TO 40 FT	STEEL	AWWA	13.620	Flange Dresser Welded	—	YES
12.00	12.000	11.731	0.135	0.751	10	370	0.014	0.03741	TO 40 FT	TO 40 FT	STEEL	AWWA	17.470	Flange Dresser Welded	—	YES
12.00	12.000	11.641	0.179	0.739	7	493	0.014	0.03779	TO 40 FT	TO 40 FT	STEEL	AWWA	23.210	Flange Dresser Welded	—	YES
12.00	12.000	11.500	0.250	0.721	14	625	0.014	0.03841	TO 40 FT	TO 40 FT	STEEL	AWWA	31.380	Flange Dresser Welded	—	YES
12.75	12.750	12.391	0.179	0.837	7	464	0.014	0.03477	TO 40 FT	TO 40 FT	STEEL	AWWA	24.680	Flange Dresser Welded	—	YES
12.75	12.750	12.250	0.250	0.818	1/4	588	0.014	0.03531	TO 40 FT	TO 40 FT	STEEL	AWWA	33.380	Flange Dresser Welded	—	YES
14.00	14.000	13.851	0.075	1.046	14	176	0.014	0.02997	TO 40 FT	TO 40 FT	STEEL	AWWA	11.390	Flange Dresser Welded	—	YES
14.00	14.000	13.791	0.105	1.037	12	247	0.014	0.03015	TO 40 FT	TO 40 FT	STEEL	AWWA	15.920	Flange Dresser Welded	—	YES
14.00	14.000	13.731	0.135	1.028	10	317	0.014	0.03032	TO 40 FT	TO 40 FT	STEEL	AWWA	20.420	Flange Dresser Welded	—	YES
14.00	14.000	13.641	0.179	1.015	7	423	0.014	0.03059	TO 40 FT	TO 40 FT	STEEL	AWWA	27.140	Flange Dresser Welded	—	YES
14.00	14.000	13.500	0.250	0.994	1/4	536	0.014	0.03102	TO 40 FT	TO 40 FT	STEEL	AWWA	36.720	Flange Dresser Welded	—	YES
16.00	16.000	15.851	0.075	1.370	14	154	0.014	0.02504	TO 40 FT	TO 40 FT	STEEL	AWWA	13.030	Flange Dresser Welded	—	YES
16.00	16.000	15.791	0.105	1.360	12	216	0.014	0.02517	TO 40 FT	TO 40 FT	STEEL	AWWA	18.210	Flange Dresser Welded	—	YES
16.00	16.000	15.731	0.135	1.350	10	277	0.014	0.02530	TO 40 FT	TO 40 FT	STEEL	AWWA	23.360	Flange Dresser Welded	—	YES
16.00	16.000	15.641	0.179	1.334	7	370	0.014	0.02549	TO 40 FT	TO 40 FT	STEEL	AWWA	31.060	Flange Dresser Welded	—	YES
16.00	16.000	15.500	0.250	1.310	1/4	468	0.014	0.02580	TO 40 FT	TO 40 FT	STEEL	AWWA	42.060	Flange Dresser Welded	—	YES
16.00	16.000	15.375	0.313	1.289	5/16	585	0.014	0.02608	TO 40 FT	TO 40 FT	STEEL	AWWA	52.360	Flange Dresser Welded	—	YES

Pipe Type -- Size in.	O.D. Inch	I.D. Inch	Wall Thickness	Area Sq. FT	SDR GA.	Press PSI	MAN "n"	Kp	Pipe Length	Lay Length	MATL Type	ASTM No.	Weight LBS/FT	Fittings Cus/Std	Coupler O.D.	Press Rated
Welded Steel Pipe																
18.00	18.00	17.851	0.075	1.738	14	137	0.014	0.02137	TO 40 FT	TO 40 FT	STEEL	AWWA	14.670	Flange Dresser Welded	—	YES
18.00	18.00	17.791	0.105	1.726	12	192	0.014	0.02147	TO 40 FT	TO 40 FT	STEEL	AWWA	20.500	Flange Dresser Welded	—	YES
18.00	18.00	17.731	0.135	1.715	10	247	0.014	0.02156	TO 40 FT	TO 40 FT	STEEL	AWWA	26.310	Flange Dresser Welded	—	YES
18.00	18.00	17.641	0.179	1.697	7	329	0.014	0.02171	TO 40 FT	TO 40 FT	STEEL	AWWA	34.990	Flange Dresser Welded	—	YES
18.00	18.00	17.500	0.250	1.670	1/4	416	0.014	0.02195	TO 40 FT	TO 40 FT	STEEL	AWWA	47.400	Flange Dresser Welded	—	YES
18.00	18.00	17.375	0.313	1.647	5/16	520	0.014	0.02216	TO 40 FT	TO 40 FT	STEEL	AWWA	59.040	Flange Dresser Welded	—	YES
20.00	20.00	19.851	0.075	2.149	14	123	0.014	0.01855	TO 40 FT	TO 40 FT	STEEL	AWWA	16.300	Flange Dresser Welded	—	YES
20.00	20.00	19.791	0.105	2.136	12	173	0.014	0.01863	TO 40 FT	TO 40 FT	STEEL	AWWA	22.790	Flange Dresser Welded	—	YES
20.00	20.00	19.731	0.135	2.123	10	222	0.014	0.01870	TO 40 FT	TO 40 FT	STEEL	AWWA	29.520	Flange Dresser Welded	—	YES
20.00	20.00	19.641	0.179	2.104	7	296	0.014	0.01881	TO 40 FT	TO 40 FT	STEEL	AWWA	38.920	Flange Dresser Welded	—	YES
20.00	20.00	19.500	0.250	2.074	1/4	375	0.014	0.01900	TO 40 FT	TO 40 FT	STEEL	AWWA	52.740	Flange Dresser Welded	—	YES
20.00	20.00	19.375	0.313	2.047	5/16	468	0.014	0.01916	TO 40 FT	TO 40 FT	STEEL	AWWA	65.720	Flange Dresser Welded	—	YES
Welded Steel Pipe Also Available in Sizes to 120"																
Concrete Pipe ASTM C76					**CLASS**											
12.0	16.0	12.0	2.000	0.785	V	UP TO 125 FT HEAD WITH GASKET	0.011	0.02240	—	4, 6, 8	CONCRETE	C76	95	STD / CUS	N/A	NO
15.0	19.5	15.0	2.250	1.227	IV		0.011	0.01664	—	4, 6, 8	CONCRETE	C76	130	STD / CUS	N/A	NO
18.0	23.0	18.0	2.500	1.767	II		0.011	0.01305	—	4, 6, 8	CONCRETE	C76	170	STD / CUS	N/A	NO
21.0	26.5	21.0	2.750	2.405	II		0.011	0.01062	—	4, 6, 8	CONCRETE	C76	215	STD / CUS	N/A	NO
24.0	30.0	24.0	3.000	3.142	II		0.011	0.00889	—	4, 6, 8	CONCRETE	C76	270	STD / CUS	N/A	NO
27.0	33.5	27.0	3.250	3.976	II		0.011	0.00760	—	4, 6, 8	CONCRETE	C76	325	STD / CUS	N/A	NO
30.0	37.0	30.0	3.500	4.909	II		0.011	0.00660	—	4, 6, 8	CONCRETE	C76	390	STD / CUS	N/A	NO
33.0	40.5	33.0	3.750	5.940	II		0.011	0.00582	—	4, 6, 8	CONCRETE	C76	460	STD / CUS	N/A	NO
36.0	44.0	36.0	4.000	7.069	II		0.011	0.00518	—	4, 6, 8	CONCRETE	C76	535	STD / CUS	N/A	NO
42.0	51.0	42.0	4.500	9.621	II		0.011	0.00422	—	4, 6, 8	CONCRETE	C76	700	STD / CUS	N/A	NO
48.0	58.0	48.0	5.000	12.566	II		0.011	0.00353	—	4, 6, 8	CONCRETE	C76	885	STD / CUS	N/A	NO
54.0	65.0	54.0	5.500	15.904	II		0.011	0.00302	—	4, 6, 8	CONCRETE	C76	1095	STD / CUS	N/A	NO
60.0	72.0	60.0	6.000	19.635	II		0.011	0.00262	—	4, 6, 8	CONCRETE	C76	1325	STD / CUS	N/A	NO
66.0	79.0	66.0	6.500	23.758	II		0.011	0.00231	—	4, 6, 8	CONCRETE	C76	1580	STD / CUS	N/A	NO
72.0	86.0	72.0	7.000	28.274	II		0.011	0.00205	—	4, 6, 8	CONCRETE	C76	1860	STD / CUS	N/A	NO
78.0	93.0	78.0	7.500	33.138	II		0.011	0.00185	—	4, 6, 8	CONCRETE	C76	2160	STD / CUS	N/A	NO
84.0	100.0	84.0	8.000	38.485	II		0.011	0.00167	—	4, 6, 8	CONCRETE	C76	2480	STD / CUS	N/A	NO
90.0	107.0	90.0	8.500	44.179	II		0.011	0.00153	—	4, 6, 8	CONCRETE	C76	2820	STD / CUS	N/A	NO
96.0	114.0	96.0	9.000	50.265	II		0.011	0.00140	—	4, 6, 8	CONCRETE	C76	3190	STD / CUS	N/A	NO
102.0	121.0	102.0	9.500	56.745	II		0.011	0.00129	—	4, 6, 8	CONCRETE	C76	3590	STD / CUS	N/A	NO
108.0	128.0	108.0	10.000	63.617	II		0.011	0.00120	—	4, 6, 8	CONCRETE	C76	4030	STD / CUS	N/A	NO
120.0	140.0	120.0	10.000	78.540	II		0.011	0.00104	—	4, 6, 8	CONCRETE	C76	4481	STD / CUS	N/A	NO

Pipe Type -- Size in.	O.D. Inch	I.D. Inch	Wall Thickness	Area Sq. FT	SDR GA.	Press PSI	MAN "n"	Kp	Pipe Length	Lay Length	MATL Type	ASTM No.	Weight LBS/FT	Fittings Cus/Std	Coupler O.D.	Press Rated
Concrete Tile Sand Aggregate																
(Non-Reinforced)																
20.00	23.500	20.000	1.750	2.182	—	—	—	—	—	1, 2	CONCRETE	—	100.0	STD	N /A	NO
30.00	36.000	30.000	3.000	4.909	—	—	—	—	—	1, 2	CONCRETE	—	300.0	STD	N /A	NO
42.00	49.000	42.000	3.500	9.621	—	—	—	—	—	2	CONCRETE	—	450.0	STD	N /A	NO
Hadite - Expanded Shale Aggregate Tile																
20.00	23.500	20.000	1.750	2.182	—	—	—	—	—	1, 2	Hadite	—	75.0	STD	N /A	NO
30.00	36.000	30.000	3.000	4.909	—	—	—	—	—	1, 2	Hadite	—	200.0	STD	N /A	NO

Pipe Data Notes:

1. Lines with Blue font indicate Pipe classes which may be non-standard or special order,(other lines which are not Blue font may also be non-standard)

2. SDR (Standard Dimension Ration) - O.D. / Wall Thickness

3. Kp Calculated for Round pipe =(5087)n^2/I.D.^4/3
   Kp Calculated for Arch pipe =(29.16)n^2/r^4/3 r= hyraulic radius=A/P

4. Max depth shown is maximum recommended bury depth and is intended as a guide only and may be appropriate for some applications. Consult application reference material for specific depths.

5. Pipe weight in LBS/FT may be used to estimate pipe cost if current costs for similar pipe class is known. Typical pipe costs are proportional on a per pound of material bases.

6. Fitting Abbreviations are as follows:

SOLV - Solvent weld
BELL - Socket joint with bell and gasket
GAS - Gasketed joint
CUS - Custom fittings(Elbow, etc.) Available on special order
INSERT - Insert fitting of inside diameter used with pipe clamps
FUSION - Butt fusion joints -field welded with special tools
BAND - Bands which clamp over two sections of pipe (not watertight) unless special sealant is used
THREADED - Standard pipe thread coupler

7. Cost data should be considered an estimate only and is intended more for comparison between different pipe rather than a firm cost estimate. Update as necessary (Costs shown are contractor or wholesale)

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Table B-1
PVC SDR-26 160 PSI

PVC-SDR PIPE
FRICTION LOSS ft/100 ft
SDR 26, Pressure Rating = 160 psi @ 73.4° F
Hazen Williams C = 150

Q Gallons per min.	1 inch 0.0078 A 1.195 ID	1-1/4 inch 0.0128 A 1.532 ID	1-1/2 inch 0.0168 A 1.754 ID	2 inch 0.0262 A 2.193 ID	2-1/2 inch 0.0384 A 2.655 ID	3 inch 0.0569 A 3.230 ID	3-1/2 inch 0.0743 A 3.692 ID	4 inch 0.0941 A 4.154 ID
1	0.0408	0.0122	0.0063	0.0021	0.0008	0.0003	0.0002	0.0001
2	0.1473	0.0439	0.0227	0.0077	0.0030	0.0012	0.0006	0.0003
3	0.3120	0.0931	0.0481	0.0162	0.0064	0.0025	0.0013	0.0007
4	0.5316	0.1585	0.0820	0.0276	0.0109	0.0042	0.0022	0.0012
5	0.8036	0.2397	0.1240	0.0418	0.0165	0.0063	0.0033	0.0019
6	1.1264	0.3359	0.1738	0.0585	0.0231	0.0089	0.0046	0.0026
7	1.4985	0.4469	0.2312	0.0779	0.0307	0.0118	0.0062	0.0035
8	1.9189	0.5722	0.2960	0.0997	0.0393	0.0151	0.0079	0.0044
9	2.3866	0.7117	0.3682	0.1241	0.0489	0.0188	0.0098	0.0055
10	2.9008	0.8651	0.4475	0.1508	0.0594	0.0229	0.0119	0.0067
11	3.4607	1.0321	0.5339	0.1799	0.0709	0.0273	0.0142	0.0080
12	4.0658	1.2125	0.6273	0.2113	0.0833	0.0321	0.0167	0.0094
13	4.7154	1.4062	0.7275	0.2451	0.0966	0.0372	0.0194	0.0109
14	5.4091	1.6131	0.8345	0.2812	0.1108	0.0427	0.0222	0.0125
15	6.1463	1.8329	0.9482	0.3195	0.1259	0.0485	0.0253	0.0142
16	6.9265	2.0656	1.0686	0.3600	0.1419	0.0546	0.0285	0.0160
17	7.7495	2.3110	1.1956	0.4028	0.1588	0.0611	0.0319	0.0179
18	(1)	2.5691	1.3290	0.4478	0.1765	0.0679	0.0354	0.0199
19	(1)	2.8396	1.4690	0.4949	0.1951	0.0751	0.0392	0.0220
20	(1)	3.1226	1.6154	0.5443	0.2145	0.0826	0.0431	0.0242
21	(1)	3.4178	1.7681	0.5957	0.2348	0.0904	0.0471	0.0265
22	(1)	3.7253	1.9272	0.6493	0.2559	0.0985	0.0514	0.0289
23	(1)	4.0450	2.0926	0.7050	0.2779	0.1070	0.0558	0.0314
24	(1)	4.3767	2.2642	0.7628	0.3007	0.1157	0.0603	0.0340
25	(1)	4.7203	2.4420	0.8227	0.3243	0.1248	0.0651	0.0367

(1) Exceeds 5.0 feet per second velocity
(2) A = Flow area, square feet
(3) For ASTM D2241, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different ratings, see ASTM D2241.

