Guidelines for Use of Pumps and Siphons for Emergency Reservoir Drawdown

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ENGINEERS • SURVEYORS • PLANNERS • SCIENTISTS

GUIDELINES FOR USE OF PUMPS AND SIPHONS FOR EMERGENCY RESERVOIR DRAWDOWN

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ABSTRACT

The Guideline for Use of Pumps and Siphons for Reservoir Drawdown provides the reader information to determine the best method to employ for reservoir drawdown. Both pumps and siphons effectively remove water from reservoirs and can provide the necessary increased capacity in emergency situations. Each site and event has unique circumstances which will determine the method best suited. This guidebook outlines a process using basic hydraulic and logistical considerations for determining the best method for reservoir drawdown. Part of this process includes outlining important factors to be used in decision making. Key topics for both pumps and siphons are explored in detail.

Where access to the dam is adequate, a pumping system could be considered. A pump can transport water over dam crests at almost any lift height and can provide a large flow rate capacity increase when sized correctly. Large pumps can be cumbersome and sometimes require continual observation to prevent maintenance issues and damage. A power source must be identified and be reliable at the dam site. With the pumping option, both energy and observation costs are significant factors for consideration.

Siphons typically require less material and equipment allowing for use in more remote locations with more difficult access and when set up properly, can require minimal oversight. Siphons are limited by the height of lift from the reservoir to the crest of the dam. They also require care during initial setup to ensure air tightness and proper inlet and outlet conditions. It is often easier to setup several smaller siphons rather than a single large system.

Some important considerations when determining which method to use are:

- Height of lift over dam crest
- Depth of drawdown required
- Discharge flowrate required
- Access available at site and power sources available
- Dam embankment stability
- Inlet and outlet conditions, water depths, armoring, and debris
- Amount of operation and maintenance time available
- Availability of supporting equipment and cost

INTRODUCTION

The purpose of this guide is to provide a resource to persons involved in the drawdown of a reservoir. Reservoir drawdown can only be accomplished when the outflow rate is greater than the inflow rate. Under normal operating conditions, reservoir drawdown is accomplished through the use of the outlet works and also through the use of spillways depending on the water level in the reservoir. What happens when the outlet works are inoperable? Not having means to control the reservoir level may create a risky situation and may place both the dam owners and public in jeopardy.

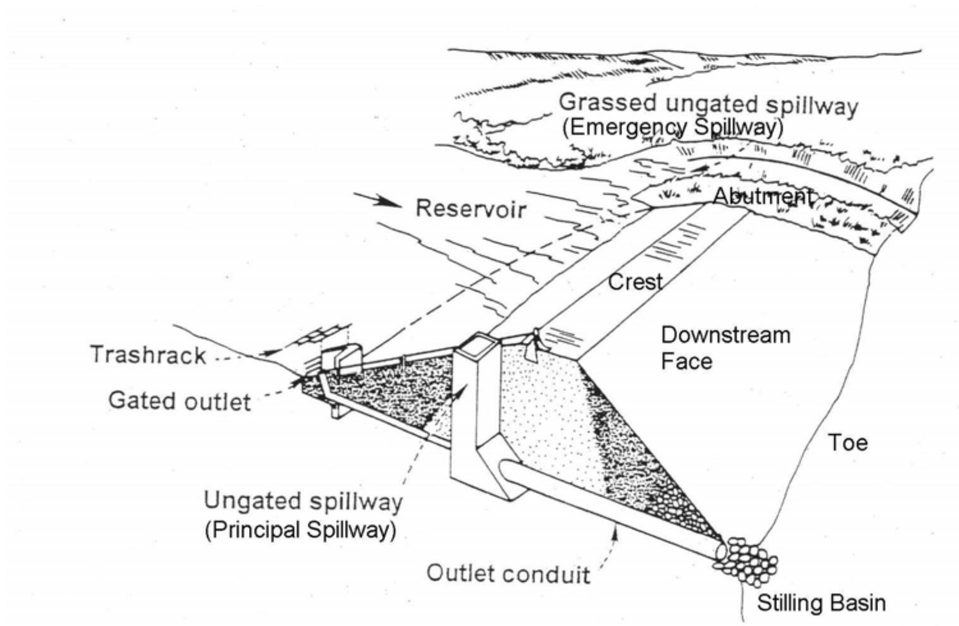

FIGURE 1 - TYPICAL DAM COMPONENTS

All dams should have a properly designed emergency spillway to control overtopping and prevent embankment failure. However, even emergency spillways have a given capacity. When inflow rates exceed the outflow capacity of a dam, such as during the failure of outlet works, alternative drawdown methods are needed. Without a mechanism to control outflows, the reservoir could overtop the dam crest resulting in damages to the dam, down-gradient properties and could place the general public at risk. This document explores the choice between pumping and siphoning alternative drawdown methods.

The guide is a reference for dam owners and operators, engineers, agencies and suppliers of materials that may be used for temporary drawdown. Further, this guide will not make the decision for you. Each situation is unique and warrants adequate consideration on how best to drawdown the reservoir. This guide supplements the decision making process by offering key points to consider during the decision making process. It can also be a useful tool for dam owners developing an Emergency Action Plan (EAP). Temporary solutions are the focus of this guide and the drawdown methods described are not intended to be permanent.

