NATURAL RESOURCES CONSERVATION SERVICE
MONTANA CONSERVATION PRACTICE STANDARD

PUMPING PLANT (NUMBER)

CODE 533

DEFINITION

A facility that delivers water at a designed pressure and flow rate. Includes the required pump(s), associated power unit(s), plumbing, appurtenances, and may include on-site fuel or energy source(s), and protective structures.

PURPOSE

This practice may be applied as a part of a resource management system to achieve one or more of the following:

- Delivery of water for irrigation, watering facilities, wetlands, or fire protection
- Removal of excessive subsurface or surface water
- Provide efficient use of water on irrigated land
- Transfer of animal waste as part of a manure transfer system
- Improvement of energy use efficiency
- Improvement of air quality

CONDITIONS WHERE PRACTICE APPLIES

This practice applies where conservation objectives require the addition of energy to pressurize and transfer water to maintain critical water levels in soils, wetlands, or reservoirs; transfer wastewater; or remove surface runoff or groundwater.

CRITERIA

General Criteria Applicable to All Purposes

Pump requirements. Design flow rate, range of operating heads, and pump type shall meet the requirements of the application.

Break horse power requirements are computed using the following equation:

$$BHP = \frac{GPM \times TDH}{3960 \times \text{Pump Efficiency}}$$

Where: GPM is the flow rate in gallons per minute.
TDH is the Total Dynamic Head in feet.

In order to select a proper pump for a particular application utilize the system curve and the pump performance curve. The system curve describes the capacity and head needed for the system at various operating conditions. The pump curve provides information on the pump's ability to produce head and flow capacity along with information on pump efficiency and brake horsepower requirements. The best selection of a pump will be one that will operate at or near its peak efficiency.

For centrifugal pumps, the available Net Positive Suction Head Available (NPSHA) needs to be greater than the required Net Positive Suction Head Required (NPSHR) for proper performance. When the NPSHR by the pump is greater than the NPSHA by the system, cavitation occurs and it may damage the pump. Reference the National Engineering Handbook (NEH), Section 15, Chapter 8, Irrigation Pumping Plants for proper pump selection.

Selection of pump materials shall be based on the physical and chemical qualities of the material being pumped and manufacturer's recommendations.

NOTE: This type of font **(AaBbCcDdEe 123..)** indicates NRCS National Standards.
This type of font (AaBbCcDdEe 123..) indicates Montana Supplement.

The capacity of pumps installed in wells shall be less than the capacity of the well. Generally, pump capacity should not exceed 70 percent of the well test. Stockwater systems with multiple stock tanks must operate at different flow and head conditions. Consider flow controls to maintain a flow rate near the pump's most efficient operating range and to prevent over pumping the well.

Stockwater pumping plants can be automatic or timed (manual) pressure systems. An automatic pressure system is controlled by a pressure switch that turns the pump on or off. A pressure tank stores water between the cut-in and cut-out pressures. The advantage of an automatic pressure system is that it does not require constant attention, and a minimum amount of power and water are used. A timed pressure system is controlled by a timer that turns the pump on or off. An overflow is required at the high point in the system. Timer or manually-operated systems are commonly used where high pressures, typically greater than 125 to 150 psi, make pressure tanks impractical. Reference the Montana Stockwater Pipeline Manual for design of stockwater systems.

Power units. Pump power units shall be selected based on the availability and cost of power, operating conditions, need for automation, and other site specific objectives. Power units shall match the pump requirements and be capable of operating efficiently and effectively within the planned range of conditions. The power unit shall be sized to meet the horsepower requirements of the pump, including efficiency, service factor, and environmental conditions.

The power consumption and operating costs of the pump are required. They can be computed by estimating the energy usage, such as electricity consumption in kilowatt hours (kW-h).

kW-h = .746 x BHP x Operating Hours/Year

Yearly costs are determined by multiplying the kW-h per year by the local unit cost and adding extra fees such as demand charges.

Electric power units may include line power, photovoltaic panels, and wind or water powered turbines.

Electrical wiring shall meet the requirements of the National Electrical Code.

Irrigation, livestock watering, and ag-waste pump systems require electrical inspections unless the pump is a direct (same size and electrical requirements) replacement of an existing power unit, or when a contractor assembles a UL-listed solar pump package. Documentation of the permit application number and date shall be included on MT-ENG-533, "Pumping Plant Certification of Installation."

Variable Frequency Drives. The owner shall inform the electric power provider that a Variable Frequency Drive will be installed prior to installation, and be responsible for following requirements of the electric power provider.