Table B-2
PVC SDR-21 200 PSI

PVC-SDR PIPE
FRICTION LOSS ft/100 ft
SDR 21, Pressure Rating = 200 psi @ 73.4° F
Hazen Williams C = 150

Q Gallons per min.	1 inch 0.0077 A 1.198 ID	1-1/4 inch 0.0123 A 1.502 ID	1-1/2 inch 0.0161 A 1.720 ID	2 inch 0.0252 A 2.149 ID	2-1/2 inch 0.0369 A 2.601 ID	3 inch 0.0547 A 3.166 ID	3-1/2 inch 0.0715 A 3.620 ID	4 inch 0.0904 A 4.072 ID
1	0.0403	0.0134	0.0069	0.0023	0.0009	0.0004	0.0002	0.0001
2	0.1455	0.0484	0.0250	0.0084	0.0033	0.0013	0.0007	0.0004
3	0.3083	0.1025	0.0530	0.0179	0.0071	0.0027	0.0014	0.0008
4	0.5252	0.1746	0.0902	0.0305	0.0120	0.0046	0.0024	0.0014
5	0.7939	0.2639	0.1364	0.0461	0.0182	0.0070	0.0036	0.0021
6	1.1127	0.3699	0.1912	0.0646	0.0255	0.0098	0.0051	0.0029
7	1.4803	0.4921	0.2543	0.0860	0.0339	0.0130	0.0068	0.0038
8	1.8956	0.6301	0.3257	0.1101	0.0434	0.0167	0.0087	0.0049
9	2.3576	0.7837	0.4050	0.1369	0.0540	0.0207	0.0108	0.0061
10	2.8656	0.9525	0.4923	0.1664	0.0657	0.0252	0.0131	0.0074
11	3.4187	1.1364	0.5873	0.1985	0.0784	0.0301	0.0157	0.0088
12	4.0165	1.3351	0.6900	0.2333	0.0921	0.0353	0.0184	0.0104
13	4.6582	1.5484	0.8002	0.2705	0.1068	0.0410	0.0213	0.0120
14	5.3434	1.7762	0.9180	0.3103	0.1225	0.0470	0.0245	0.0138
15	6.0717	2.0182	1.0431	0.3526	0.1392	0.0534	0.0278	0.0157
16	6.8425	2.2745	1.1755	0.3974	0.1568	0.0602	0.0313	0.0177
17	7.6554	2.5447	1.3151	0.4446	0.1755	0.0674	0.0351	0.0198
18	(1)	2.8288	1.4620	0.4942	0.1951	0.0749	0.0390	0.0220
19	(1)	3.1267	1.6159	0.5463	0.2156	0.0828	0.0431	0.0243
20	(1)	3.4383	1.7770	0.6007	0.2371	0.0910	0.0474	0.0267
21	(1)	3.7634	1.9450	0.6575	0.2595	0.0996	0.0519	0.0292
22	(1)	4.1020	2.1200	0.7167	0.2828	0.1086	0.0565	0.0319
23	(1)	4.4539	2.3019	0.7782	0.3071	0.1179	0.0614	0.0346
24	(1)	4.8192	2.4906	0.8420	0.3323	0.1276	0.0664	0.0374
25	(1)	5.1976	2.6862	0.9081	0.3584	0.1376	0.0716	0.0404

(1) Exceeds 5.0 feet per second velocity
(2) A = Flow area, square feet
(3) For ASTM D2241, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different ratings, see ASTM D2241.

Table B-3
PVC SDR-17 250PSI

PVC-SDR PIPE
FRICTION LOSS ft/100 ft
SDR 17, Pressure Rating = 250 psi @ 73.4° F
Hazen Williams C = 150

Q Gallons per min.	1 inch 0.0074 A 1.162 ID	1-1/4 inch 0.0117 A 1.464 ID	1-1/2 inch 0.0153 A 1.676 ID	2 inch 0.0239 A 2.095 ID	2-1/2 inch 0.0351 A 2.537 ID	3 inch 0.0520 A 3.088 ID	3-1/2 inch 0.0680 A 3.530 ID	4 inch 0.0860 A 3.970 ID
1	0.0470	0.0152	0.0079	0.0026	0.0010	0.0004	0.0002	0.0001
2	0.1695	0.0548	0.0284	0.0096	0.0038	0.0014	0.0008	0.0004
3	0.3592	0.1161	0.0601	0.0203	0.0080	0.0031	0.0016	0.0009
4	0.6118	0.1978	0.1024	0.0345	0.0136	0.0052	0.0027	0.0015
5	0.9249	0.2990	0.1547	0.0522	0.0205	0.0079	0.0041	0.0023
6	1.2964	0.4190	0.2169	0.0731	0.0288	0.0111	0.0058	0.0033
7	1.7247	0.5575	0.2885	0.0973	0.0383	0.0147	0.0077	0.0043
8	2.2085	0.7139	0.3695	0.1246	0.0491	0.0188	0.0098	0.0055
9	2.7468	0.8879	0.4595	0.1550	0.0610	0.0234	0.0122	0.0069
10	3.3386	1.0791	0.5585	0.1884	0.0742	0.0285	0.0148	0.0084
11	3.9831	1.2875	0.6663	0.2247	0.0885	0.0340	0.0177	0.0100
12	4.6795	1.5126	0.7828	0.2640	0.1039	0.0399	0.0208	0.0117
13	5.4272	1.7542	0.9079	0.3062	0.1205	0.0463	0.0241	0.0136
14	6.2255	2.0123	1.0414	0.3513	0.1383	0.0531	0.0277	0.0156
15	7.0740	2.2865	1.1834	0.3992	0.1571	0.0603	0.0314	0.0177
16	7.9720	2.5768	1.3336	0.4498	0.1771	0.0680	0.0354	0.0200
17	(1)	2.8830	1.4921	0.5033	0.1981	0.0761	0.0396	0.0224
18	(1)	3.2048	1.6587	0.5595	0.2202	0.0846	0.0441	0.0249
19	(1)	3.5423	1.8333	0.6184	0.2434	0.0935	0.0487	0.0275
20	(1)	3.8953	2.0160	0.6800	0.2677	0.1028	0.0536	0.0302
21	(1)	4.2637	2.2066	0.7443	0.2930	0.1125	0.0586	0.0331
22	(1)	4.6472	2.4052	0.8113	0.3193	0.1226	0.0639	0.0361
23	(1)	5.0460	2.6115	0.8809	0.3467	0.1331	0.0694	0.0392
24	(1)	5.4598	2.8257	0.9531	0.3752	0.1440	0.0751	0.0424
25	(1)	5.8885	3.0476	1.0279	0.4046	0.1554	0.0810	0.0457

(1) Exceeds 5.0 feet per second velocity
(2) A = Flow area, square feet
(3) For ASTM D2241, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different ratings, see ASTM D2241.

Table B-4
PVC SDR-13.5 315PSI

PVC-SDR PIPE
FRICTION LOSS ft/100 ft
SDR 13.5, Pressure Rating = 315 psi @ 73.4° F
Hazen Williams C = 150

Q Gallons per min.	1 inch 0.0069 A 1.121 ID	1-1/4 inch 0.0109 A 1.414 ID	1-1/2 inch 0.0143 A 1.618 ID	2 inch 0.0223 A 2.023 ID	2-1/2 inch 0.0327 A 2.449 ID	3 inch 0.0485 A 2.982 ID	3-1/2 inch 0.0633 A 3.408 ID	4 inch 0.0802 A 3.834 ID
1	0.0557	0.0180	0.0093	0.0031	0.0012	0.0005	0.0002	0.0001
2	0.2011	0.0649	0.0337	0.0113	0.0045	0.0017	0.0009	0.0005
3	0.4260	0.1375	0.0713	0.0240	0.0095	0.0036	0.0019	0.0011
4	0.7258	0.2342	0.1215	0.0409	0.0161	0.0062	0.0032	0.0018
5	1.0972	0.3541	0.1837	0.0619	0.0244	0.0094	0.0049	0.0027
6	1.5378	0.4963	0.2575	0.0867	0.0342	0.0131	0.0068	0.0039
7	2.0459	0.6603	0.3425	0.1154	0.0455	0.0174	0.0091	0.0051
8	2.6198	0.8455	0.4386	0.1478	0.0583	0.0223	0.0117	0.0066
9	3.2583	1.0516	0.5455	0.1838	0.0725	0.0278	0.0145	0.0082
10	3.9603	1.2782	0.6630	0.2234	0.0881	0.0338	0.0176	0.0099
11	4.7248	1.5249	0.7910	0.2665	0.1051	0.0403	0.0210	0.0118
12	5.5509	1.7915	0.9293	0.3131	0.1234	0.0473	0.0247	0.0139
13	6.4378	2.0777	1.0778	0.3631	0.1432	0.0549	0.0286	0.0161
14	7.3848	2.3834	1.2363	0.4165	0.1642	0.0629	0.0328	0.0185
15	8.3912	2.7082	1.4048	0.4733	0.1866	0.0715	0.0373	0.0210
16	(1)	3.0520	1.5832	0.5334	0.2103	0.0806	0.0421	0.0237
17	(1)	3.4146	1.7713	0.5967	0.2353	0.0902	0.0471	0.0265
18	(1)	3.7958	1.9690	0.6633	0.2615	0.1002	0.0523	0.0295
19	(1)	4.1956	2.1764	0.7332	0.2891	0.1108	0.0578	0.0326
20	(1)	4.6137	2.3932	0.8063	0.3179	0.1218	0.0636	0.0358
21	(1)	5.0499	2.6195	0.8825	0.3479	0.1334	0.0696	0.0392
22	(1)	5.5042	2.8552	0.9619	0.3792	0.1453	0.0759	0.0427
23	(1)	5.9765	3.1002	1.0444	0.4118	0.1578	0.0824	0.0464
24	(1)	6.4666	3.3544	1.1301	0.4456	0.1708	0.0891	0.0502
25	(1)	(1)	3.6178	1.2188	0.4805	0.1842	0.0961	0.0542

(1) Exceeds 5.0 feet per second velocity
(2) A = Flow area, square feet
(3) For ASTM D2241, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different ratings, see ASTM D2241.

Table B-5
PVC Schedule 40

Table 5.6
PVC-IPS SCHEDULE RATED PIPE
FRICTION LOSS ft/100 ft
Schedule 40 (3)
Hazen Williams C = 150

Q Gallons per min.	1 inch 450 psi 0.0060 A 1.049 ID	1-1/4 inch 370 psi 0.0104 A 1.380 ID	1-1/2 inch 330 psi 0.0141 A 1.610 ID	2 inch 280 psi 0.0233 A 2.067 ID	2-1/2 inch 300 psi 0.0332 A 2.469 ID	3 inch 260 psi 0.0513 A 3.068 ID	3-1/2 inch 240 psi 0.0687 A 3.548 ID	4 inch 220 psi 0.0884 A 4.026 ID
1	0.0770	0.0202	0.0096	0.0028	0.0012	0.0004	0.0002	0.0001
2	0.2778	0.0731	0.0345	0.0102	0.0043	0.0015	0.0007	0.0004
3	0.5886	0.1548	0.0731	0.0216	0.0091	0.0032	0.0016	0.0008
4	1.0028	0.2637	0.1245	0.0369	0.0155	0.0054	0.0027	0.0014
5	1.5159	0.3987	0.1882	0.0557	0.0234	0.0081	0.0040	0.0022
6	2.1248	0.5588	0.2637	0.0781	0.0329	0.0114	0.0056	0.0030
7	2.8267	0.7434	0.3509	0.1039	0.0437	0.0152	0.0075	0.0040
8	3.6198	0.9519	0.4493	0.1331	0.0560	0.0194	0.0096	0.0052
9	4.5020	1.1839	0.5588	0.1655	0.0696	0.0242	0.0119	0.0064
10	5.4720	1.4390	0.6792	0.2011	0.0846	0.0294	0.0145	0.0078
11	6.5282	1.7168	0.8103	0.2400	0.1010	0.0351	0.0173	0.0093
12	7.6696	2.0170	0.9520	0.2819	0.1186	0.0412	0.0203	0.0110
13	8.8950	2.3392	1.1041	0.3270	0.1376	0.0478	0.0235	0.0127
14	(1)	2.6833	1.2665	0.3751	0.1578	0.0548	0.0270	0.0146
15	(1)	3.0490	1.4391	0.4262	0.1793	0.0623	0.0307	0.0166
16	(1)	3.4361	1.6218	0.4803	0.2021	0.0702	0.0346	0.0187
17	(1)	3.8443	1.8145	0.5374	0.2261	0.0785	0.0387	0.0209
18	(1)	4.2736	2.0171	0.5973	0.2514	0.0873	0.0430	0.0232
19	(1)	4.7236	2.2296	0.6603	0.2779	0.0965	0.0475	0.0257
20	(1)	5.1943	2.4517	0.7260	0.3055	0.1061	0.0523	0.0282
21	(1)	5.6855	2.6836	0.7947	0.3344	0.1161	0.0572	0.0309
22	(1)	6.1970	2.9250	0.8662	0.3645	0.1266	0.0623	0.0337
23	(1)	6.7287	3.1760	0.9405	0.3958	0.1374	0.0677	0.0366
24	(1)	(1)	3.4364	1.0176	0.4283	0.1487	0.0732	0.0396
25	(1)	(1)	3.7062	1.0976	0.4619	0.1604	0.0790	0.0427

(1) Exceeds 5.0 feet per second velocity
(2) A = Flow area, square feet
(3) For ASTM D1785, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different pressure ratings, see ASTM D1785. Pressure rating is at 73.4° F.