It should be noted that information in this guide is basic in nature. Dam owners are encouraged to contact a professional engineer if the situation is complicated. Some situations or sites may require additional analysis. Some factors that could warrant further investigation are, but not limited to:

- Remote locations,
- Large crest width,
- Long-term solution needed,
- Specific and/or large outflow rate required, and
- Dam stability issues.

Example scenarios of when this guide would be utilized:

- Emergency repair – In the event an outlet works is inoperable and the risk of significant inflow exists, a pump or siphon could be used to drawdown the reservoir to allow repair of the outlet works and prevent overtopping of the reservoir. In an emergency situation, the dam owner should reference the EAP. A well-developed EAP should offer:
  - safe drawdown rates and maximum discharge rates for each dam,
  - provide the dam owner/operator with all necessary information, and
  - include emergency drawdown procedures and methods.

- Standard maintenance – The use of the drawdown methods described in this guide are not limited to emergency situations. For example, if maintenance of dam structure requires drawing down the reservoir at a more expedited rate than the outlet structure and spillway can provide, then drawdown may be supplemented using a pump or siphon.

- Source of water delivery – In lieu of traditional outlet works, some dams have used siphons or pumps as the only source of water delivery. For example, if a dam historically had issues such as piping and erosion with an existing outlet works, the owner may elect to abandon the outlet works for a siphon.

OVERVIEW OF PUMP OPTIONS

Pumping water over the dam crest to drawdown a reservoir can be a timely and effective method. Proper sizing of the inlet pipe, pump, air vent, and outlet erosion protection are critical to ensure drawdown needs are met with success. This section reviews the basic components of pumps to help the dam owner understand and select the best pumping configuration for the site. Often, a pump supplier can assist the owner through this process. The pump supplier should query the dam owner about site specific information to assist in the system configuration.

Pumps and the required parts come in a wide range of types and manufacturers. The basic layout of a pumping system can generally be broken down into five components. The components of a typical pumping system are the inlet pipe, pump, power source, air valves and outlet pipe.

PUMPING SYSTEM COMPONENTS

Inlet Pipe: Selection of the pipe size and type will affect the performance of the pumping system. A pipe diameter with sufficient cross sectional area should be used to prevent excess friction and transitional losses. When flow velocities exceed approximately 12 feet per second these effects can hinder pumping capacity. Table 1 includes general guidelines for the size of pipe required for a given flow, although it is important to rely on the pump supplier for recommendations. Be sure that the pipe being used will be capable of withstanding the pressures expected.

Also consider the need for an inlet screen to prevent debris from entering the pump and causing damage.

The following table provides rule-of-thumb guidance on the inlet pipe sizes required per flow rate to avoid excessive losses from water velocity. A pump supplier will also offer guidance based on a particular pump model.

TABLE 1 - SUGGESTED INLET PIPE DIAMETER PER FLOW RATE

Flow up to (gpm)	Pipe diameter (in)
300	4
600	6
1100	8
1700	10
2500	12

Pump and Power Source: A common pump type used for pumping irrigation water is a centrifugal pump. This type of pump has two main components: an impeller attached to a rotating shaft, and a stationary casing or housing (volute) enclosing the impeller. The impeller consists of a number of blades that are usually curved and are arranged in a regular pattern around the shaft.

As the impeller rotates, fluid is moved into the housing through the center of the casing and flows radially outward.

FIGURE 2 – TWO SUBMERSIBLE PUMPS PRIOR TO INSTALLATION

Several considerations are associated with this type of mechanism. First, some type of power source must be available. Several different types of pumps are currently available that allow the pump to be run from different energy sources including electricity and diesel engines. A second consideration is availability and transportation of the pump and associated equipment.

A person should be assigned to monitor the pump throughout operation every 3-12 hours at a minimum. Some installations warrant continuous monitoring. Consult with the pump supplier for operation and maintenance recommendations.

The pump needs to be sized to pump the necessary calculated flow rate and overcome the maximum elevation difference between the dam crest and the reservoir. Pump manufacturers publish pump curves showing pump performance against varying Total Dynamic Head (TDH). TDH is the sum of elevation and hydraulic losses that the pump must overcome. The pump curve will indicate the flow rate a pump can generate when pushing against TDH values. The largest TDH value may occur when the pump has been in operation for a while and the water level in the reservoir had dropped to its lowest elevation.

It is important to understand that some pumped systems could create a siphoning effect. An engineer or pump supplier may help determine if a siphon effect could indeed occur. Provisions should be made to avoid a siphon effect with a pumped system because a siphon in this case may damage the pump. Installation of an air vacuum valve of the appropriate size at the appropriate location could break the water seal and prevent a siphon effect.

To prevent the NPSHA from reducing to an unsafe level, it may be necessary to relocate the pump as water level drops. Also, the elevation of the reservoir should be provided to pump suppliers since high elevations can cause NPSHA reduction.

Pumps may be fairly large and bulky depending on the size.
A trailer may be required for the transport of the pump and associated equipment. The pump may also be mounted on a skid for ease of mobility. If the location of the reservoir is not close to a maintained road, then that restriction must be adequately addressed.