The Variable Frequency Drive shall be protected against overheating.

The Variable Frequency Drive control panel shall provide the read out display of flow rate or pressure.

Photovoltaic panels. The photovoltaic array shall be sized based on average data for the location and the time of year pumping occurs, according to manufacturer's recommendations. The photovoltaic array shall provide the power necessary to operate the pump at the design flow rate, with the appropriate service factor considering a minimum panel degradation of 10 years. Fixed arrays shall be oriented to receive maximum sunlight. Panel tilt angle shall be based on the location latitude and time of year for power requirements. Panels shall be mounted securely to resist movement by environmental factors.

An acceptable PV powered pumping plant shall include the following components:

- **Photovoltaic array and mounting structure**
- **Pump, including intake and outlet piping**
- **Electrical system**
- **Protective structures**
- **Provisions for water storage.**

Float switches, timers or other monitoring devices shall be included to minimize the waste of water.

SOLAR RADIATION DATA

Site-specific data are preferable for system design. Where site-specific data is not available, solar radiation values may be estimated using the National Renewable Energy Laboratory (NREL), "Solar Radiation Data Manual for Flat-Plate and

Concentrating Collectors." This data is available on-line.

The solar radiation values for the period where the ratio of daily water requirement to average daily solar radiation is largest shall be used to size the PV array.

PV SYSTEM COMPONENTS

Electrical components must be designed and installed in accordance with all applicable provisions of the National Electrical Code (NEC). All components shall be warranted against material and workmanship defects for a period of no less than one year from installation.

An electrical inspection is not required if the system is less than 90 volts or the system is provided as a UL-listed package.

PV modules must have as a minimum, a manufacturer's warranty against power degradation in excess of 10% of the rated power for no less than 10 years after installation.

The array mounting structure may be fixed or portable. It shall be designed with adequate anchors to maintain alignment under the normally expected loads and to support the array under extreme conditions.

A pump controller, inverter, fuses, surge protection and other electronic components shall be provided as recommended by the pump and PV module manufacturers, or as necessary to meet NEC requirements. Provisions shall be included to protect the pump from common pump faults, overload, electrical short circuits, and low water (dry running), as recommended by the pump manufacturer. A circuit breaker shall be provided as a means for disconnecting the array from the system. All electronic components shall be housed in a weather resistant enclosure (National Electrical Manufactures Association (NEMA) 3R or equivalent). The system components shall be grounded in accordance with the NEC.

Wiring materials and methods shall be in accordance with the NEC. All wiring shall be sized for a minimum of 125% of the maximum expected currents, and when feasible maintain the total distance voltage drop to less than 2.5%.

SOLAR PUMPS

The pump must be capable of delivering the design water requirement at the estimated total dynamic pumping head when solar power is available. When solar-powered pumping systems are used, and other sources of water are not available, a minimum of three-day storage per pasture is required. When the source of water is a well, depth, yield, static water level and drawdown level at the design pumping rate shall be determined.

The pump and fittings must be constructed from materials appropriate for the quality of water expected. Stainless steel, brass or plastic material shall be specified when Total Dissolved Solids (TDS) in water are greater than 500 ppm. The pump intake must be adequately screened to prevent entrance of sand or other objectionable material.

All components of the system shall be protected from damage by livestock or wildlife with fencing or other appropriate measures.

Windmills. Pumping units shall be sized according to pumping lifts and capacities, as specified by the manufacturer. The diameter of the mill shall be based on the stroke length **(typically the long stroke)** and the average wind speed. Towers shall be proportioned to the mill diameter, with adequate height for efficient and safe operation.

Water powered pumps (hydraulic rams). Pumping units shall be sized according to flow rate, lift, fall, and efficiency. Bypass water shall be returned to the stream or storage facility, without erosion or impairment to water quality.

Suction and discharge pipes. To prevent cavitation, suction and discharge pipes shall be designed to account for suction lift, net positive suction head, pipe diameter and length, minor losses, temperature, and altitude. The size of suction and discharge pipes shall be based on hydraulic analysis, operating costs, and compatibility with other system components.

Suction lines from centrifugal pumps or suction bowls on turbine pumps are often installed in sumps. Sump dimensions versus flow, clearance between the pump suction and the floor and sidewalls, and submergence shall be as shown in NEH, Section 15, Chapter 8, or NEH, Section 16, Chapter 7, or the manufacturer's recommendations. Safety precautions such as hand rails or walkways shall be provided around open sumps.