Table B-6
PVC Schedule 80

PVC-IPS SCHEDULE RATED PIPE
FRICTION LOSS ft/100 ft
Schedule 80 (3)
Hazen Williams C = 150

Q Gallons per min.	1 inch 630 psi 0.0050 A 0.957 ID	1-1/4 inch 520 psi 0.0089 A 1.278 ID	1-1/2 inch 470 psi 0.0123 A 1.500 ID	2 inch 400 psi 0.0205 A 1.939 ID	2-1/2 inch 420 psi 0.0294 A 2.323 ID	3 inch 370 psi 0.0459 A 2.900 ID	3-1/2 inch 350 psi 0.0617 A 3.364 ID	4 inch 320 psi 0.0798 A 3.826 ID
1	0.1203	0.0294	0.0135	0.0039	0.0016	0.0005	0.0003	0.0001
2	0.4344	0.1062	0.0487	0.0139	0.0058	0.0020	0.0010	0.0005
3	0.9204	0.2250	0.1031	0.0295	0.0123	0.0042	0.0020	0.0011
4	1.5681	0.3833	0.1757	0.0503	0.0209	0.0071	0.0034	0.0018
5	2.3704	0.5795	0.2656	0.0761	0.0316	0.0107	0.0052	0.0028
6	3.3225	0.8122	0.3723	0.1066	0.0442	0.0150	0.0073	0.0039
7	4.4202	1.0805	0.4953	0.1419	0.0588	0.0200	0.0097	0.0052
8	5.6602	1.3836	0.6342	0.1817	0.0753	0.0256	0.0124	0.0066
9	7.0397	1.7209	0.7888	0.2259	0.0937	0.0318	0.0154	0.0082
10	8.5564	2.0916	0.9587	0.2746	0.1139	0.0387	0.0188	0.0100
11	10.2081	2.4954	1.1438	0.3276	0.1359	0.0461	0.0224	0.0120
12	(1)	2.9317	1.3438	0.3849	0.1596	0.0542	0.0263	0.0141
13	(1)	3.4001	1.5585	0.4464	0.1852	0.0628	0.0305	0.0163
14	(1)	3.9002	1.7877	0.5121	0.2124	0.0721	0.0350	0.0187
15	(1)	4.4318	2.0314	0.5818	0.2413	0.0819	0.0398	0.0212
16	(1)	4.9944	2.2893	0.6557	0.2720	0.0923	0.0448	0.0239
17	(1)	5.5878	2.5613	0.7336	0.3043	0.1033	0.0501	0.0268
18	(1)	6.2117	2.8472	0.8155	0.3383	0.1148	0.0557	0.0298
19	(1)	6.8658	3.1471	0.9014	0.3739	0.1269	0.0616	0.0329
20	(1)	(1)	3.4607	0.9912	0.4111	0.1396	0.0677	0.0362
21	(1)	(1)	3.7879	1.0850	0.4500	0.1527	0.0741	0.0396
22	(1)	(1)	4.1287	1.1826	0.4905	0.1665	0.0808	0.0432
23	(1)	(1)	4.4829	1.2841	0.5326	0.1808	0.0877	0.0469
24	(1)	(1)	4.8506	1.3893	0.5763	0.1956	0.0949	0.0507
25	(1)	(1)	5.2315	1.4984	0.6215	0.2110	0.1024	0.0547

(1) Exceeds 5.0 feet per second velocity
(2) A = Flow area, square feet
(3) For ASTM D1785, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different pressure ratings, see ASTM D1785. Pressure rating is at 73.4° F.

Table B-7
PVC Schedule 120

PVC-IPS SCHEDULE RATED PIPE
FRICTION LOSS ft/100 ft
Schedule 120 (3)
Hazen Williams C = 150

Q Gallons per min.	1 inch 720 psi 0.0060 A 0.915 ID	1-1/4 inch 600 psi 0.0104 A 1.230 ID	1-1/2 inch 540 psi 0.0141 A 1.450 ID	2 inch 470 psi 0.0233 A 1.875 ID	2-1/2 inch 470 psi 0.0332 A 2.275 ID	3 inch 440 psi 0.0513 A 2.800 ID	3-1/2 inch 380 psi 0.0687 A 3.300 ID	4 inch 430 psi 0.0884 A 3.626 ID
1	0.1498	0.0354	0.0159	0.0045	0.0018	0.0006	0.0003	0.0002
2	0.5405	0.1280	0.0574	0.0164	0.0064	0.0023	0.0010	0.0007
3	1.1453	0.2711	0.1216	0.0348	0.0136	0.0049	0.0022	0.0014
4	1.9512	0.4619	0.2072	0.0593	0.0231	0.0084	0.0038	0.0024
5	2.9496	0.6982	0.3133	0.0896	0.0349	0.0127	0.0057	0.0036
6	4.1342	0.9786	0.4391	0.1256	0.0490	0.0178	0.0080	0.0051
7	5.5000	1.3020	0.5842	0.1671	0.0651	0.0237	0.0106	0.0067
8	7.0430	1.6672	0.7481	0.2139	0.0834	0.0303	0.0136	0.0086
9	8.7596	2.0736	0.9304	0.2661	0.1037	0.0377	0.0170	0.0107
10	10.6468	2.5203	1.1308	0.3234	0.1261	0.0459	0.0206	0.0130
11	(1)	3.0068	1.3491	0.3858	0.1504	0.0547	0.0246	0.0155
12	(1)	3.5325	1.5850	0.4533	0.1767	0.0643	0.0289	0.0183
13	(1)	4.0970	1.8383	0.5257	0.2050	0.0746	0.0335	0.0212
14	(1)	4.6996	2.1087	0.6030	0.2351	0.0855	0.0384	0.0243
15	(1)	5.3401	2.3961	0.6852	0.2672	0.0972	0.0437	0.0276
16	(1)	6.0180	2.7003	0.7722	0.3011	0.1095	0.0492	0.0311
17	(1)	6.7331	3.0211	0.8639	0.3369	0.1225	0.0550	0.0348
18	(1)	7.4848	3.3584	0.9604	0.3745	0.1362	0.0612	0.0387
19	(1)	(1)	3.7121	1.0615	0.4139	0.1506	0.0676	0.0427
20	(1)	(1)	4.0819	1.1673	0.4552	0.1656	0.0744	0.0470
21	(1)	(1)	4.4679	1.2776	0.4982	0.1812	0.0814	0.0515
22	(1)	(1)	4.8699	1.3926	0.5430	0.1975	0.0887	0.0561
23	(1)	(1)	5.2877	1.5121	0.5896	0.2145	0.0963	0.0609
24	(1)	(1)	5.7214	1.6361	0.6380	0.2321	0.1042	0.0659
25	(1)	(1)	6.1706	1.7646	0.6881	0.2503	0.1124	0.0711

(1) Exceeds 5.0 feet per second velocity
(2) A = Flow area, square feet
(3) For ASTM D1785, materials 1120, 1120 or 2120. These are the most commonly used materials. Other materials have different pressure ratings, see ASTM D1785. Pressure rating is at 73.4° F.

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Table B-8
PE ID Controlled (Insert Fittings)

Table 5.9
POLYETHYLENE (PE) SDIR-PR RATED PIPE
FRICTION LOSS ft/100 ft
ASTM D2239 (3)
Hazen Williams C = 145

Q Gallons per min.	1 inch 0.0060 A 1.049 ID	1-1/4 inch 0.0104 A 1.380 ID	1-1/2 inch 0.0141 A 1.610 ID	2 inch 0.0233 A 2.069 ID	2-1/2 inch 0.0333 A 2.469 ID	3 inch 0.0513 A 3.068 ID	4 inch 0.0884 A 4.026 ID
1	0.0820	0.0216	0.0102	0.0030	0.0013	0.0004	0.0001
2	0.2958	0.0778	0.0367	0.0109	0.0046	0.0016	0.0004
3	0.6268	0.1648	0.0778	0.0230	0.0097	0.0034	0.0009
4	1.0678	0.2808	0.1325	0.0393	0.0165	0.0057	0.0015
5	1.6142	0.4245	0.2004	0.0593	0.0250	0.0087	0.0023
6	2.2624	0.5950	0.2808	0.0832	0.0350	0.0122	0.0032
7	3.0099	0.7915	0.3736	0.1106	0.0466	0.0162	0.0043
8	3.8543	1.0136	0.4784	0.1417	0.0596	0.0207	0.0055
9	4.7937	1.2606	0.5950	0.1762	0.0742	0.0257	0.0069
10	5.8265	1.5322	0.7232	0.2142	0.0901	0.0313	0.0083
11	6.9512	1.8280	0.8628	0.2555	0.1075	0.0373	0.0099
12	8.1666	2.1476	1.0137	0.3002	0.1263	0.0439	0.0117
13	9.4714	2.4908	1.1757	0.3482	0.1465	0.0509	0.0135
14	(1)	2.8572	1.3486	0.3994	0.1681	0.0583	0.0155
15	(1)	3.2466	1.5324	0.4538	0.1910	0.0663	0.0176
16	(1)	3.6587	1.7269	0.5114	0.2152	0.0747	0.0199
17	(1)	4.0934	1.9321	0.5722	0.2408	0.0836	0.0223
18	(1)	4.5505	2.1478	0.6361	0.2677	0.0929	0.0247
19	(1)	5.0297	2.3740	0.7030	0.2959	0.1027	0.0273
20	(1)	5.5308	2.6106	0.7731	0.3253	0.1130	0.0301
21	(1)	6.0538	2.8574	0.8462	0.3561	0.1236	0.0329
22	(1)	6.5985	3.1145	0.9223	0.3881	0.1348	0.0359
23	(1)	7.1646	3.3817	1.0015	0.4214	0.1463	0.0389
24	(1)	(1)	3.6590	1.0836	0.4560	0.1583	0.0421
25	(1)	(1)	3.9464	1.1687	0.4918	0.1707	0.0455

Table B-9
PE OD Controlled (Butt Fusion)

Table 5.10

HIGH DENSITY POLYETHYLENE (HDPE)
FRICTION LOSS ft/100 ft
ASTM D1248, Type III
Hazen Williams C = 150

Q Gallons per min.	1-1/2 inch 130 psi SDR 13.5 0.0143 A 1.62 ID	2 inch 130 psi SDR 13.5 0.0220 A 2.01 ID	1-1/2 inch 160 psi SDR 11 0.0131 A 1.55 ID	2 inch 160 psi SDR 11 0.0203 A 1.93 ID	1-1/2 inch 200 psi SDR 9 0.0119 A 1.48 ID	2 inch 200 psi SDR 9 0.0183 A 1.83 ID	1-1/2 inch 255 psi SDR 7.3 0.0104 A 1.38 ID	2 inch 255 psi SDR 7.3 0.0159 A 1.71 ID
1	0.0093	0.0032	0.0115	0.0040	0.0144	0.0051	0.0202	0.0071
2	0.0335	0.0117	0.0415	0.0143	0.0520	0.0185	0.0731	0.0257
3	0.0709	0.0248	0.0879	0.0302	0.1101	0.0392	0.1548	0.0545
4	0.1208	0.0422	0.1498	0.0515	0.1876	0.0667	0.2637	0.0928
5	0.1826	0.0639	0.2264	0.0778	0.2835	0.1008	0.3987	0.1403
6	0.2559	0.0895	0.3173	0.1091	0.3974	0.1413	0.5588	0.1967
7	0.3405	0.1191	0.4222	0.1451	0.5287	0.1880	0.7434	0.2616
8	0.4360	0.1525	0.5406	0.1858	0.6771	0.2408	0.9519	0.3350
9	0.5422	0.1896	0.6724	0.2311	0.8421	0.2995	1.1839	0.4167
10	0.6590	0.2305	0.8172	0.2809	1.0235	0.3640	1.4390	0.5065
11	0.7863	0.2750	0.9750	0.3351	1.2211	0.4343	1.7168	0.6042
12	0.9237	0.3231	1.1454	0.3937	1.4346	0.5102	2.0170	0.7099
13	1.0713	0.3747	1.3285	0.4566	1.6638	0.5917	2.3392	0.8233
14	1.2289	0.4298	1.5239	0.5238	1.9085	0.6787	2.6833	0.9444
15	1.3964	0.4884	1.7316	0.5952	2.1686	0.7712	3.0490	1.0731
16	1.5737	0.5504	1.9514	0.6707	2.4439	0.8691	3.4361	1.2093
17	1.7606	0.6158	2.1832	0.7504	2.7343	0.9724	3.8443	1.3530
18	1.9572	0.6845	2.4270	0.8342	3.0396	1.0810	4.2736	1.5041
19	2.1633	0.7566	2.6826	0.9221	3.3597	1.1948	4.7236	1.6625
20	2.3789	0.8320	2.9499	1.0140	3.6945	1.3139	5.1943	1.8282
21	2.6038	0.9107	3.2288	1.1098	4.0438	1.4381	5.6855	2.0010
22	2.8381	0.9926	3.5193	1.2097	4.4076	1.5675	6.1970	2.1810
23	3.0816	1.0777	3.8213	1.3135	4.7858	1.7020	6.7287	2.3682
24	3.3343	1.1661	4.1346	1.4212	5.1783	1.8416	(1)	2.5624
25	3.5961	1.2577	4.4593	1.5328	5.5849	1.9862	(1)	2.7636

(1) Exceeds 5.0 feet per second velocity
(2) Flow area, square feet

Table B-10
Galvanized or Black Steel – Schedule 40

Table 5.14
BLACK OR GALVANIZED STEEL PIPE
FRICTION LOSS ft/100 ft
Schedule 40 (Standard)
Seamless & Electric Welded ASTM A120
Hazen Williams C = 100

Q Gallons per min.	1/2 inch 350 psi 0.0021 A 0.622 ID	3/4 inch 350 psi 0.0037 A 0.824 ID	1 inch 350 psi 0.0060 A 1.049 ID	1-1/4 inch 500 psi 0.0104 A 1.380 ID	1-1/2 inch 500 psi 0.0141 A 1.610 ID	2 inch 500 psi 0.0233 A 2.067 ID	2-1/2 inch 500 psi 0.0332 A 2.469 ID	3 inch 500 psi 0.0513 A 3.068 ID
1	2.0792	0.5285	0.1631	0.0429	0.0202	0.0060	0.0025	0.0009
2	7.5050	1.9077	0.5886	0.1548	0.0731	0.0216	0.0091	0.0032
3	15.9018	4.0420	1.2472	0.3280	0.1548	0.0458	0.0193	0.0067
4	27.0903	6.8859	2.1248	0.5588	0.2637	0.0781	0.0329	0.0114
5	40.9521	10.4094	3.2120	0.8447	0.3987	0.1181	0.0497	0.0173
6	57.3995	14.5900	4.5020	1.1839	0.5588	0.1655	0.0696	0.0242
7	76.3630	19.4103	5.9894	1.5751	0.7434	0.2202	0.0926	0.0322
8	97.7858	24.8556	7.6696	2.0170	0.9520	0.2819	0.1186	0.0412
9	121.6193	30.9137	9.5390	2.5085	1.1840	0.3506	0.1476	0.0512
10	(1)	37.5740	11.5941	3.0490	1.4391	0.4262	0.1793	0.0623
11	(1)	44.8270	13.8322	3.6376	1.7169	0.5085	0.2140	0.0743
12	(1)	52.6646	16.2506	4.2736	2.0171	0.5973	0.2514	0.0873
13	(1)	61.0791	18.8470	4.9564	2.3394	0.6928	0.2915	0.1012
14	(1)	70.0639	21.6194	5.6855	2.6836	0.7947	0.3344	0.1161
15	(1)	79.6125	24.5658	6.4603	3.0493	0.9030	0.3800	0.1319
16	(1)	89.7194	27.6845	7.2804	3.4364	1.0176	0.4283	0.1487
17	(1)	(1)	30.9738	8.1455	3.8447	1.1386	0.4791	0.1663
18	(1)	(1)	34.4321	9.0549	4.2739	1.2657	0.5326	0.1849
19	(1)	(1)	38.0581	10.0085	4.7240	1.3990	0.5887	0.2044
20	(1)	(1)	41.8504	11.0058	5.1948	1.5384	0.6474	0.2248
21	(1)	(1)	45.8077	12.0465	5.6860	1.6838	0.7086	0.2460
22	(1)	(1)	49.9289	13.1303	6.1975	1.8353	0.7723	0.2681
23	(1)	(1)	54.2129	14.2569	6.7293	1.9928	0.8386	0.2912
24	(1)	(1)	58.6585	15.4260	7.2811	2.1562	0.9074	0.3150
25	(1)	(1)	63.2648	16.6373	7.8529	2.3255	0.9786	0.3398

(1) Exceeds 10.0 feet per second velocity
(2) A = Flow area, square feet
(3) It is good design practice to design steel pipe operating pressure for not more that 50% of test pressure. The pressures shown are 50% of ASTM A120 test pressures.