Another pump consideration is the availability of Net Positive Suction Head (NPSH). NPSH is the difference in the total head on the inlet or suction side of the pump and the liquid vapor pressure on the inside of the pump expressed as head. It can also be thought of as the total amount of suction pressure available to the pump. Each pump manufactured has a published NPSH curve to determine the amount of NPSH required (NPSHR) at a particular flow rate. When pumps operate at low flow rates and/or when adequate straight runs of piping are not provided upstream of the pump inlet, the amount of NPSH available (NPSHA) decreases. If the amount of NPSHA drops below the NPSHR, the pump may experience cavitation. Cavitation is a situation that results from the liquid pressure being reduced to the vapor pressure of the liquid. When the liquid pressure reaches the vapor pressure inside of the pump, the liquid boils. Over a period of time, the impact of the air bubbles breaking against the inner components of the pump will drastically shorten the life of the pump impeller, mechanical seals, bearings, and other components.

An indicator of cavitation is the sound of gravel being pumped. If you hear this sound, IMMEDIATELY TURN OFF THE PUMP.

When considering the size and number of pumps for your system, factor in redundancy to account for the risk of pump downtime due to maintenance or failure.

FIGURE 3 – A 90 BEND IS DIRECTED UP ON THE OUTLET PIPE TO DISSIPATE ENGERGY

Outlet Pipe: It is important to ensure that the outlet of the pipe does not cause damage to the downstream slope of the dam embankment. Scour and/or saturation of the embankment or toe can cause serious stability problems. To ensure dam stability problems are avoided, outlets should be located well downstream of the dam toe and have adequate scour protection. Outlet protection measures will vary depending on dam stability, downstream conditions, and the pumping flow rate.

Install the outlet pipe to avoid isolated high points in the line.

Combination Air Valves, Air Release Valves and Air Vacuum Breaker Valves: Air in pipeline systems is a significant consideration. Air will enter the inlet if it is too close to the water surface or if the water being pumped is entrained with air. Air in the line collects at high points in the system and trapped air can reduce pipe capacity, increase wear on the pipe and reduce pump efficiency. The crest of the dam is often the high point in the system and warrants an air release valve if conditions suggest this could be an issue. Air release valves should be attached to any other high point(s) in the pipeline to allow air trapped in the pipe to escape.

FIGURE 4 - VALVES INSTALLED ON A PIPE

The air release valve can be either an automatic air release valve or a less expensive manual release value. As the name implies, the manual valve requires manual operation. The selection of an automatic versus manual value is based on the duration of time the siphon or pumping system is installed and the availability of resources to operate a manual valve.

A vacuum breaker valve is used in situations where vacuum protection is a must or where column separation is predicted. The vacuum breaker is mounted at critical pipeline high points, and allows for rapid inflow of atmospheric air to reduce vacuum conditions in piping systems. Without a vacuum breaker, a pumping system could inadvertently create a siphon effect or significant low pressure in the discharge line. The installation of a vacuum breaker at the high point will introduce air to the system to avoid a siphon effect such that the water flowing downhill is free flow and not acting as a siphon. The risk to creating an uncontrolled siphon effect on a pumped system is that too much water could be pulled through the pump causing increased velocities and increasing the risk of cavitation. Further, a vacuum breaker reduces low pressures in the line and prevents pipe collapse associated with low pressures in the line. A pump supplier or engineer may opt to design the pump system to exclude a vacuum breaker and include a siphon effect; however, this analysis must be carefully examined as to avoid cavitation in the system or pipe collapse.

Column separation is a phenomenon that can occur during a water-hammer event. If the pressure in a pipeline drops rapidly to the vapor pressure of the liquid, the liquid vaporizes and a "bubble" of vapor forms in the pipeline.

A qualified professional engineer or pump supplier may suggest critical locations in the pump system to avoid issues with air entrainment or air vacuums.

A combination air valve is an air release valve and vacuum breaker valve in one component.

PUMPING SYSTEM ADVANTAGES

The advantages to a pump dewatering system include ease of installation and ability to handle a high degree of lift. Pumps are relatively quick to set up and are manufactured in many different types as well as sizes. Also, pumps are able to deal with a large elevation lift, which is important considering a siphon alternative may not be feasible when lifts greater than 15-20 feet are required. Required lift refers to the vertical distance from the water surface elevation to the highest point that the water may need to be pumped to in order to drawdown the reservoir. Normally that high point would be the top of the embankment of the dam. Pumps can be sized to provided whatever lift is required. Pumps are capable of handling significant lift because the greater the lift, a larger pump or an intermediate “booster” pump can be installed to lift the water over the dam crest. Pumps are advantageous in a situation where the reservoir levels need to be lowered quickly where the lift exceeds 15-20 feet.

PUMPING SYSTEM DISADVANTAGES

Pumps are often large and heavy, requiring a trailer for transportation to a site. If the dam site is located in a remote location with restricted access, a pump may not be a very good option. Pumps are also costly to rent at a price of approximately $150-$350 a day excluding freight and fuel. Not all pump sizes are stocked by pump suppliers for short notice use. The pumps available may have too low of a pump capacity and may not be able to handle the amount of elevation change required. A pump supplier may have to order in the particular size needed which may take several weeks (pump suppliers are not a prevalent as pipe suppliers and travel distances can increase because of that).

