# Chapter 1

# Introduction

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## TABLE OF CONTENTS

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## 1.1 PURPOSE AND OBJECTIVES

The purpose of the Missouri Livestock Watering Systems Handbook is to provide Natural Resources Conservation Service (NRCS) personnel, and others where appropriate, with detailed technical information and procedures for planning, designing and managing of livestock watering systems.

Livestock watering systems are installed to (1) provide improvement in the beneficial use of pasture and rangeland by providing better distribution of livestock, (2) prevent loss of water by evaporation and seepage, (3) maintain and improve the plant growth and cover; and (4) prevent erosion resulting from overgrazing near water sources.

This handbook is only a guide, it does not set NRCS policy or standards. Policy and standards are in NRCS documents such as the National Planning Procedures Handbook, the National Engineering Manual, and conservation practice standards contained in Section IV of the Field Office Technical Guide (FOTG).

FOTG standards and specifications must be used in conjunction with practices and procedures covered by this handbook. The best available procedures and data should always be used, whether or not they are in this handbook.

## 1.2 GENERAL

Livestock watering systems come in many configurations and sizes. They may vary from a short piece of pipe between a spring and stockwater tank, to many miles of pipeline with pressures at the low point as high as 500 psi. The design should ensure that the maximum pressure does not exceed the strength of the pipeline. A design may be as critical for a short pipeline as for a long one.

Consider what can happen if a pipeline fails. If there is little or no backup water available in a field and the problem is not discovered promptly, livestock will perish. During hot, dry weather a cow can only survive three or four days without water. Thirsty cows present a danger to people and property.

A livestock water system can be a great improvement over previously used watering systems. Stockwater ponds tend to dry up at the worst times and livestock become mired down in the mud. Windmills often do not work when they are needed and hauling water is a expensive, difficult, inefficient way of watering livestock. On the other hand, a livestock watering system can be made to be a very dependable water distribution system. Not only can it be dependable, but good quality water can be delivered to optimum locations to promote good grazing distribution and serve healthy animals.

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 handbook 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 non-flowing) 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 non-pressurized tank (usually underground) for storing water.

**Clearance Head** Certain vertical distance above the natural ground at which the hydraulic grade line passes.

**Contamination** The introduction into water of microorganisms, chemicals, toxic substances, wastes, or wastewater in a concentration that makes the water unfit for its next intended use.

**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** Introduction of any chemical, organic material, live organism, or radioactive material that will lower the quality of the natural ground water. 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.

**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.

**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 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 3 or more for short-term loading to 2 for long-term loading.

**Dimension Ratio (DR)** The ratio of the specified average inside diameter to the specified minimum wall thickness.

**Drawdown** The vertical distance the water level drops in a well pumped at a given rate.

**Delivery Rate** The rate at which a quantity of water is delivered in a certain time period to a given location.

**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.

**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. Polyethylene (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 psig (**p**ounds per **s**quare **i**nch **g**age pressure).

**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.

**HDPE - High Density Polyethylene Pipe** — Tougher high density polyethylene plastic material, able to be used for above ground installations.

**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.

**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 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 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 7500 gallons. It is equivalent to 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.

**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 non-offensive 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 7500 gallons; 1 kernel of corn in 13 bushels; 6 1/4 sq. in. in an acre.

**Peak Use Rate** The flow rate necessary to meet the expected maximum water demand in the system.

**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.

**pH** A measure of the acidity or alkalinity of water. Below 7 is acid, above 7 is alkaline.

**pHs** pH at which water having the same alkalinity and calcium content is just saturated with calcium carbonate.

**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.

**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 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 drinking.

**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 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** The maximum rating at which a component is able to perform in a system.

**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 cannot.

**Pressure Test** A test in which current pressure can be estimated anywhere in a system.

**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. |
| **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 U. S. Geological Survey. |
| **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 watertightness. |
| **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)**<br>**SDR-PR** | Standard Dimension Ratio - Pressure Rated pipe. It is a PVC pipe material. |
| **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 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 waterlevel. 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.

**Sure 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** 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.

**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 1 to 3 feet high from bottom of channel to top of ridge.

**Water Bearing Zone** A depth of ground below surface that has the potential to provide 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 Table Well** A well where the water level is at the surface of the aquifer.

**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 | 43,5660 |
| Acres | Square yards | 4,840 |
| Acre Feet | Gallons | 325,851 |
| Cubic Feet | Gallons | 7.48 |
| Cubic Feet | Cubic Inches | 1,728 |
| 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 | $8.35 \times 10^{-6}$ |
| 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 |