Table B-11
Galvanized or Black Steel – Schedule 80

BLACK OR GALVANIZED STEEL PIPE
FRICTION LOSS ft/100 ft
Schedule 80 (Standard)
Seamless & Electric Welded ASTM A120
Hazen Williams C = 100

Q Gallons per min.	1/2 inch 424 psi 0.0016 A 0.546 ID	3/4 inch 425 psi 0.0030 A 0.742 ID	1 inch 425 psi 0.0050 A 0.957 ID	1-1/4 inch 750 psi 0.0089 A 1.278 ID	1-1/2 inch 750 psi 0.0123 A 1.500 ID	2 inch 750 psi 0.0205 A 1.939 ID	2-1/2 inch 750 psi 0.0294 A 2.323 ID	3 inch 750 psi 0.0459 A 2.900 ID
1	3.9223	0.8805	0.2550	0.0623	0.0286	0.0082	0.0034	0.0012
2	14.1580	3.1784	0.9204	0.2250	0.1031	0.0295	0.0123	0.0042
3	29.9983	6.7346	1.9503	0.4767	0.2185	0.0626	0.0260	0.0088
4	51.1052	11.4730	3.3225	0.8122	0.3723	0.1066	0.0442	0.0150
5	77.2552	17.3436	5.0226	1.2278	0.5628	0.1612	0.0669	0.0227
6	108.2829	24.3093	7.0397	1.7209	0.7888	0.2259	0.0937	0.0318
7	144.0573	32.3405	9.3655	2.2894	1.0494	0.3006	0.1247	0.0423
8	(1)	41.4133	11.9929	2.9317	1.3438	0.3849	0.1596	0.0542
9	(1)	51.5070	14.9160	3.6462	1.6713	0.4787	0.1986	0.0674
10	(1)	62.6040	18.1296	4.4318	2.0314	0.5818	0.2413	0.0819
11	(1)	74.6888	21.6292	5.2872	2.4235	0.6942	0.2879	0.0977
12	(1)	87.7474	25.4108	6.2117	2.8472	0.8155	0.3383	0.1148
13	(1)	101.7673	29.4709	7.2041	3.3022	0.9458	0.3923	0.1332
14	(1)	(1)	33.8060	8.2639	3.7879	1.0850	0.4500	0.1527
15	(1)	(1)	38.4133	9.3901	4.3041	1.2328	0.5114	0.1736
16	(1)	(1)	43.2899	10.5822	4.8506	1.3893	0.5763	0.1956
17	(1)	(1)	48.4333	11.8395	5.4269	1.5544	0.6447	0.2188
18	(1)	(1)	53.8411	13.1614	6.0328	1.7280	0.7167	0.2433
19	(1)	(1)	59.5110	14.5474	6.6681	1.9099	0.7922	0.2689
20	(1)	(1)	65.4410	15.9970	7.3325	2.1003	0.8711	0.2957
21	(1)	(1)	71.6290	17.5097	8.0259	2.2989	0.9535	0.3236
22	(1)	(1)	78.0733	19.0850	8.7480	2.5057	1.0393	0.3528
23	(1)	(1)	(1)	20.7225	9.4986	2.7207	1.1285	0.3830
24	(1)	(1)	(1)	22.4218	10.2775	2.9438	1.2210	0.4144
25	(1)	(1)	(1)	24.1825	11.0845	3.1749	1.3169	0.4470

(1) Exceeds 10.0 feet per second velocity
(2) A = Flow area, square feet
(3) It is good design practice to design steel pipe operating pressure for not more that 50% of test pressure. The pressures shown are 50% of ASTM A120 test pressures.

Table B-12
Stainless Steel Tubing Nominal Dimensions

Seamless, not corroded ASTM A106, A312-TP 304 or TP316						
Weight or Sch.	**Nom. Size**	**OD (in)**	**Nom. Wall (in)**	**Min. Wall (in)**	**Plain Ends Max. psi**	**Thd'd Ends Max. psi**
5S	1/2	.84	.065	.0568	2863.4	
10S	1/2	.84	.083	.0726	3715.3	
40S	1/2	.84	.109	.0953	4995.4**	1889.3
80S	1/2	.84	.147	.1286	6980	3652.5
5S	3/4	1.05	.065	.0568	2264.8	
10S	3/4	1.05	.083	.0726	2928.7	
40S	3/4	1.05	.113	.0988	4073.5**	1642
80S	3/4	1.05	.154	.1347	5720.6	3142.2
5S	1	1.315	.065	.0568	1792	
10S	1	1.315	.109	.0953	3079.8**	
40S	1	1.315	.133	.1163	3796.4**	1453.5
80S	1	1.315	.179	.1566	5266	2796.3
5S	1.5	1.9	.065	.0568	1226.7	
10S	1.5	1.9	.109	.0953	2091.9**	
40S	1.5	1.9	.145	.1268	2821.8	1236.3
80S	1.5	1.9	.2	.175	3977.2	2322.7
5S	2	2.375	.065	.0568	976.6	
10S	2	2.375	.109	.0953	1659.6**	
40S	2	2.375	.154	.1347	2377.3	592.1
80S	2	2.375	.218	.1907	3433.2	1576.6

Stainless Steel Tubing (-325°F to +300°F)

Table B-13
Red Brass Pipe Nominal Dimensions

Red Brass Pipe (-325°F to +300°F)

Seamless, not corroded ASTM B43 Annealed						
Weight or Sch.	**Nom. Size**	**OD (in)**	**Nom. Wall (in)**	**Min. Wall (in)**	**Plain Ends Max. psi**	**Thd'd Ends Max. psi**
Std.	1/2	.84	.107	.101	2128.5	871.7
XH	1/2	.84	.149	.141	3102.3	1735.9
Std.	3/4	1.05	.114	.108	1793.2	806.2
XH	3/4	1.05	.157	.148	2541.8	1487.4
Std.	1	1.315	.126	.119	1560.9	620.1
XH	1	1.315	.182	.172	2337.3	1329.1

Table B-14
Red Brass Pipe Allowable Working Pressure

ALLOWABLE INTERNAL PRESSURE (psi)

Red Brass (alloy 230) Pipe and Nipples

IMPORTANT: The figures below are provided as a general guide, only to show approximate and relative pressures allowable. Numerous factors can result in lower or higher allowed pressures, such as temper of pipe, type of joint and joining materials, type and length of threads and the specific nature and configuration of application. Therefore, **do not use and do not rely** on the below listed pressure ratings when pressure is any consideration in the application, but consult a competent engineer and refer to ANSI B 31.

(All figures are in psi, at the given temperature in Farenheit)

Std. Nom. Pipe, Dia.	Nipples (threaded pipe) @100F	@300F	@400F	Pipe (plain ends) @100F	@300F	@400F
Regular (Sched. 40)						
1/8"	370	370	230	2640	2640	1650
1/4"	870	870	550	2610	2610	1640
3/8"	890	890	570	2280	2280	1440
1/2"	900	900	570	2160	2160	1350
3/4"	810	810	520	1800	1800	1130
1"	630	630	400	1580	1580	1000
1-1/4"	690	690	430	1440	1440	900
1-1/2"	630	630	400	1280	1280	800
2"	540	540	350	1050	1050	670
2-1/2"	450	450	280	1040	1040	650
3"	510	510	320	1000	1000	630
3-1/2"	570	570	370	1000	1000	630
4"	510	510	320	880	880	550
5"	410	410	270	710	710	450
6"	340	340	220	600	600	380
8"	360	360	230	560	560	350
10"	360	360	230	520	520	330
12"	320	320	200	450	450	280
Extra Strong (Sched. 80)						
1/8"	1960	1960	1240	4630	4630	2900
1/4"	2210	2210	1340	4200	4200	2640
3/8"	1840	1840	1150	3360	3360	2100
1/2"	1760	1760	1100	3130	3130	1970
3/4"	1510	1510	950	2560	2560	1600
1"	1340	1340	850	2360	2360	1490
1-1/4"	1160	1160	730	1950	1950	1220
1-1/2"	1090	1090	680	1770	1770	1120
2"	1000	1000	630	1520	1520	950
2-1/2"	970	970	620	1600	1600	1000
3"	910	910	570	1420	1420	900
3-1/2"	860	860	550	1300	1300	820
4"	840	840	530	1230	1230	770
5"	770	770	480	1080	1080	680
6"	800	800	500	1060	1060	670
8"	710	710	450	910	910	570
10"	550	550	350	710	710	450

Subject to errors - Not Responsible/Not Liable for errors.

Values based on formula in The Code for Pressure Piping, ANSI B 31.

Table B-15
Table of Dimensions and Weights of Copper Tube Types K, L, M

Dimensions and Weights of Types K, L, M[1] and DWV[2] Tube

Nominal or Standard Size, in.	Outside Diameter, in. All Types	Inside Diameter, in.				Wall Thickness, in.				Theoretical Weight Pounds per Linear Foot			
		K	L	M	DWV	K	L	M	DWV	K	L	M	DWV
1/4	0.375	0.305	0.315	*	*	0.035	0.030	*	*	0.145	0.126	*	*
3/8	0.500	0.402	0.430	0.450	*	0.049	0.035	0.025	*	0.269	0.198	0.145	*
1/2	0.625	0.527	0.545	0.569	*	0.049	0.040	0.028	*	0.344	0.285	0.204	*
5/8	0.750	0.652	0.666	*	*	0.049	0.042	*	*	0.418	0.362	*	*
3/4	0.875	0.745	0.785	0.811	*	0.065	0.045	0.032	*	0.641	0.455	0.328	*
1	1.125	0.995	1.025	1.055	*	0.065	0.050	0.035	*	0.839	0.655	0.465	*
1-1/4	1.375	1.245	1.265	1.291	1.295	0.065	0.055	0.042	0.040	1.04	0.884	0.682	0.650
1-1/2	1.625	1.481	1.505	1.527	1.541	0.072	0.060	0.049	0.042	1.36	1.14	0.940	0.809
2	2.125	1.959	1.985	2.009	2.041	0.083	0.070	0.058	0.042	2.06	1.75	1.46	1.07
2-1/2	2.625	2.435	2.465	2.495	*	0.095	0.080	0.065	*	2.93	2.48	2.03	*
3	3.125	2.907	2.945	2.981	3.030	0.109	0.090	0.072	0.045	4.00	3.33	2.68	1.69
3-1/2	3.625	3.385	3.425	3.459	*	0.120	0.100	0.083	*	5.12	4.29	3.58	*
4	4.125	3.857	3.905	3.935	4.009	0.134	0.110	0.095	0.058	6.51	5.38	4.66	2.87
5	5.125	4.805	4.875	4.907	4.981	0.160	0.125	0.109	0.072	9.67	7.61	6.66	4.43
6	6.125	5.741	5.845	5.881	5.959	0.192	0.140	0.122	0.083	13.9	10.2	8.92	6.10
8	8.125	7.583	7.725	7.785	7.907	0.271	0.200	0.170	0.109	25.9	19.3	16.5	10.6
10	10.125	9.449	9.625	9.701	*	0.338	0.250	0.212	*	40.3	30.1	25.6	*
12	12.125	11.315	11.565	11.617	*	0.405	0.280	0.254	*	57.8	40.4	36.7	*

[1] ASTM B 88-96
[2] ASTM B 306-96
* Not available

Table B-16
Recommended Maximum Working Pressure for Copper Solder Joints

Recommended Maximum Internal Working Pressure (psi) for Joints in Types K, L, and M Tube

Solder or Brazing Alloy Used in Joints	Service Temperature °F	Nominal or Standard Size, in. 1/4 to 1 (incl)	1-1/4 to 2 (incl)	2-1/2 to 4 (incl)	5 to 8 (incl)
50 - 50 Tin-Lead Solder[1][2]	100	200	175	150	130
	150	150	125	100	90
	200	100	90	75	70
	250	85	75	50	50
	Saturated Steam	15	15	15	15
95 - 5 Tin-Antimony Solder[1]	100	500	400	300	150
	150	400	350	275	150
	200	300	250	200	150
	250	200	175	150	140
	Saturated Steam	15	15	15	15
Brazing Alloys Melting at or above 1100°F	100-150-200	*	*	*	*
	250	300	210	170	150
	350	270	190	150	150
	Saturated Steam	120	120	120	120

[1] See ASTM B 32
[2] Not permitted in potable (drinking) water systems.
* Recommended maximum pressure is the rated pressure of annealed tube shown in Table 6.