Other disadvantages to pumping systems are that they require an energy source and must be monitored during the period that they are pumping. However, different types of pumps have the ability to run from different power sources. Several of the types of power sources that a pump may run off of include: electric motor, diesel engine, gasoline engine, tractor PTO, and hydraulic flow and pressure. Pumps need to be regularly maintained and monitored during the period of time that the pump is being operated. If a pump were to cavitate or were to run dry, serious damage could occur to the pump, reducing efficiency or stopping operation altogether.

OVERVIEW OF SIPHON OPTIONS

Siphons are an inverted u-shaped pipe or closed conduit that are filled or primed to allow atmospheric pressure to force water from a reservoir over an embankment dam and out the other end of the pipe. The pipe or conduit is designed to run full and under a pressure differential. The inlet of the pipe forms a vacuum and draws water up through the pipe, over a designated lift, and discharges the water at a location below the original water level. A seal between the water surface and the pipe inlet and outlet keeps air from entering the pipe and allows water to flow through the pipe, over the embankment to the location of the outlet. In some situations, a vacuum breaker valve may be required on the down-gradient end of the siphon. A professional engineer can advise on the need and location of a vacuum breaker valve. Siphons can effectively draw down the level of the surface in the reservoir and move the excess water to a convenient location downstream of the dam in the outlet channel in some situations.

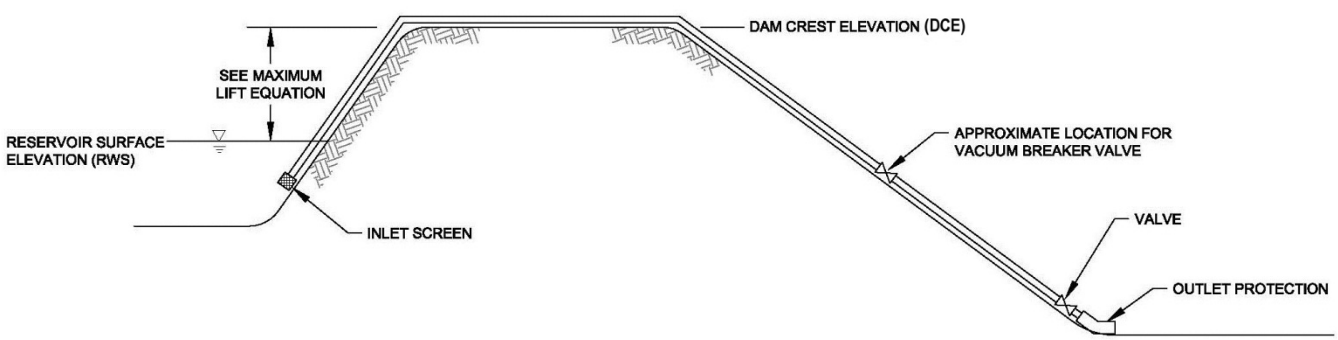

FIGURE 5 - TYPICAL SIPHON COMPONENTS

UNDERSTANDING SIPHON DESIGN GRADES

This section reviews key design criteria to help the reader understand if a siphon is appropriate for their specific site. A series of equations are presented to help the dam owner determine if the site elevations and siphon will serve drawdown needs. A professional engineer can also assist with the calculations and design.

The greatest challenges with siphon design all relate to the elevations of the siphon pipe. Most important are the dam crest elevation in relation to minimum water surface elevation. If this difference in elevation is too great, the siphon will not work. Siphon operation is based on atmospheric pressure lifting the water up the siphon. Siphon operation is limited to the elevation difference that produces water vaporization. If the lift is too great, the water will vaporize, which results in the inability to create a siphon effect and may even cause pipe collapse.

If the dam crest is too high compared to the surface water elevation, consider digging a temporary notch in the dam crest to reduce required lift.

When deciding if a siphon will work for your site, the most important equation to understand is the *Maximum Siphon Lift Equation*. To determine if the elevations in the system are appropriate for siphon design, the first measurement that should be taken is the difference from the dam crest elevation (DCE) to the minimum reservoir water surface (RWS) elevation. Figure 5 shows the location of the RWS and DCE. This value can be used to determine if a siphon is hydraulically feasible at the site according to the *Maximum Siphon Lift Equation*.

FIGURE 6 - NOTCHING THE CREST OF A DAM TO REDUCE LIFT FOR SIPHON

$$DCE - RWS \leq 20' - \frac{RWS}{1000}$$

This equation is based on the atmospheric pressure at sea level. Note that water vapor pressure decreases with increasing elevation. It is important to consider that the reservoir surface elevation changes as the siphon draws down water. The equation should be reviewed for the worst case situation, which is the lowest reservoir water surface level desired. As the water level lowers, the vertical distance from the water level to the top of the embankment will increase. If that distance increases beyond what the siphon can lift, it will stop working, perhaps not drawing down the reservoir water level far enough. If the left side of the equation is greater than the right side of the equation, then a siphon will not work for your site.