Discharge pipes from manure transfer pumps can have pipe friction losses higher than those for clean

water. The velocity in these pipes should be less than 5 feet per second, with a minimum of 2 fps to prevent sedimentation. Table 11-1 in the Agricultural Waste Management Field Handbook presents the relative increase in friction loss for slurries.

Pumps used to transfer feedlot runoff or control water tables shall be designed for:

1. **Continuous operation for full storage drawdown, and/or**

2. **Periodic operation with 10-15 cycles per hour.**

These modes of operation will extend the pump life and protect the on/off switch. The relationship between inflow, outflow, sump storage, and cycle times is given by:

$$\frac{60}{n} = \frac{7.5\,S}{Q_p - Q_i} + \frac{7.5\,S}{Q_i}$$

Where; n = Number of cycles per hour
S = Storage volume in cubic feet
Qp = Pumping rate in gpm
Qi = Inflow rate in gpm
7.5 = conversion factor from gallons to cubic feet.

Appurtenances such as gate valves, check valves, pressure reducing valves, pressure gages, pipe connections, and other protective devices, shall be included to meet the requirements of the application.

Screens, filters, trash racks, or other devices shall be installed as needed to prevent the intake of sand, gravel, debris, or other objectionable material into the pump. Intake screens shall be designed according to applicable Federal and State guidelines, to avoid entrainment or trapping of aquatic organisms.

Backflow prevention devices shall be included according to Federal, State, **Tribal,** and Local laws, to prevent contamination of water sources connected to the pumping plant. **Reference the National Engineering Manual (NEM), Part 503, Safety, on protection of domestic water supply.**

Buildings and accessories. Pumps shall be securely mounted on a solid foundation such as pilings or concrete. Foundations shall be designed to safely support the loads imposed by the pumping plant and appurtenances. Sheet piling or other measures shall be used, as required, to prevent piping beneath the foundation.

Where buildings are necessary to protect the pumping plant, provisions shall be included for adequate ventilation and accessibility for equipment maintenance, repairs, or removal.

Protective measures shall be taken to assure pumps and appurtenances such as pressure sensors are not subject to extreme cold temperatures. If these units are to be operated in the winter, insulated or heated housing shall be provided.

Suction bays or sumps shall be designed to prevent the introduction of air at the intake.

The discharge bay or the connection to the distribution system shall meet all hydraulic and structural requirements.

Structures and equipment shall be designed to provide adequate safety features to protect operators, workers, and the public from potential injury. Drive shaft covers shall be required on all exposed rotating shafts.

Manufactured tanks shall not be used for well pits unless they are determined to be structurally sound by one of the following methods in accordance with NEM, MT512.33:

1. **A structural analysis performed by an NRCS Engineer with the proper job approval authority or sealed by a registered Professional Engineer.**

2. **A performance test completed by the tank manufacturer in accordance with the applicable specifications of the American Society of Testing and Materials (ASTM).**

<u>Irrigation Water Management</u>. Provisions for the connection of flow and pressure measurement devices shall be included in power plant system design.

<u>Energy Efficiency</u>. For fossil fuel or electrical grid power sources, pumping plant installations shall meet or exceed the Nebraska Pumping Plant Performance Criteria. Refer to the NRCS, National Engineering Handbook, Part 652, National Irrigation Guide, Exhibit 9-10 and Table 12-2.

Table 12–2. Nebraska pumping plant performance criteria

Energy source	bhp–h 1/ per unit of energy	wHp–h 2/ per unit of energy 3/	Energy units
Diesel	16.66	12.5	gallon
Gasoline	11.5 4/	8.66	gallon
Liquid Propane	9.20 4/	6.89	gallon
Natural Gas	82.2 5/	61.7	1,000 cu. ft.
Electricity	1.18 6/	0.885 7/	kilowatt-hour

1/ bhp–h (brake horsepower-hours) is the work being accomplished by the power unit (engine or motor) with only drive losses considered.

2/ wHp–h (water horsepower-hours) is the work being accomplished by the pumping plant, engine, or motor and pump.

3/ Based on 75 percent pump efficiency.

4/ Taken from Test D of Nebraska Tractor Test Reports. Drive losses are accounted for in the data. Assumes no cooling fan.

5/ Manufacturer's data corrected for 5 percent gear head drive loss with no cooling fan. Assumes natural gas energy content of 925 Btu per cubic foot. At 1,000 Btu per cubic foot, energy content uses 88.9 Hp-h per 1,000 cubic feet for natural gas. Btu per cubic feet can vary from season to season and from winter to summer.

6/ Assumes 88 percent electric motor efficiency.