Table B-17
Rated Working Pressure for Copper Types K, L, and M

Rated Internal Working Pressure (psi) for Types K, L, and M Tube[1]

Nominal or Standard Size, in.	TYPE	Annealed[2]							Drawn[3]						
		S = 6000 psi 100°F	S = 5100 psi 150°F	S = 4800 psi 200°F	S = 4800 psi 250°F	S = 4700 psi 300°F	S = 4000 psi 350°F	S = 3000 psi 400°F	S = 9000 psi 100°F	S = 9000 psi 150°F	S = 9000 psi 200°F	S = 9000 psi 250°F	S = 8700 psi 300°F	S = 8500 psi 350°F	S = 8200 psi 400°F
1/4	K	1074	913	860	860	842	716	537	1612	1612	1612	1612	1558	1522	1468
	L	912	775	729	729	714	608	456	1367	1367	1367	1367	1322	1292	1246
	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3/8	K	1130	960	904	904	885	753	565	1695	1695	1695	1695	1638	1601	1544
	L	779	662	623	623	610	519	389	1168	1168	1168	1168	1129	1103	1064
	M	570	485	456	456	447	380	285	855	855	855	855	827	808	779
1/2	K	891	758	713	713	698	594	446	1337	1337	1337	1337	1293	1263	1218
	L	722	613	577	577	565	481	361	1082	1082	1082	1082	1046	1022	986
	M	494	420	395	395	387	329	247	741	741	741	741	716	700	675
5/8	K	736	626	589	589	577	491	368	1104	1104	1104	1104	1067	1043	1006
	L	631	537	505	505	495	421	316	947	947	947	947	916	895	863
	M	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3/4	K	852	724	682	682	668	568	426	1278	1278	1278	1278	1236	1207	1165
	L	582	495	466	466	456	388	291	873	873	873	873	844	825	796
	M	407	346	326	326	319	271	204	611	611	611	611	590	577	556
1	K	655	557	524	524	513	437	327	982	982	982	982	949	928	895
	L	494	420	395	395	387	330	247	741	741	741	741	717	700	676
	M	337	286	270	270	264	225	169	506	506	506	506	489	477	461
1-1/4	K	532	452	425	425	416	354	266	797	797	797	797	771	753	727
	L	439	373	351	351	344	293	219	658	658	658	658	636	622	600
	M	338	287	271	271	265	225	169	507	507	507	507	490	479	462
1-1/2	K	494	420	396	396	387	330	247	742	742	742	742	717	700	676
	L	408	347	327	327	320	272	204	613	613	613	613	592	579	558
	M	331	282	265	265	259	221	166	497	497	497	497	480	469	453
2	K	435	370	348	348	341	290	217	652	652	652	652	630	616	594
	L	364	309	291	291	285	242	182	545	545	545	545	527	515	497
	M	299	254	239	239	234	199	149	448	448	448	448	433	423	408
2-1/2	K	398	338	319	319	312	265	199	597	597	597	597	577	564	544
	L	336	285	269	269	263	224	168	504	504	504	504	487	476	459
	M	274	233	219	219	215	183	137	411	411	411	411	397	388	375
3	K	385	328	308	308	302	257	193	578	578	578	578	559	546	527
	L	317	270	254	254	248	211	159	476	476	476	476	460	449	433
	M	253	215	203	203	199	169	127	380	380	380	380	367	359	346
3-1/2	K	366	311	293	293	286	244	183	549	549	549	549	530	518	500
	L	304	258	243	243	238	202	152	455	455	455	455	440	430	415
	M	252	214	202	202	197	168	126	378	378	378	378	366	357	345
4	K	360	306	288	288	282	240	180	540	540	540	540	522	510	492
	L	293	249	235	235	230	196	147	440	440	440	440	425	415	401
	M	251	213	201	201	197	167	126	377	377	377	377	364	356	343
5	K	345	293	276	276	270	230	172	517	517	517	517	500	488	471
	L	269	229	215	215	211	179	135	404	404	404	404	390	381	368
	M	233	198	186	186	182	155	116	349	349	349	349	338	330	318
6	K	346	295	277	277	271	231	173	520	520	520	520	502	491	474
	L	251	213	201	201	196	167	125	376	376	376	376	364	355	343
	M	218	186	175	175	171	146	109	328	328	328	328	317	310	299
8	K	369	314	295	295	289	246	184	553	553	553	553	535	523	504
	L	270	230	216	216	212	180	135	406	406	406	406	392	383	370
	M	229	195	183	183	180	153	115	344	344	344	344	332	325	313
10	K	369	314	295	295	289	246	184	553	553	553	553	535	523	504
	L	271	231	217	217	212	181	136	407	407	407	407	393	384	371
	M	230	195	184	184	180	153	115	344	344	344	344	333	325	314
12	K	370	314	296	296	290	247	185	555	555	555	555	536	524	506
	L	253	215	203	203	199	169	127	380	380	380	380	368	359	346
	M	230	195	184	184	180	153	115	345	345	345	345	333	326	314

[1] Based on maximum allowable stress in tension (psi) for the indicated temperatures.
[2] Type M tube is not available in the annealed temper. Annealed values are provided for guidance when drawn temper Type M is brazed or welded.
[3] When brazing or welding is used to join drawn tube, the corresponding annealed rating must be used.

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WELL PUMPS AND PIPING

Kevin Rafferty
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Well pumps for larger geothermal applications are normally of the lineshaft, vertical turbine type with the electric motor located on the surface. This type of pump with oil lubrication and adequate allowance for thermal expansion has proven to be a reliable design. Unfortunately, it is not an economical selection for small residential and commercial applications. In fact, there really is no completely satisfactory solution to small flow rate, hot water well pumping applications. The two most commonly used options are conventional electric submersible pumps and jet pumps.

SUBMERSIBLE PUMPS

In the case of conventional submersibles, most manufacturers warrantee their submersible motors for continuous operation in water equal to or less than 86°F. To operate standard motors in water temperatures in excess of this value, a combination of strategies can be used. This involves assuring a minimum flow rate past the motor for cooling and possibly increasing the motor size. A major manufacturer (Franklin, 1999) of submersible motors recommends the following procedure:

> "A minimum water velocity past the motor of 3 ft/sec is required for applications in which the water temperature exceeds 86°F. For small applications, using a nominal 4" submersible motor, this would require a minimum flow rate of 15 gpm and the use of nominal 4" well casing or a 4" ID flow inducer sleeve. The sleeve is a sheet metal shroud that fits over the motor and forces the water to flow past the motor before entering the pump intake. Flow inducer sleeves are available from the motor manufacturer as an accessory."

In addition to assuring the minimum flow velocity past the motor is achieved, it may also be necessary, depending upon the water temperature, to increase the size of the motor as well. This is only necessary at water temperatures greater than 122°F for small motors (<5 hp), and water temperatures greater than 113°F for medium size motors (7.5 to 30 hps). Table 1 provides "Temperature Correction Factors" for submersible motors. The values in the table assume that other measures have been taken to assure a minimum velocity of 3 ft/sec past the motor as discussed above.

The required brake horsepower from the pump manufacturers curve is multiplied by the "Temperature Correction Factors" from Table 1. The resulting "corrected horsepower" is then used to select a motor with a "Service Factor Horsepower" of equal or greater value from Table 2.

Table 1. Temperature Correction Factor (Franklin, 1999)

Max. Water Temp.	<5 HP	7.5 to 30 HP
140	1.25	1.62
131	1.11	1.32
122	1.00	1.14
113 and below	1.00	1.00

Table 2. Service Factor Horsepower (Franklin, 1999)

Nominal HP	Service Factor HP
1/3	0.58
½	0.80
3/4	1.12
1	1.40
1 ½	1.95
2	2.50
3	3.45
5	5.75
7 ½	8.65
10	11.50
15	17.25
20	23.00

Example: Select a motor for an application in which the water temperature is 137°F and a break horsepower requirement of 2.1 hp. In a normal cold-water application, we might choose a nominal 2-hp motor for this duty. Based on the water temperature, however, a "Temperature Correction Factor" of 1.25 is selected from Table 1. Multiplying the correction factor by the required BHP results in a corrected horsepower of 2.63 hp. From Table 2, we would select a nominal 3-hp motor for this application. Since it is the smallest motor with a service factor horsepower higher than the 2.63 required.

This procedure can be used for applications up to a temperature of 140°F. As an alternative, or for water temperatures up to 167°F, a motor specifically designed for operation at higher water temperatures must be used. These motors are available from at least one manufacturer in sizes of 2 through 10 hp in 3-phase and 2-, 3- and 5-hp single phase. No special shrouding or sizing considerations apply. Since these motors are designed for oil field duty and are low-production products, a significant cost premium applies.

JET PUMPS

An alternative to submersible pumps is the jet pump. This is a type of well pump in which both the pump and electric motor are located aboveground and thus, special consideration related to submersible motors are eliminated. This type of pump recirculates a flow of water between the surface and a "jet" located below the water surface in the well. The configuration of the "jet" (more accurately a venturi) causes the recirculating water to draw in water from the well and deliver it to the surface. These pumps are less efficient than submersible pumps and for a given horsepower may produce only 20 to 30% of the flow as submersibles. Based on data available in the Geo-Heat Center, most jet pump systems have a maximum allowable water temperature of 140°F; though, we are aware of systems in which they have been successful at temperatures up to 180°F. These temperatures appear to be more related to the pump than to the downhole components (piping and jet). Jet pumps are limited to 1-1/2 hp and flow rates of approximately 10 gpm at a depth to water of 50 ft.

PRESSURE TANKS

Pressure tanks can be used to deliver hot water to a small heating system just as they are used for delivering cold water to the home. Older, air cushion-type tanks, in which the air is directly exposed to the geothermal water are not recommended. This type of tank allows the water to absorb oxygen from the air and greatly accelerates the corrosion of any iron and/or steel components downstream. Pressure tanks used for hot water applications should be of the "diaphragm" type. Most tanks equipped with a butyl rubber diaphragm have a maximum water temperature rating of 160°F. Some larger tanks are rated for as high as 200°F water. Be sure to verify that the tank you are using is rated for operation at a water temperature equal to or greater than the well water temperature.

PIPING

Pipe Sizing

The size of pipe necessary for a particular flow rate is determined by the pressure drop which is considered acceptable by the designer. Some general guidelines have been developed in the past for this purpose. Basically, the decision is based upon a balance between the pumping costs over the life of the line (to overcome the pressure loss) compared to the first cost of the pipe. Larger pipe costs more to buy, but results in lower pressure drop (and pumping cost) for a given flow rate. Based on maximum pressure loss rate of 4 ft per 100 ft of pipe recommended by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) in their energy consumption standard 90, the following maximum flow rates for various pipe sizes would apply:

Table 3. Recommended Maximum Flow Rates

Nominal Pipe Size (inches)	Maximum Flow Rate (gpm)
½	2
3/4	4
1	8
1 1/4	12
1 ½	22
2	40
2 ½	70
3	120
4	260
6	550

Plastic Pipe for Hot Water Applications

Both steel and copper pipe should be used with caution in direct-buried installations carrying geothermal water. Steel pipe is susceptible to both interior (from the geothermal water) and external (from soil moisture) corrosion. Of these, past experience has proven that the exterior corrosion is by far the most serious. Uninsulated steel pipe carrying hot water appears to have a useful service life of approximately 7 to 10 years. Copper pipe suffers less from exterior corrosion than steel, but is more susceptible to interior corrosion from the geothermal fluid. Most geothermal fluids contain some hydrogen sulphide, the compound that gives the water a rotten egg smell. Hydrogen sulphide is very aggressive toward copper. In addition, some geothermal fluids can rapidly (3 to 4 years) deteriorate the solder used to join the copper pipe. For these reasons, these otherwise standard materials have seen little use in geothermal applications, unless a heat exchanger is used to isolate the geothermal fluid.

Piping, to deliver hot water from the well to the pressure tank or to the point of use, can be of a variety of materials. Plastic materials are often used to eliminate the danger of corrosion, both internal and external. The most commonly available plastic piping materials are PVC and CPVC. In both cases, it is necessary to evaluate the suitability of the pipe in terms of both temperature and pressure. Thermoplastic piping is characterized by a diminished ability to handle pressure at elevated temperatures. PVC pipe has a maximum service water temperature of 140°F and CPVC a maximum service temperature of 180°F. In both cases, the pressure rating of the pipe is greatly reduced at these temperatures. Table 4 provides pressure rating adjustment factors for PVC and CPVC piping at various water temperatures.

Table 4. PVC and CPVC Pressure Rating Correction Factors (NIBCO, undated)

Temperature	PVC	CPVC
70	1.0	1.0
80	0.9	0.96
90	0.75	0.92
100	0.52	0.85
110	0.50	0.77
120	0.40	0.70
130	0.30	0.62
140	0.22	0.55
150	NR	0.47
160	NR	0.40
170	NR	0.32
180	NR	0.25

Table 5. Maximum Operating Pressure in PSI (NIBCO, undated)

Nominal Size	
½	600
3/4	480
1	450
1 1/4	370
1 ½	330
2	280
2 ½	300
3	260
4	220
6	180

Example: Calculate the maximum operating pressure for 2-in. PVC pipe at a temperature of 130°F.

Table 5 presents pressure ratings for both PVC and CPVC pipe at 73°F. To arrive at the maximum operating pressure for any other temperature, multiply the temperature correction factor from Table 4 times the 73°F pressure rating in Table 5.

From Table 5, the pressure rating at 73°F is 280 psi. At 130°F, a de-rating factor of 0.30 applies. This results in a maximum operating pressure for this application of 0.30 x 280 = 84 psi.

The question of heat loss from buried piping is a frequent concern of small system owners. Whether or not the piping will lose enough heat to significantly reduce the temperature of the water at the other end of the line is worth some evaluation. Heat Loss from buried piping is influenced by the soil thermal conductivity, pipe material, water temperature and burial depth among other parameters. Figure 1 presents heat loss information for plastic (PVC and CPVC) pipe at a 3-ft burial depth for two different soil types and three different pipe sizes. The highest heat losses are experienced

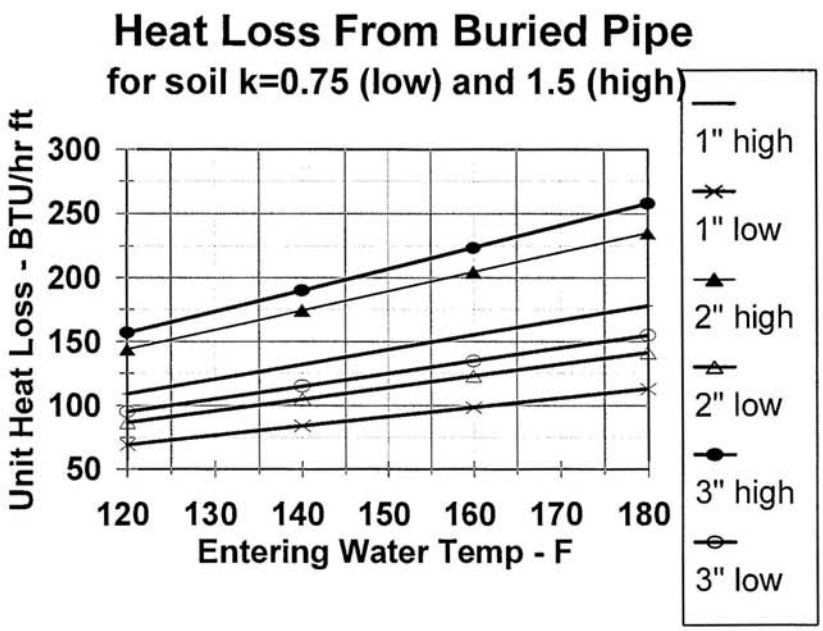

Figure 1. Heat loss from buried pipe (soil k - 0.75 (low) and 1.5 (high)).

in heavy damp soil, indicated as "high" (1.5 Btu/hr•ft) in the figure. Dry, light soil indicated as "low" (0.75 Btu/hr•ft) in the figure retards heat losses. Most soils will fall somewhere between these two. The descriptors high and low refer to the thermal conductivity (Figure 1) of the soil usually expressed in Btu/hr•ft°F. The figure provides heat loss in Btu/hr per linear ft. In order to determine the temperature loss in a line, it is necessary to know the length and the quantity of water flowing (gpm) in the line. The greater the flow rate, the lower the temperature change for a given situation.