If the site will allow a siphon, another equation can be used to determine the siphon flow capacity. This will help you estimate the size and number of siphons needed. This equation, known as the *Predicted Siphon Flowrate Equation* is a variation of the Bernoulli Equation simplified to account for typical siphon applications for clean water. This equation is only valid for dam sites that: 1) the elevation satisfies the Maximum Lift Equation, and 2) a vacuum breaker valve does not interrupt the siphon effect between the reservoir water surface and the outfall water surface.

$$Q = 0.0438 D^{2.5} H^{0.5} \left(12 fL + KD + D\right)^{-0.5}$$
$$f = 425\left(n^2 / D^{0.33}\right)$$

In these equations:

- Q is flow in cubic feet per second (cfs) is calculated from the equation above,
- D is the siphon pipe diameter in inches,
- H is the elevation difference from the outlet to the reservoir water surface (RWS),
- f is the dimensionless friction factor that is calculated from the equation above,
- n is the Manning's n value for the pipe material that can be found in most hydraulic reference book, and
- L is the total length of pipe.

- K is the sum of dimensionless coefficients of hydraulic losses associated with siphon components such as entrance grates, bends, valves, exits, etc.

The value of H is measured from the outlet water surface downstream of the dam to the reservoir water surface elevation; the dam crest elevation is irrelevant in this equation. The value of K will ultimately depend on the layout and components used in the siphon. The table below shows typical K values for selected components. (AWWA, M11 Fourth Edition)

TABLE 2 - SUGGESTED "K" VALUES FOR SELECT COMPONENTS

Component	**"K" value**
Entrance Loss	0.8
45° Bend	0.3
Gate Valve (fully open)	0.2
Ball Valve (fully open)	10.0
Butterfly Valve (fully open)	0.2
Check Valve	10.0
Exit Loss	1.0

The two relationships that must be evaluated when designing a drawdown siphon are:

1. The *Maximum Siphon Lift Equation* will indicate the ability of the siphon to lift water over the dam crest. This relationship will determine if the siphon method can be further investigated.

2. The *Predicted Siphon Flowrate Equation* will indicate the flowrate expected for a given siphon diameter and elevation difference. This equation will indicate the diameter and number of siphons that may be required to meet the reservoir drawdown objectives.

The critical case that must be evaluated for each equation is the **lowest reservoir water surface elevation** expected. This will correlate to the largest siphon lift (greatest vacuum pressures) and the smallest water surface elevation difference from the siphon inlet to outlet (lowest predicted flow rate). These measurements can be taken and recorded to determine if the dam site is suitable for siphon operation. This information should be kept in the dam's EAP and updated if the dam geometry is changed.

SIPHON COMPONENTS

In the event a siphon is used to convey water over the crest of a dam for drawdown purposes, there are several key features that should be considered during the design process. The components include the pipe material and type, outlet works, priming appurtenances, and venting. These components are explored further in the following section.

Pipe Materials: Siphon pipe materials can have an effect on the operation as well. Pipe materials vary in many different ways both structurally and hydraulically. It is especially important that the selected pipe can withstand the negative vacuum pressures of a siphon. Pipe material such as aluminum or thin walled plastic pipe should only be used with caution and only in applications with minimal lift. Local availability will often be a determining factor in which material to use. Table 2 provides some basic information on pipe material characteristics. Each material can typically be found in a wide range of sizes that will accommodate siphon operations.

FIGURE 7 - HDPE PIPE BEING UNLOADED

The selection of a pipe material should consider whether or not there is a pipe, joints, and accessories supplier located near or relatively close to the dam site. Access to the site for the transportation of materials to the dam is also a consideration. How the pipe is to be brought in or what the local distributor has available may determine how many siphons are to be used and what size of pipe will be used. It may be more economical and timely to use multiple smaller diameter pipes rather than a large diameter pipe. Pipe suppliers are an important source of information and guidance when setting up a siphon.

TABLE 3 - SIPHON MATERIAL OPTIONS

Pipe Material	Considerations
HDPE	▪ Very flexible, which can eliminate the need for bend fittings. ▪ Can be fusion welded together to create a very air tight system, but welding can be expensive, time consuming and subject to the availability of appropriate equipment. ▪ May not be readily available in some locations. ▪ Pipe is buoyant and will float if measures are not taken to weigh the pipe down. ▪ Bend radius of pipe can be used to eliminate fittings.
PVC	▪ Can be bell/spigot jointed for good seal. ▪ Rigid pipe so bend fittings or the use of flexible couplers may be needed. ▪ Very common, most pipe suppliers will have a quantity in stock. ▪ Must have adequate wall thickness (Schedule 40 or 80) to withstand vacuum pressures. Schedule 80 may be more appropriate at the crest of the dam to withstand greater vacuum pressures. ▪ Usually the least expensive option due to availability.
Steel	▪ Weld joints would be best for air tightness but time consuming and may be expensive. ▪ Pipe is capable of withstanding large pressures differentials. ▪ Relatively heavy creating difficulty in transport and setup. ▪ Relatively expensive.
CMP	▪ Typically not a good choice because of difficulty obtaining an air

Pipe Material	Considerations
	tight seal, hydraulic capacity, and more difficult to set up. ▪ Could be a good choice to transport outlet water to better downstream location to reduce erosion and effect of dam embankment.
Aluminum Pipe	▪ Often readily available. ▪ Pipe collapsing strength is minimal and should only be used if lift is minimal.

Inlet: The inlet of a siphon must be configured to prevent air from entering in the pipe. If the water level is within two feet of the inlet, air may be introduced into the system with the creation of a vortex. One solution used to address this condition is placing a flat piece of plywood above the inlet to serve as an “anti-vortex baffle”. Another way to prevent a vortex is to throttle the flow using the valve installed on the down-gradient end of the siphon.