7/ Direct connection, assumes no drive loss.

Additional Criteria Applicable to the Improvement of Air Quality

Replacement pumping plants shall have lower total emissions of oxides of nitrogen and fine particulate matter, compared to the unit being replaced.

New, replacement, or retrofitted pumping equipment shall utilize a non-combustion power source, or cleaner-burning technologies or fuels.

CONSIDERATIONS

When planning this practice, the following should be considered as applicable:

- The removal of surface water by a pumping plant can affect downstream flows or aquifer recharge volumes. Consider potential the long-term impacts downstream of the pumping plant.
- If using a pumping plant to remove surface water or groundwater flowing into a wetland, consider the potential impacts on existing wetland hydrology.
- The operation and maintenance of a pumping plant can involve the use of fuels and lubricants that when spilled may adversely affect surface or groundwater quality. Consider measures to protect the environment from potential spills. In some cases, secondary containment of spilled fuel may be required by Federal, State**, Tribal, or Local** laws or regulations.
- Pumping plants are often constructed in flood-prone areas or can be subject to other unexpected natural events. Consider how the pumping plant may be protected from extreme natural events and the consequences of damage or failure.
- **Consideration shall be given to the stability of the river section where pumps are located near the river bank.**
- Include protective sensors to detect low or stopped flow, or pressures that are too high or too low.
- **Include the use of Variable Frequency Drive Control systems to protect the pump and conserve energy.**
- **In lightning-prone areas, consideration should be given to locating the system away from high points in the topography, installing lightning rods adjacent to the system, and including lightning surge protection in the system specifications.**
- The visual appearance of buildings or structures associated with the pumping plant should be compatible with the surrounding environment.
- When installing new or replacing existing combustion equipment, non-combustion and renewable energy sources, such as solar, wind, and water, should be considered.

PLANS AND SPECIFICATIONS

Plans and specifications for constructing pumping plants shall be in accordance with this standard and describe the requirements for properly installing the practice to achieve its intended purpose. As a minimum, the plans and specifications shall include the following:

- A plan view showing the location of the pumping plant in relationship to other structures or natural features.
- Detail drawings of the pumping plant and appurtenances, such as piping, inlet and outlet connections, mounting, foundations, and other structural components.
- Written specifications that describe the site-specific details of installation.

OPERATION AND MAINTENANCE

An Operation and Maintenance plan specific to the pumping plant being installed shall be prepared for use by the owner and responsible operator. The plan shall provide specific instructions for operating and maintaining facilities to ensure the pumping plant functions properly as designed. As a minimum, the plan shall address the following:

- Inspection or testing of all pumping plant components and appurtenances.
- Proper start-up and shut-down procedures for the operation of the pumping plant.
- Routine maintenance of all mechanical components (power unit, pump, drive train, etc.) in accordance with the manufacturer's recommendations.
- Procedures to protect the system from damage due to freezing temperatures.
- When applicable, procedures to frequently check the power unit, fuel storage facilities, and fuel lines, for leaks and repair as needed.
- Periodic checks and removal of debris as necessary from trash racks and structures, to assure adequate flow capacity reaching the pumping plant intake.
- Periodic removal of sediment in suction bays, to maintain design capacity and efficiency.
- Inspection and maintenance of anti-siphon devices, if applicable.
- Routine test and inspection of all automated components of the pumping plant, to assure the proper functioning as designed.
- Inspection and maintenance of secondary containment facilities, if applicable.
- Periodic inspection of all safety features, to ensure proper placement and function.
- Prior to retrofitting any electrically powered equipment, electrical service must be disconnected and the absence of stray electrical current verified.

REFERENCES

NRCS, National Engineering Handbook, Part 652, National Irrigation Guide.

National Engineering Handbook (NEH), Section 15, Chapter 8, “Irrigation Pumping Plants”.

National Engineering Handbook (NEH), Section 16, Chapter 7, “Drainage Pumping”.

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“Understanding Pumps, Controls, and Well”, The Irrigation Association, August 2000.

“Sprinkler Irrigation Systems”, Midwest Plan Service (MWPS), First Edition, 1999.

National Renewable Energy Laboratory. Solar Radiation Data Manual for Flat-Plate Concentrating Collectors. National Renewable Energy Laboratory, Golden, CO, April 1994.

Naval Facilities Engineering Command. Maintenance and Operation of Stand-Alone Photovoltaic Systems. Revised 1991. Photovoltaic Design Assistance Center, Sandia National Laboratories, Albuquerque, New Mexico.

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