Example: Calculate the heat loss and temperature drop for a 2-in. line, 250 ft long which is carrying 10 gpm of 150°F water. Assume worst case conditions for the soil.

From Figure 1, the heat loss per foot is approximately 1750 Btu/hr per linear foot using the curve for high heat loss (high soil thermal conductivity). The total heat loss for the line would be 175 Btu/hr x 250 ft = 43,750 Btu/hr.

The temperature drop in the line can be calculated by dividing the total heat loss by 500 x gpm; where, the gpm is the flow in the line, in this case 10 gpm. As a result, the temperature loss would be: 43,750 Btu/hr/(500 x 10) = 8.75°F.

For lines of a few hundred feet in length, the temperature loss is almost directly proportional to the water flow. For the above example, the temperature drop at 20 gpm would be approximately 4.4°F and at 2 gpm would be approximately 44°F. As a result, one method of controlling the temperature loss in a line is to maintain a flow that results in an acceptable temperature at the end of the line.

The above examples and discussion are based on what is referred to as the "steady-state" heat loss from a buried pipe line. This means that the line has been carrying the flow of hot water long enough that the surrounding soil has been heated up to an "equilibrium" condition. At initial start up, the temperature loss would be much greater than the values indicated since a great deal of heat would be required to raise all the soil around the line from it's undisturbed temperature to a value closer to the pipe temperature. This issue can also have implications as far as the way the line is operated. If a line is to carry only intermittent flow or if it is to carry widely varying flow, it is important to make the heat loss and temperature drop calculations at the worst case condition. For intermittent flow applications, it is sometimes useful to maintain a small, constant flow to stabilize the line temperature and avoid wide temperature fluctuations.

The obvious way to minimize heat loss from a buried line is to insulate the pipe or at least increase the thermal resistance between the pipe wall and the soil. Several methods are available to accomplish this task. The most common is pipe insulation of some type. In larger applications with long pipelines, pre-insulated pipe is often employed. This is a product that consists of a carrier pipe (through which the water flows), a layer of urethane foam insulation and a jacket to protect the insulation from soil moisture. The cost of pre-insulated pipe in the two inch size is on the order of $10 per foot higher than bare pipe material in the same size. As a result, small project developers are often interested in identifying other options to reduce heat loss from buried lines. One of the least costly approaches is to bed the pipe in a dry,

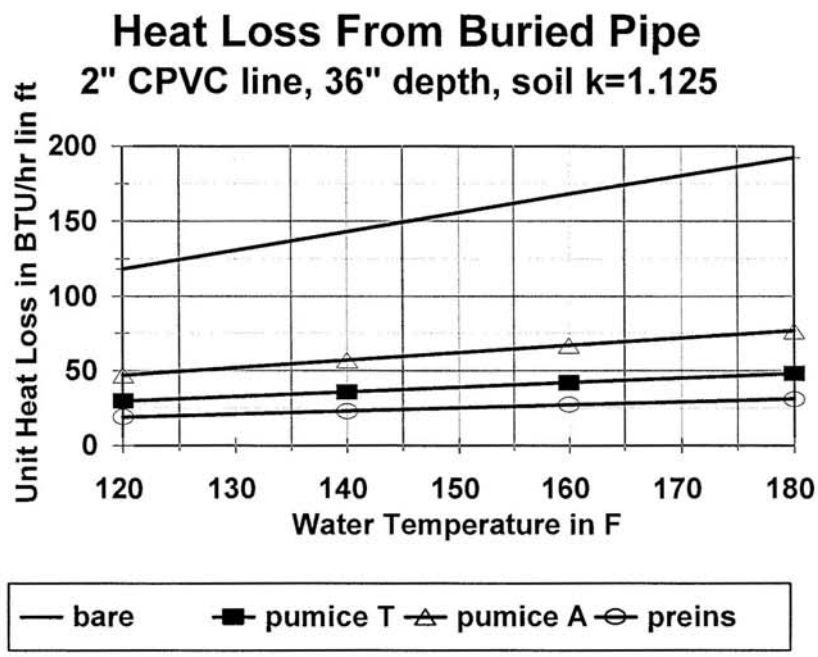

Figure 2. Heat los from buried pipe (2-in. CPVC line, 36 in. depth, soil k =1.125).

low thermal conductivity material that readily drains away any water from the pipe. A common material fitting this description is pumice. The thermal conductivity of dry pumice is approximately 0.085 Btu/ht•ft°F or about 10% that of most soils. This value is approximately 3 to 4 times that of commonly used pipe insulation materials.

The pumice is installed in the pipe zone in such a way that the pipe is surrounded by several inches of pumice on all sides. Figure 2 indicates the effectiveness of the pumice approach relative to an uninsulated line, and a pre-insulated line with 1inch of polyurethane insulation. In theory, the pumice (pumice T) will approach the performance of the pre-insulated line. In actual installations, however, experience has shown that the conductivity of the pumice is degraded by moisture in the soil. The actual performance of pumice is reflected in the curve labeled "pumice A." This constitutes approximately a 60% reduction in heat loss compared to the uninsulated line using a 6-in. thick layer of pumice around the line. At $10 per yard for the pumice and using a trench 12 in. wide, sheeting should be placed over the top of the pumice to protect it from vertical percolation of water in the soil. To prevent soil invasion of the pumice (which would raise its conductivity), a filter cloth can be used to line the ditch.

The black polyethylene pipe insulation available in tubular form at many home improvement stores is not intended for below grade installation. Though it is suitable for use in pipe temperatures up to 180°F in many cases, it's performance under buried conditions is not known. Under no circumstances should it be installed on steel pipe in direct-buried applications. This type of insulation can trap moisture next to the pipe and greatly increase exterior corrosion.

HEAT EXCHANGERS IN GEOTHERMAL SYSTEMS

In large geothermal direct-use systems, it is common practice to isolate the geothermal water from the balance of the system using a heat exchanger. The geothermal water passes through one side of the heat exchanger and the heating system water the other side. Thin stainless steel plates separate the two water flows so that there is no actual contact or mixing. Only heat passes through the plates from the geothermal water to the "clean" water. The use of the heat exchanger eliminates the potential for corrosion or scaling in the heating equipment in the building. In large applications where there may be tens of hundreds of individual heating units, the cost of the heat exchanger relative to the value of the equipment it protects is favorable. For very small systems, such as those addressed in this document, it is normally more economical to use the geothermal water directly in the heating equipment and accept a shorter service life for the heating units.

An exception to this is in the heating of domestic hot water. A small version of the plate heat exchanger called a brazed-plate heat exchanger (BPHX) serves well in this application. It's performance does not reach the level of the larger plate exchangers and it cannot be disassemble to be cleaned, but it is cost effective for small domestic water heating applications. Rather than being held together with the heavy end plates, large bolts and gaskets of plate-and-frame heat exchangers, the heat transfer plates in BPHXs, as the name implies, are brazed together with copper. The copper is subject to attack by hydrogen sulphide in the geothermal water, but testing has demonstrated (Rafferty, 1990) that service lives of 7 to 12 years in most geothermal fluids can be expected. These are the type of heat exchangers recommended in the domestic hot water heating portion of this document.

REFERENCES

Franklin Electric, 1999. Applications - All Motors / website: http://www.franklinelect.com/manual/g.htm. Franklin Electric, Bluffton, IN.

NIBCO, undated Chemtrol Plastic Piping Handbook, NIBCO, Inc., Elkhart, IN.

Rafferty, K., 1990. "Brazed-Plate Heat Exchangers for Geothermal Applications." Geo-Heat Center, Klamath Falls, OR.

Storage

Franklin Electric submersible motors are a water lubricated design. The filling solution consists of a mixture of deionized water and Propylene Glycol, a non-toxic antifreeze. The solution will prevent damage from freezing for temperatures down to -40°F (-40°C). Repeated freezing and thawing should be avoided to prevent possible loss of solution.

There may be an interchange of filling solution with well water during operation. Care must be taken with motors removed from wells during freezing conditions to prevent damage.

When the storage temperature does not exceed 100°F, (37°C), storage time should be limited to two years. Where temperatures reach 130°F, (54°C), storage time should be limited to one year.

Loss of a few drops of liquid will not damage the motor as an excess amount is provided, and the filter check valve will allow lost liquid to be replaced by filtered well water upon installation. If there is reason to believe there has been a considerable amount of leakage, consult the factory for checking procedures.

Frequency of Starts

The average number of starts per day over a period of months or years influences the life of a submersible pumping system. Excessive cycling affects the life of control components such as pressure switches, starters, relays and capacitors, plus splines and bearings. Rapid cycling can also cause motor overheating and winding failures.

The pump size, tank size and other controls should be selected to keep the starts per day as low as practical for longest life, based upon the maximum number of starts per 24 hour day, as shown in Table 1.

Motors should be allowed to run a minimum of one minute to dissipate heat build up from starting current.

Table 1 Number of Starts

	Maximum Starts Per 24 Hr. Day	
Motor Rating	Single Phase	Three Phase
Up to 3/4 HP	300	300
1 HP thru 5 HP	100	300
7 1/2 HP thru 30 HP	50	100
40 HP and over		100

Mounting Position

Motors are suitable for operation in mounting positions from vertical shaft up to horizontal. If 4 inch motors thru 2 HP are started more than 10 times per day, it is recommended the shaft be tilted up at 15° from horizontal to minimize coast-down wear of the upthrust washer.

Reference: Franklin Electric, service data, page 263SD, Mar 30 1994

Application — All Motors

Transformer Capacity Required For Submersible Motors

Single Phase or Three Phase

Distribution transformers must be adequately sized to satisfy the KVA requirements of the submersible motor. When transformers are too small to supply the load, there is a reduction in voltage to the motor.

Table 2 references the motor horsepower rating, single phase and three phase, total effective KVA required, and the smallest transformer required for open or closed three phase systems. Open systems require larger transformers since only two transformers are used.

Other loads would add directly to the KVA sizing requirements of the transformer bank.

Use of Engine Driven Generators

Single Phase or Three Phase

Table 3 lists recommended generator sizes, based on typical 80°C rise continuous duty generators, with 35% maximum voltage dip during starting, for specific Franklin three wire motors, single or three phase.

This chart is conservative and it is recommended the generator manufacturer be consulted whenever possible, especially on larger sizes.

There are two types of generators available, externally and internally regulated. Most are externally regulated. They use an external mounted voltage regulator that senses the output voltage. As the voltage dips at motor start up, the regulator increases the output voltage of the generator.

Internally regulated generators have an extra winding in the generator stator and are also called self excited. The extra winding senses the output current to automatically increase the output voltage.

Generators must be sized to deliver at least 65% of the rated voltage during motor starting to ensure adequate motor starting torque. Besides sizing, generator frequency is all important as the motor speed varies with the frequency (HZ). Due to pump affinity laws a pump running at 1 to 2 HZ below motor nameplate frequency design will not meet its performance curve. Conversely, a pump running at 1 to 2 HZ above may trip overloads.

Generator Operation. Always start the generator before the motor is started, and always stop the motor before the generator is shut down. The motor thrust bearing may be damaged when generators are allowed to coast down with the motor connected. This same condition occurs when generators are allowed to run out of fuel.

Follow generator manufacturer's recommendations for derating at higher elevations or using natural gas.

WARNING: To prevent accidental electrocution, automatic or manual transfer switches must be used any time a generator is used as standby or back up on power lines. Contact power company for use and approval.

Table 2 TRANSFORMER CAPACITY

Motor HP	Total Effective KVA Required	Smallest KVA Rating - Each Transformers: Open WYE or DELTA 2 Transformers	Smallest KVA Rating - Each Transformers: Closed WYE or DELTA 3 Transformers
1 1/2	3	2	1
2	4	2	1.5
3	5	3	2
5	7.5	5	3
7 1/2	10	7.5	5
10	15	10	5
15	20	15	7.5
20	25	15	10
25	30	20	10
30	40	25	15
40	50	30	20
50	60	35	20
60	75	40	25
75	90	50	30
100	120	65	40
125	150	85	50
150	175	100	60
175	200	115	70
200	230	130	75

Table 3 ENGINE DRIVEN GENERATORS

Motor HP	Minimum Rating of Generator: Externally Regulated		Minimum Rating of Generator: Internally Regulated	
	KW	KVA	KW	KVA
1/3	1.5	1.9	1.2	1.5
1/2	2.0	2.5	1.5	1.9
3/4	3.0	3.8	2.0	2.5
1	4.0	5.0	2.5	3.125
1 1/2	5.0	6.25	3.0	3.8
2	7.5	9.4	4.0	5.0
3	10.0	12.5	5.0	6.25
5	15.0	18.75	7.5	9.4
7 1/2	20.0	25.0	10.0	12.5
10	30.0	37.5	15.0	18.8
15	40.0	50.0	20.0	25.0
20	60.0	75.0	25.0	31.0
25	75.0	94.0	30.0	37.5
30	100.0	125.0	40.0	50.0
40	100.0	125.0	50.0	62.5
50	150.0	188.0	60.0	75.0
60	175.0	220.0	75.0	94.0
75	250.0	313.0	100.0	125.0
100	300.0	375.0	150.0	188.0
125	375.0	469.0	175.0	219.0
150	450.0	563.0	200.0	250.0
175	525.0	656.0	250.0	313.0
200	600.0	750.0	275.0	344.0

NOTE: FOR BEST STARTING OF TWO-WIRE MOTOR MINIMUM GENERATOR RATINGS 50% HIGHER THAN SHOWN ARE RECOMMENDED.

Reference: Franklin Electric, service data, page 263SD, Mar 30 1994

Use of Check Valves

It is recommended that one or more check valves always be used in submersible pump installations. A line check valve, if the pump does not have a built-in check valve, should be installed in the discharge line within 25 feet of the pump and below the drawdown level of the water supply. For deeper settings, it is recommended that a line check valve be installed every 200 feet.