FIGURE 8 - INLET SCREEN ON SIPHON INTAKE

Other siphon inlet considerations include buoyancy and debris. If the pipe is of buoyant material, then provisions should be made to sink the pipe for adequate submergence. Options for sinking the pipe include metal collars around the pipe or installing rebar tie-downs around the pipe. A debris grate may be needed to prevent large debris from entering the pipe. In that case, the debris rack may provide sufficient weight to counter buoyancy effects. An engineer or pipe supplier may assist with buoyancy calculations.

Outlet: In order for the siphon to function optimally, the outlet should be submerged to avoid air entrainment in the siphon. A plunge basin may be an ideal place to locate the outlet of the siphon. The greater the depth of water over the outlet, the less likelihood of entraining air in the pipe. Again, two feet is a good minimum depth over the end of the pipe.

If vandalism is a concern, it may be appropriate to bury the entire down-gradient end of the siphon. An exposed pipe is vulnerable to damage and a damaged pipe has the potential to siphon water down the face of a dam. The uncontrolled release of water down the dam face could create erosion of embankment and dam stability issues.

FIGURE 9 - OUTLET OF SIPHON WITH VALVES

Priming appurtenances: To prime the siphon, both ends of the siphon pipe must be closed and a fitting is needed at the top of the siphon to fill the pipe from above. To close the ends of the pipe, it is recommended installing a gate or butterfly valve. This will also give the dam owner the ability to control flow from the pipe. The fitting on top of the siphon may simply include a tee, a cap for the tee and a small pump to fill the siphon.

There are various methods available to prime the siphon system.

- Fill both the down-gradient and up-gradient end of the siphon pipe with water through the tee fitting that is placed at the crest of the siphon. The method requires that valves are installed at both the inlet and outlet. The tee diameter must be large enough to allow air to escape as water fills the pipe. A 2" pump needs at least a 3" tee. Place the airtight cap on the tee when the pipe is full of water.

- Fill the down-gradient side of the siphon through a fitting that is placed at the crest of the siphon. This method requires that a valve is installed at the outlet. A vacuum pump then draws air out and draws water through the inlet side of the siphon. The vacuum pump could be a pumper (vac) truck or a vacuum pump installed on the engine manifold of a truck.

Once the pipe is full the upstream valve, and downstream valve if applicable, is opened to initiate the siphon flow.

Check the siphon daily or as operating conditions require. Once the siphon is started, flow should continue without problems if there are not air leaks. Anything that breaks the siphon effect will stop flow and the system may need to be restarted.

As the water level in the dam decreases, the difference in total head operating the siphon is less. Therefore, the greatest flow from siphon will be immediately after starting the siphon and flow will gradually taper off the longer the siphon operates.

Air vacuum breaker valves: An air vacuum breaker valve should be considered on the down-gradient side of the siphon. A vacuum breaker valve is used in situations where vacuum protection is a must or where column separation is predicated. The valve allows for rapid inflow of atmospheric air to reduce vacuum conditions in piping systems. For a siphon, the vacuum breaker is mounted on a down-gradient side of the siphon below the elevation of the reservoir water surface elevation. The installation of a vacuum breaker at this location will introduce air to the system to stop the siphon effect and control water from flowing downhill. A siphon effect is still maintained between the reservoir water, over the crest and on the down-gradient side of the pipe until the location of the vacuum breaker where free flow continues in the pipe. The installation of a vacuum breaker prevents the risk of pipe collapse on the down-gradient side of the siphon.

An engineer or pipe supplier may opt to design the siphon to exclude a vacuum breaker such that the siphon effect is from pipe inlet to pipe outlet; however, this analysis must be carefully examined as to avoid pipe collapse as a result of vacuum pressures. A stronger pipe material may be required to withstand the vacuum pressures.

SIPHON ADVANTAGES

Siphons are economical, easily built, and have proven a reliable means of water conveyance. Generally, the materials are of greater availability than pumps and the maintenance associated with an actively running siphon can be lower than a pumping system. Aside from the initial construction of the siphon, fewer people may be needed to maintain the structure while it is moving water. The materials are both cost effective and reusable in the case of an emergency situation requiring reservoir drawdown happening again in the future. Finally, no power source is required to run a properly installed siphon once in operation.

SIPHON DISADVANTAGES

Site specific grade limitations are the greatest challenge to the performance of a siphon. Siphons are limited to about 20' of lift at mean sea level and about 1 foot less for each 1,000 feet above MSL. "Lift" refers to the vertical distance from the water surface at the inlet of the pipe and the highest point in the pipe. If the siphon were to carry water from the surface of a reservoir up over an embankment, and to an outlet on the downhill side of the embankment away from the reservoir, the lift would be the vertical distance from the water's surface at the inlet to the top of the embankment. Also, depending on your starting elevation, the siphon's maximum lift may be closer to 15' as atmospheric pressure decreases. The elevations at your site may make it challenging for a siphon to work or be at the upper limits of the area that a siphon may effectively perform. Other common challenges stem from issues with pipe material type, pressure ratings and maintaining air tightness.

CONSIDERATIONS FOR SELECTING PUMP VS. SIPHON

The choice between pumping and siphon methods will be unique to each site and situation. One method might be appropriate for a site during one occurrence but not the next. Several key pieces of information should be evaluated to decide which method to employ. The table below provides some insight to the differences in the two methods. These criteria may differ depending on the site and situation.

Consider the downstream capacity and effects on the dam embankment, downstream channel, infrastructure, and public safety

Drawdown Rate will equal the flow rate of the drawdown system minus the inflow rate.

Site characteristics and logistical considerations should be the first order of business in the decision-making process between drawdown methods. This information will determine whether or not siphoning or pumping methods are feasible. If one method is ruled out, then the remaining method can be further investigated to determine more specific criteria for the reservoir drawdown. Once a site has been determined to be suitable for both siphoning and pumping, then additional considerations can be evaluated to select an appropriate method. The chart below depicts an example of how this process might be applied to a drawdown situation.

TABLE 4 - DRAWDOWN SYSTEM SELECTION CONSIDERATIONS

Consideration	Pump	Siphon	Notes
Lift	No limit, check pump curves	Typically limited to less than 20' lift, see Siphon Overview	A good understanding of the required lift for your site will help you determine if a siphon is a feasible option. If the required lift is too great, it can be immediately determined that a pump is the only option. Consider cutting a notch in the embankment to reduce overall required lift to allow a siphon to work can be an alternative.
Power	Required (electrical, generator, etc.)	Only required for initial priming of siphon	The availability and cost of power is a significant consideration. Remember to account for fuel consumption and fuel cost when evaluating a pump option.
Priming	Not required in most situations	Required to start siphon	Priming a siphon can be challenging. If the siphon effect is lost, then the siphon will need to be re-primed.
Lead Time	Varies, can be long for large pumps	Varies, usually not as long as pumps	Depending on the urgency of the situation, lead time for supplies may be a critical factor. Often, lead time on pumps is associated with the size and number of pumps needed. Lead time for siphon materials is based on the availability of pipe material. Consult with a pipe supplier to determine which pipe sizes are standard on the shelf pipe sizes. Special fittings or special

Consideration	Pump	Siphon	Notes
			installation equipment will also affect lead time.
Monitoring	Required every 3-12 hours, sometimes required continuously	Once per day or longer if site is isolated	If the pumping or siphon operation is not monitored constantly, there is a risk of damage or failure occurring on the pipeline (vandalism, seam failure, gasket failure, etc.) which if undiscovered, could lead to damage on the downstream side (and even possibly the upstream side) of the dam embankment. The unintended release of water onto an unprotected soil embankment could lead to erosion and damage the embankment, which could become serious quickly.
Capacity	Varies with pump size and lift. Capacity is determined from pump curve and site conditions.	Varies with pipe size and lift related to water surface elevation. Capacity is determined by Predicted Siphon Flowrate equation or energy equation.	The capacity and configuration of the dewatering system may be dependent on the availability of materials. In other words, several small pumps or siphons may be used compared to a large pump or siphon. Determine the drawdown rate desired and research pump and pipe options based on that information.
Access	Must have good vehicle access for large pumps	May work best if access to site is limited	Many reservoirs located in mountainous terrain have limited access. If the material can only be brought in by helicopter or horseback, consider the weight and size of the material.
Cost	Pipe and appurtenances materials cost plus on-going costs associated with pump rental fees and fuel/power	Pipe and appurtenances materials cost	The cost of the system is often a driver in deciding which drawdown method is most appropriate. When deciding on the more appropriate method, be sure to include up-front materials cost, on-going costs associated with rental fees and power and monitoring costs. Will the reservoir require routine dewatering? If so, consider purchasing pumps or piping materials to serve future needs.

CASE STUDIES

The section provides real-life examples from dam owners with a need to drawdown a reservoir using a pump or siphon. The case studies outline the challenges of the situation and the decisions the dam owner made to drawdown the reservoir. These case studies examine the findings from each of these examples.

PARK LAKE DAM

<u>Stats</u>

Dam: Earthen

County, State: Jefferson County, Montana

Storage capacity: 423 acre-feet

Elevation of reservoir water: 6,347 feet to 6,355 feet

Elevation of dam crest: 6,364 feet

Outlet elevation of siphon pipe: 6,307 feet

FIGURE 10 – PARK LAKE DAM

<u>Scenario</u>

Park Lake Dam was scheduled for reconstruction in the summer of 2005. The reservoir did not have a low level outlet; therefore, a dewatering contractor was procured to drain the reservoir. During kick-off of the reconstruction project, a State inspector discovered a crack in the dam. The emergency action plan was implemented, which included notifying downstream residents by the Sheriff that evacuation may become necessary. Due to the risk encountered, the State began 24-hour monitoring. The dewatering contractor was asked to advance the schedule for dewatering.

FIGURE 11 - CRACK IN DAM EMBANKMENT

The contractor implemented a dewatering plan, which was refined during the dewatering process. The initial plan included installation of a 12-inch diameter aluminum pipe 600 feet long. Unfortunately, this siphon attempt was unsuccessful and the pipe collapsed on itself. The contractor continued to refine the siphon design and worked with the pipe supplier to install two sets of 8-inch diameter HDPE pipe. During this process, the owner of the dam rented 2 sets of galvanized steel pipe to supplement the dewatering system. Estimates from the owner suggest that each siphon was conveying approximately 6.5 cubic feet per second.