Swing type check valves should never be used with submersible pumps. When the pump stops, there is a sudden reversal of flow before the swing check closes, causing a sudden change in the velocity of the water. Spring loaded check valves should be used as they are designed to close quickly as the water flow stops and before it begins to move in the reverse direction. There is little or no velocity of flow when the spring loaded valve closes and no hydraulic shock or water hammer is produced by the closing of the valve.

Check valves are used to hold pressure in the system when the pump stops.They are also used to prevent backspin, waterhammer and upthrust. Any of these three or a combination of them can lead to immediate pump or motor failure, a shortended service life or operating problems in the system

A. Backspin - with no check valve or if the check valve fails, the water in the drop pipe and the water in the system can flow back down the discharge pipe when the motor stops. This can cause the pump to rotate in a reverse direction as the water flows back down the pipe. If the motor is started while this is happening, a heavy strain may be placed across the pump-motor assembly. It can also cause excessive thrust bearing wear because the motor is not turning fast enough to ensure an adequate film of water in the thrust bearing.

B. Upthrust - with no check valve, or with a leaking check valve, the unit starts each time under zero head conditions. With most pumps, this causes an uplifting or upthrust on the impellers-shaft assembly in the pump. This upward movement carries across the pump-motor coupling and creates an upthrust condition in the motor. Repeated upthrust at each start can cause premature wear and failure of either or both the pump and the motor.

C. Water Hammer - If the lowest check valve is more than 30 feet above the standing water level or the lower check valve leaks and the check valve above holds, a partial vacuum is created in the discharge piping. On the next pump start, water moving at very high velocity fills the void and strikes the closed check valve and the stationary water in the pipe above it, causing a hydraulic shock. This shock can split pipes, break joints and damage the pump and/or motor. Water hammer is an easily detected noise. When discovered, the system should be shut down and the pump installer contacted to correct the problem.

Wells-Large Diameter, Uncased Top feeding & Screened Sections

Franklin Electric submersible motors are designed to operate with a cooling flow of water over the motor.

If the pump installation does not ensure at least the minimum flow shown in Table 5, a flow inducer sleeve as shown in FIG. 1 must be used. Some conditions requiring a flow sleeve are:

- Well diameter is too large to meet Table 5 flow requirements.
- Pump is in an open body of water.
- Pump is in a rock well or below the end of the well casing.
- The well is "top-feeding".
- Pump is set in or below any part of screens or perforations.

Effects of Torque

During the starting of a submersible pump, the torque developed by the motor must be supported through the pump, delivery pipe or other supports. Most pumps rotate in the direction which causes unscrewing torque on right hand threaded pipe or pump stages. All threaded joints, pumps and other parts of the pump support system must be capable of withstanding the maximum torque repeatedly without loosening or breaking. Unscrewing joints will break the electrical cable and may cause loss of the pump-motor unit.

To safely withstand maximum unscrewing torques with a minimum safety factor of 1.5, tightening all threaded joints to at least 10 lb. ft per motor horsepower is recommended. It may be necessary to tack or strap weld pipe joints on high horsepower pumps, especially at shallower settings.

Table 4 Torque Required (Examples)

Motor H.P. Rating	x 10 Lb. Ft.	Minimum Safe Torque-Load
1 HP & Less	1 x 10	10 Lb. Ft.
20 HP	20 x 10	200 Lb. Ft.
75 HP	75 x 10	750 Lb. Ft.
200 HP	200 x 10	2,000 Lb. Ft.

Reference: Franklin Electric, service data, page 263SD, Mar 30 1994

Application — All Motors

Water Temperature and Flow

Franklin Electric submersible motors are designed to operate with loading up to maximum service factor horsepower in water up to 86 degrees F (30°C) with a water flow past the motor of 0.25 ft/sec for 4" High Thrust motors and 0.5 ft/sec for 6 & 8 inch motors. Table 5 shows minimum flow rates, in GPM, for various well diameters and motor sizes.

If the motors are operated in water over 86 degrees F (30°C), water flow past the motor and/or the motor horsepower must be increased to maintain safe motor operating temperatures as shown in HOT WATER APPLICATIONS on page 6.

Table 5 Required Cooling Flow

Minimum GPM required for motor cooling in water up to 86°F (30°C).

Inches Casing or Sleeve I.D.	4" High Thrust Motor .25 ft/sec GPM	6" Motor .5 ft/sec GPM	8" Motor .5 ft/sec GPM
4	1.2	—	—
5	7	—	—
6	13	9	—
7	20	25	—
8	30	45	10
10	50	90	55
12	80	140	110
14	110	200	170
16	150	280	245

.25 ft/sec = 7.62 cm/sec
.50 ft/sec = 15.24 cm/sec
1 inch = 2.54 cm

Head Loss From Flow Past Motor

The following lists the approximate feet of head loss from flow between an average length motor and smooth casing or flow inducer sleeve.

Table 6 Head Loss Past Motor

Motor (Nominal)		4"	4"	4"	6"	6"	6"	8"	8"
Casing I.D. Inches		4"	5"	6"	6"	7"	8"	8.1"	10"
GPM	25	1.9							
	50	6.3							
	100	21.0	0.3		1.7				
	150		0.6	0.2	3.7				
	200		1.1	0.4	6.3	0.5		6.8	
	250		1.8	0.7	9.6	0.8		10.4	
	300		2.5	1.0	13.6	1.2	0.2	14.6	
	400				23.7	2.0	0.4	24.6	
	500					3.1	0.7	37.3	0.6
	600					4.4	1.0	52.2	0.8
	800								1.5
	1000								2.4

Flow Inducer Sleeve

If the flow rate is less than specified or coming from above the pump, then a flow inducer sleeve must be added for motor cooling. A flow sleeve is always required in an open body of water. FIG 1. shows a typical flow inducer sleeve construction.

Example: A six-inch motor and pump that delivers 60 GPM will be installed in a 10" well, 90 GPM past the motor is required in a 10" I.D. well. An 8" or smaller sleeve must be added to the pump to provide a cooling flow of water past the motor.

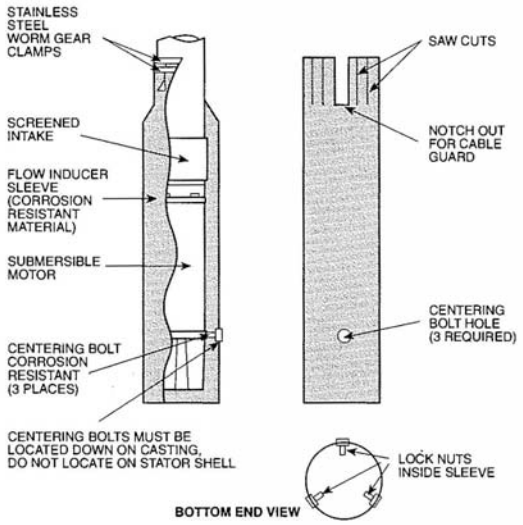

FIG 1

Reference: Franklin Electric, service data, page 263SD, Mar 30 1994

Hot Water Applications

When the pump-motor operates in water hotter than 86°F (30°C), the best motor cooling and most economical motor result when a flow rate of at least 3 ft/sec is provided.

When selecting the correct motor to drive a pump at elevated water temperatures, and 3 ft/sec the flow rate pump horsepower required and water temperature must be used with a heat factor multiplier to calculate the rated HP motor needed.

1. The flow past the motor must be a minimum of 3 ft/second. Using Chart A, determine pump GPM delivery required for different well or sleeve diameters and motor sizes. If necessary, add a flow sleeve to obtain at least 3 ft/sec flow rate.

Chart A — Minimum GPM Required to Obtain 3 ft/sec Flow Rate

Inches Casing or Sleeve I.D.	4" High Thrust Motor GPM	6" Motor GPM	8" Motor GPM
4	15	—	—
5	80	—	—
6	160	52	—
7	—	150	—
8	—	260	60
10	—	520	330
12	—	—	650
14	—	—	1020
16	—	—	1460

BRAKE

2. Determine pump horsepower required from the pump manufacturer's curve.

Manufacturer's Pump Curve

FIG 2

3. Multiply the pump horsepower required by the heat factor multiplier from Chart B.

Chart B — Heat Factor Multiplier at 3 ft/sec Flow Rate

Maximum Water Temp	1/3 – 5 HP	7 1/2 – 30 HP	Over 30 HP
140°F (60°C)	1.25	1.62	2.00
131°F (55°C)	1.11	1.32	1.62
122°F (50°C)	1.00	1.14	1.32
113°F (45°C)	1.00	1.00	1.14
104°F (40°C)	1.00	1.00	1.00
95°F (35°C)	1.00	1.00	1.00

4. Select a rated HP motor on Chart C whose SFHP is at least the value calculated in Item 3.

Chart C — Service Factor Horsepower

HP	SFHP	HP	SFHP	HP	SFHP	HP	SFHP
1/3	.58	3	3.45	25	27.50	100	115.00
1/2	.80	5	5.75	30	34.50	125	143.75
3/4	1.12	7 1/2	8.65	40	46.00	150	172.50
1	1.40	10	11.50	50	57.50	175	201.25
1 1/2	1.95	15	17.25	60	69.00	200	230.00
2	2.50	20	23.00	75	86.25		

Reference: Franklin Electric, service data, page 263SD, Mar 30 1994

Application — All Motors

Hot Water Applications - Example

EXAMPLE: A 6" pump end requiring 39 HP input will pump 124°F water in an 8" well at a delivery rate of 140 GPM. From Chart A, a 6" flow sleeve will be required to increase the flow rate to at least 3ft/sec.

Using Chart B, the 1.62 heat factor multiplier is selected because the HP required is over 30 HP and water temperature above 122°F. Multiply 39 x 1.62 which equals 63.2. This is the minimum service factor horsepower motor which is usable at 39 HP in 124°F water. Using Chart C, select a motor with a service factor horsepower above 63.2. A 60 HP motor has a service factor horsepower of 69, so a 60 HP motor may safely be used.

	F		Degrees C or F		C	
			260		127	
			250		121	
			240		115	
			230		110	
			220		104	
			210		99	
			200		93	
			190		88	
			180		82	
			170		77	
			160		71	
			150		65	
			140		60	
	266		130		54	
	248		120		49	
	230		110		43	
	212		100		38	
	194		90		32	
	176		80		27	
	158		70		21	
	140		60		15	
	122		50		10	
	104		40		4	
	86		30		-1	
	68		20		-7	
	50		10		-12	
	32		0		-18	
	14		-10		-23	
	-4		-20		-29	
	-22		-30		-34	
	-40		-40		-40	

FIG 3 Temperature Conversion

Reference: Franklin Electric, service data, page 263SD, Mar 30 1994

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APPENDIX C

MATERIALS SOURCES

The following types of plumbing devices are commonly used in stockwater pipeline systems. The specific brands and models listed are examples of commonly used items and do not represent a comprehensive listing. Other acceptable devices, brands, and models may be available. The price ranges shown are not intended for estimates since any list price is only current for a very short time, but rather the prices are intended to show costs relative to various models for comparison purposes. The models and sizes shown are only a partial listing of what is most likely available and are models which have been commonly used in systems, in SD, and most likely distributed by local suppliers. There are companies other than those listed that make quality products for water system use.

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For further details on equipment desired, please contact the sales representative or manufacturer. Other good sources of helpful information are well drillers, pump installers, and rural water districts.

See Chapter 7 for discussion of purpose and uses for various system components.

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C1 VALVES

C1.1 Air-Release Valves (one-way air release valve)

Continuous acting valves that have a small venting orifice generally ranging between 1/16 and 3/8 inch in size. This type of valve releases pockets of air from the pipeline once the line is filled and under working pressure. These devices require venting to the atmosphere. They periodically dispense small amounts of water during normal operation so provisions must be made to dispose of such water.

Brand Name	Model No	Inlet Size (in)	Orifice Size (in)	Maximum Pressure	Price Range
Apco	50	1/2, 3/4, 1	3/32	150	<$50
Apco	55	1/2	3/32	150	<$100
Apco	65	3/4	1/8	150	<$100
Apco	50	1/2, 3/4, 1	1/16	300	<$50
Apco	200A	1, 2	3/16	150	<$150
Apco	200A	1, 2	3/32	300	<$150
Val-Matic	15	1/2, 3/4, 1	1/16	175	<$100
Val-Matic	22	1/2, 3/4, 1	3/32	175	<$150
Val-Matic	25	3/4, 1	1/8	150	<$150
Val-Matic	25	3/4, 1	5/64	300	<$150
Val-Matic	38	1, 2	3/16	150	<$200
Val-Matic	38	1, 2	3/32	300	<$180
Bermad	4405	1	---	170	<$100
Waterman	CAV-6	1	---	150	<$175

C1.2 Air-and-Vacuum Valve (two-way valve)

These valves have a large venting orifice, exhaust large quantities of air from the pipeline during filling operations, allow air to re-enter the line and prevent a vacuum from forming during emptying. These valves are not continuous acting because they do not allow further escape of air at working pressure once the valves close. These devices require venting to the atmosphere. They periodically dispense small amounts of water during normal operation, so provisions must be made to dispose of such water.

Brand Name	Model No	Inlet Size (in)	Orifice Size (in)	Maximum Pressure	Price Range
Apco	141	1/2	1/2	300	<$100
Apco	142	1	1	300	<$150
Apco	144	2	2	150	<$200
Val-Matic	100	1/2	1/2	150/300	<$200
Val-Matic	101	1	1	150/300	<$200
Val-Matic	102	2	2	150/300	<$350
Bermad	4420	2	---	170	<$150
Waterman	AV-150	1-1/2, 2	$1\,^{1}/_{8}$, $1\,^{3}/_{4}$	150	<$50
Waterman	AV-150	3, 4	$2\,^{3}/_{8}$, 3 ½	100	<$100
Waterman	AVP-1	1-3	plastic	110	<$50-100
CLA - VAL	33A	1, 2	.125	500	<$200

C1.3 Air-Vacuum-Air Release Valve (three-way valve)

Three-way valves combine the functions of the previous two valves. These devices require venting to the atmosphere. They periodically dispense small amounts of water during normal operation. Provision must be made to dispose of such water.

Brand Name	Model No	Inlet Size (in)	Orifice Size (in)	Maximum Pressure	Price Range
Apco	143C	1	1 & 5/64	300	<$200
Apco	145C	2	2 & 3/32	300	<$300
Val-Matic	201C	1	1 & 5/64	300	<$300
Val-Matic	202C	2	2 & 3/32	300	<$450
Bermad	4415	2	---	170	<$200
Waterman	CRP8	1	plastic	85	<$50
Waterman	CRP8	2	---	100	<$100
Waterman	AVR-2	$^3/_4$,1,1-$^1/_4$,1-$^1/_2$	2 $^1/_8$	150	<$300
Waterman	CR-100	2	2 & 1/16	100	<$150

C1.4 Pressure Reducing Valve

Pressure reducing valves reduce pressure to pipelines, hydrants, float valves, etc. Access to the valve is required for adjustment and maintenance.

Brand Name	Model No.	Size (in)	Note	Reduced Press Setting Range	Maximum Operating Pressure
Honeywell Braukmann	DS05	½ - 1	(1)(3)(50	15-150	400
Watts	25AUB	½ - 2	(6)(3)	25-75	300
Watts	25AUB HP	½ - 2	(6)(3)	75-125	300
Watts	25AUB LP	½ - 2	(6)(3)	10-35	300
Watts	U5B	½ - 2	(1)(3)	25-75	300
Watts	U5B HP	½ - 2	(1)(3)	75-125	300
Watts	U5B LP	½ - 2	(1)(3)	10-35	300
Watts	223, 223S	½ - 2$^1/_2$”	(2)(4)	25-75	300
Watts	223 HP, 223S HP	½ - 2$^1/_2$”	(2)(4)	varies w/size (up to 145)	300
Watts	223 LP, 223S LP	½ -2$^1/_2$”	(2)(4)	10-35	300
Watts	N45B EZ	½ -1”	(5)(3)(6)	25-75	400
Watts	N45B EZ	1$^1/_4$”-2”	(5)(3)(6)	25-75	300

(1) Standard Capacity Valve – reduced pressure falloff average at high flow rates
(2) High Capacity Valve – a valve designed for high flow rates and less pressure loss through the valve (reduced pressure falloff is less)
(3) Integral Strainer
(4) Without strainer or with strainer (S)
(5) Pressure may be set without use of pressure gauge (pressure set by adjusting dial on valve)
(6) Low capacity valve – reduced pressure falloff is significant at high flow rates

C1.5 Pressure Relief Valve

Keeps pressure in pipelines at a safe value when a pump pressure switch or pressure reducer valve malfunctions.

Brand Name	Model No.	Size (in)	Note	Maximum Operating Pressure	Relief Setting PSI
Watts	174-A	¾-2		160	30-160
Cash-Acme	FWC	1/2, 3/4		175	
Waterman	AA-6	2, 2½		120	11-120
Waterman	AA-96	3, 4	(1)	150	12-150
Zurn/Wilkins	P1500	1/2, 3/4		175	25-175

(1) Large discharge orifice and flow rate

C1.6 Flow Control Valve

This type of valve controls flow rate in a pipeline. It is can be used near a pump to control surge pressures during pump start up in long pipelines with remote pressure tanks or to limit pipeline outlets to a predetermined maximum flow.

Brand Name	Model No.	Size (in)	Note	Maximum Operating Pressure	Flow Rate GPM
Kates	4FA	1-1/2	(1)	150 & 300	
Dole	GY	$^3/_4$	(2)	125	1-11.5
Dole	GX	1	(2)	125	1-30

(1) Adjustable
(2) Nonadjustable

C1.7 Float Valve

Brand Name	Model No.	Size	Note	Maximum Operating Pressure
Hudson Valve	Hudson	½", 1"		-
Roberts	R400	½", ¾", 1"	Copper ball bob float	100 psi
Roberts	R600	1 ¼", 1 ½"	Copper ball bob float	125 psi
Watts	750 (3/4") 1000 (1")	¼"- 2"	Bronze body adj. float arm	165 psi

C2 PRESSURE TANKS

Brand Name	Model No/ Series.	Size	Note (4)	Maximum Operating Pressure(1)
Flexcon	Fex-Lite	15-119	(fiberglass/epoxy resin)	125
Flexcon	H2Pro	14-119	Steel	125
Clayton Mark	galvanized	12-480	no bladder	50
Flint and Walling	AT	4-119	(3)	100
Myers	MIL	2-14	in-line tank (3)	100
Myers	MPD	14-119	Vertical Stand (3)	100
Sta-Rite	SR	20-120	(fiberglass/epoxy resin)	100
Sta-Rite	PSP	50-119	Steel w/ PVC bladder	125
Well Mate	WM	14.5-80	(fiberglass/epoxy resin)	100
Well Mate	WM-WB	47-120	(fiberglass/epoxy resin)	125
Wel-X-Trol	WX/100,200,300	2.0-119	Non-ASME (3)	100
Wel-X-Trol	WX/420 Series	165-550	Non-ASME (2)	100
Wel-X-Trol	WX/400	17.5-88	Non-ASME & (ASME) (3)	150 125,175,250)
Wel-X-Trol	WX/440,450	53-528	Non-ASME & (ASME) (2)	150 (125,175,250)
Well-Rite	WR	14 -119	Non-ASME (3)	125
Wessels	FX	2.1-528	Non-ASME (2)	150
Wessels	FXT	8-210	ASME (3)	200
Wessels	FXA	10-3,963	ASME (2)	125,200,250

NOTES

(1) These are maximum operating pressures as listed by the manufacturer for the particular model listed. These pressures should not be exceeded.

(2) Replaceable Bladder

(3) Fixed Diaphram (nonreplaceable bladder)

(4) ASME rated tanks are fabricated and certified as meeting an ASME code. They are manufactured under controlled conditions by certified welders. The maximum operating pressure for an ASME tank is based on a higher factor of safety than a non-ASME tank, they are of higher quality and higher cost.

C3 STOCK TANKS

Type Tank	Supplier	Size	Gauge
Corrugated Galv. Steel Bottomless	Hastings Equity Grain Bin Mfg. Hastings, Nebraska (NE)	15-30’ dia., 25.5 & 33”	10/20
Corrugated Galv. Steel Bottomless	Sioux Steel Sioux Falls, SD	15-27’ dia., 25 & 33”	12
Corrugated Galv. Steel Bottomless	Conrad American Grand Island, NE	-	12/20
Fiberglass	Mer-Tex Amarillo, Texas (TX)	4-25 ft.	
Fiberglass	Montana Fiberglass (formerly Zanes Stock Tanks) Lewistown, Montana (MT)	4–19 ¼ dia. 3’ x 4’ - 8’ x 20.75’ rect.	
Fiberglass	Fiberglass Structures Inc. (Component Structures, Inc.) Laurel, MT	6 – 10’ dia. 3’ x 4’ - 3’ x 10’ rect.	BUL-TUF

C4 CENTRAL STORAGE TANKS

Type Tank	Supplier	Size	Style
Polyethylene	Den Hartog Industries Hospers, Iowa (IA)	1,000 – 10,500 gallon	Above Ground
Polyethylene	Den Hartog Industries Hospers, IA	850 – 11,700 gallon	Direct Bury
Fiberglass	Containment Solutions Inc. Conroe, TX	550 – 40,000 gallon	Direct Bury
Fiberglass	Xerxes Corporation Minneapolis, Minnesota (MN)	600 – 50,000 gallon	Direct Bury
Pre-Cast Concrete	Local Suppliers	1,000 – 5,000 gallon	Direct Bury

C5 PUMPS

Brand Name	Supplier	Type	Notes
Aermotor	Aermotor Conway, Arkansas (AR)	Submersible, Jet Inline Booster	
Aermotor Windmill	Aermotor Windmill Co. San Angelo, TX	Windmills	
Bowjon	Bowjon Burbank, California (CA)	Windmill driven air pump	
Dankoff	Dankoff Solar Products Inc. Santa Fe, New Mexico (NM)	Solar Pumps	
Fleming Hydro-Ram	Ram Company Lowesville, Virginia (VA)	Hydraulic Ram	
Flint & Walling	Flint & Walling Inc. Kendallville, Indiana (IN)	Submersible, Jet Inline Booster	
Franklin Little Rock, AR	Franklin Pump Systems Inc. Inline Booster	Submersible, Jet pumps	Includes Formerly branded Jacuzzi
Goulds	Goulds Pumps Inc. Seneca Falls, New York (NY)	Submersible, Jet Inline Booster	
Grundfos	Grundfos Pumps Corp. Olathe, KS	Submersible, Jet Inline Booster, Solar	Including speed models
Farm Trol	Farm Trol Equipment Theresa, Wisconsin (WI)	Pasture Nose Pumps	
McDonald	A.Y. McDonald Mfg. Co. Dubuque, IA	Submersible, Jet Inline Booster	
Myers	Myers Pentair Water Ashland, Ohio	Submersible, Jet Inline Booster	
Red Jacket	Red Jacket Water Products Auburn, NY	Submersible, Jet Inline Booster	
Rife	Rife Hydraulic Engine Mfg. Co. Inc. Nanticoke, Pennsylvania	Hydraulic Ram Pasture Nose Pumps	
Sta-Rite	Sta-Rite Industies Inc. Delavan, WI	Submersible, Jet Inline Booster	

C6 GENERATORS

Brand Name	Supplier	Type	Notes
GenPro	GenPro Power Systems Rapid City, SD	Remote well site generators	
TWEgen	TW Enterprises Billings, MT	Remote well site generators	

C7 MANUFACTURERS REGISTER

The following companies have products referenced in this appendix. The specific companies listed are examples of companies whose products have been used in small private waters systems in the state and do not represent a comprehensive listing. Other acceptable companies and brands may be available. **Generally, all of these companies have Web sites which should be referred to for the most up-to-date information.**

APCO Valve & Primer Corporation 1420 South Wright Blvd. Schaumburg, IL 60193-4599 Phone (630) 529-9000 or (800) 323-6969 Fax (708) 529-6969	Air Valves
Bermad Inc. Anaheim, CA Phone (800) 821-6825 Fax (714) 666-2533	Air Valves
Cash-Acme 2400 7th Avenue Cullman, Alabama Phone (877) 700-4242 Fax (877) 700-4280	Pressure Relief Valves
Honeywell Minneapolis, MN	Pressure Regulators
Zurn/Wilkins 1747 Commerce Way Paso Robles, CA 93446 Phone (805) 238-7100 Fax (805) 238-5766	Pressure Relief Valves
Waterman Industries Sales Inc. 1701 N. Nashville Lubbock Texas Phone (806) 763-5943 Fax (806) 763-8167	Air Valves, Pressure Relief Valves
Watts Regulator Company 815 Chestnut Street North Andover, MA 01845 Phone (978) 688-1811 Fax (978) 794-1848	Air Valves, Pressure Relief Valves Pressure Regulators, Pressure Relief Valves, Float Valves
Val-Matic Valve and Manufacturing Corp. 905 Riverside Drive Elmhurst, IL 60126 Phone (630) 941-7600 Fax (630) 941-8042	Air Valves
CLA-VAL Phone (949) 722-4800 Fax (949) 548-5411	Air Valves

Hudson Valve Company Inc. 6000 Schirra Court Bakersfield, California 93313 Phone (800) 748-6218 Fax (805) 831-9035	Float Valves
Ford Meter Box Company Inc. P.O. Box 443 Wabash, Indiana 46992-0443 Phone (214) 563-3171 Fax (800) 826-3487	Valves
Mueller Company Decator, Illinois Phone (800) 423-1323 Fax (217) 425-7202	Valves
Aermotor Windmill Co. P.O. Box 5110 San Angelo, TX 76902 Phone (800) 854-1566 Fax (325) 651-4948	Windmills
Aermotor P.O. Box 1364 584 Commerce Rd. Conway, AR Phone (501) 329-9811 Fax (501) 329-9812	Pumps
A.Y. McDonald P.O. Box 508 Dubuque, IA 52004-0508 Phone (563) 583-7311 Fax (563) 588-0720	Pumps
Bowjon 2829 Burton Avenue Burbank, CA 91504 Phone (213) 846-2620	Wind Driven Air Pump
Dankoff Solar Products Inc. Santa Fe, NM Phone (704) 583-0016 Fax (704) 583-9588	Solar Pumps
Farm Trol Equipment 409 Mayville St. Theresa, WI 53091 Phone (414) 488-3221	Pasture Nose Pumps
Flint & Walling Inc. 95 North Oak St. Kendallville, IN 46755 Phone (800) 348-9422 Fax (800) 848-2535	Pumps, Pressure Tanks

Franklin Pump Systems Inc. 12401 Interstate 30 Little Rock, AR 72209 Phone (501) 455-1234 Fax (800) 662-6044	Pumps
Goulds Pumps Inc. 2881 East Bayard St. Seneca Falls, NY 13148 Phone (315) 568-7123	Pumps
Grundfos Pumps Corp. 17100 West 118th Terrace Olathe, KS 66061 Phone (913) 227-3400 Fax (913) 227-3500	Pumps
Myers Pentair Water 1101 Myers Parkway Ashland, OH 44805 Phone (419) 289-6898 Fax (419) 289-6658	Pumps
Ram Company 512 Dillard Hill Rd. Lowesville, Virginia 22967 Phone 800 227-8511	Hydraulic Ram Pump
Red Jacket Water Products 58 Wright Ave. Auburn, NY 13021 Phone (866) 325-4210 Fax (866) 325-4211	Pumps
Rife Hydraulic Engine Mfg. Co. Inc. Line and Grove St. P.O. Box 95 Nanticoke, PA 18634 Phone (570) 740-1100 Fax (570) 740-1101	Hydraulic Rams, Nose Pumps
Sta-Rite Industries Inc. 293 Wright St. Delavan, WI 53115 Phone (414) 728-9181 Fax (414) 728-2348	Pumps
GenPro Power Systems 2121 Rand Road Rapid City, SD 57702 Phone (605) 341-6160 Fax (605) 341-9790	Remote Well Site Generators
TWEnterprises Inc. 636 Logan Lane Billings, MT 59105 Phone (800) 955-3795 Fax (406) 245-4333	Remote Well Site Generators

Centenial Plastics LLC 1830 Centenial Ave. Hastings, NE 68901 Phone (402) 462-2227 Fax (402) 462-5529	Polyethylene Pipe
Diamond Plastics 1212 Johnstown Road P.O. Box 1608 Grand Island, Nebraska 68802 Phone (308) 384-4400 Fax (308) 384-9345	PVC Pipe 2” to 4” ASTM D 2241
Eagle Plastics P.O. Box 229 146 North Maple Hastings, Nebraska 68902-0229 Phone (402) 461-3040 Fax (402) 461-3409	PVC & PE Pipe
Endot Industries 60 Green Pond Road Rockaway, New Jersey 07866 Phone (800) 443-6368 Fax (973) 625-4087	Polyethylene Pipe
Plexco Performance Pipe Division Chevron Chemical Company 1050 Busse Highway, Suite 200 Bensenville, Illinois 60106 Phone (630) 350-3754 Fax (630) 350-2148	Polyethylene Pipe
PolyPipe Industries Inc. P.O. Box 390 Gainsville, TX 76240 Phone (800) 433-5632 Fax (940) 668-2704	Polyethylene Pipe
Phillips Drisco Pipe 2929 North Central Expressway Suite #300 Richardson, Texas 75080 Phone (972) 783-2666 Fax (972) 783-2689	Polyethylene Pipe

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