Findings

In the end, the dewatering system included the four sets of 8-inch diameter siphons operating concurrently for approximately two weeks. The unsuccessful attempt to siphon using the aluminum pipe was likely attributed to weak pipe strength associated with aluminum pipe notwithstanding the vacuum pressures in the pipe. Reviewing the elevation of the crest of the dam at 6,364 and considering that 1’ of lift is lost for every 1,000 feet of elevation above mean sea level, these siphons could only lift water a total of 13.6 feet. The result is that the siphon would not work below a reservoir surface elevation of 6350.4 feet.

FIGURE 12 – CRUSHED ALUMINUM PIPE

FIGURE 13 – INSTALLATION OF ORIGINAL ALUMINUM PIPE

FIGURE 14 - FOUR SIPHONS IN PARALLEL OPERATION. THE PRIMING FITTINGS ARE SHOWN.

FIGURE 15 – AIR VALVES

<u>Stats</u>

Dam: Earthen

Construction date: 1921

County, State: Sanders County, Montana

Storage capacity: 3856 acre-feet

Surface area: 350 acres

Elevation of dam crest: 2,864 feet

<u>Scenario</u>

FIGURE 16 – LOWER DRY FORK DAM

Lower Dry Fork Dam is located within the Flathead Indian Irrigation Project. The storage water in Lower Dry Fork Reservoir serves irrigators within the Camas Division of the Irrigation Project. During an effort to construct an upstream pad for a drill rig to perform investigation drilling along the outlet works of the dam, work crews - inadvertently (and unknowingly) placed material over the outlet works. Flathead Indian Irrigation Project (FIIP) staff did not discover the blocked outlet works until the reservoir had already reached full pool at the beginning of the irrigation season. With the outlet works blocked, FIIP was unable to begin making water delivery discharges out of the reservoir into the Camas C Canal below the dam. Irrigators were unable to receive water and there was risk that the emergency spillway would be put into action.

FIGURE 17 – FUSION OF HDPE PIPE

FIIP had to act quickly to find a solution. The project manager had an engineering background and understood siphon fundamentals. Calculations were performed and it was determined that a siphon was possible. It was decided that notching the dam crest would reduce the lift height of the siphon and improve the overall function and capacity of the siphons. The bending radius of the pipe material was utilized to eliminate bend fittings in the pipe. The FIIP manager used a level rod and graph paper in the field to identify key grades, and from this information, the siphon design was sketched up.

FIGURE 18 –PLACEMENT OF SIPHON PIPE

The solution included installation of three 18-inch HDPE siphons. Upon delivery of the HDPE pipe, three siphons were fusion welded and installed within five days. The installation also included the incorporation of steel bands around the inlet side of the pipe to counter the buoyancy of the pipe. The maximum flow obtained was approximately 60 cubic feet per second, which was realized immediately after the siphon was put into action. During operation of the siphon, vortices began to form when the siphon lift was approximately 16 feet. The valves were throttled back and the vortices subsided.

FIGURE 19 – HDPE BEFORE IT WAS PLACED

Findings

The Flathead Indian Irrigation Project was in critical need of water to satisfy water user demand and to bring the reservoir elevation levels down from the spillway level. Upon review, it was determined that the site was appropriate for a gravity siphon. Complete drawdown of the reservoir was not an immediate priority and the timeline for the repair of the outlet structure was not immediate. FIIP needed a solution that would deliver water and not involve the high cost and maintenance associated with renting pumps for a long duration.

FIGURE 20 – BACKFILL BEING INSTALLED OVER OUTLET PIPE.

FIGURE 21 – DISCHARGE PIPE RUNNING DOWN CROW DAM EMBANKMENT

Stats

Dam: Earthen

County, State: Lake County, Montana

Storage capacity: 10,350 acre-feet (temporarily restricted to 3,500 acre-feet due to need for spillway repairs)

Elevation of reservoir water: 2,867 feet

Elevation of dam crest: 2,875 feet

Scenario

Crow Dam, located in the South Division of the Flathead Indian Irrigation Project (FIIP), provides water to irrigators in the Moise Valley area of the Project. The outlet works of the dam was in disrepair. The outlet works consist of two cylinder gates. One cylinder gate had experienced failure of both operating/lift stems and had slammed shut earlier during operational discharges. It was damaged and no longer operable. The backup cylinder gate was also exhibiting symptoms of being damaged and immediate access to the outlet works gate shaft was needed to inspect and repair the backup gate. The mandatory instream flow of 21 cubic feet per second in the downstream creek needed to be maintained during the dewatering, inspection, and repair of the outlet works gates.

FIGURE 22 - SUBMERSIBLE PUMPS AND FLOATATION

The FIIP manager inspected the site and determined that grade limitations would rule out a siphon. At that point, pump suppliers were contacted to coordinate sizing and delivery of pumps. Two different suppliers offered two different pumping plans and related costs. One pump supplier suggested skid mounted suction pumps with diesel motors. One pump supplier suggested submersible pumps connected to a generator. FIIP preferred the submersible pumps due to expected fluctuating water levels in the reservoir (expected to exceed 25 feet in elevation over a 7 day period). There was

FIGURE 23 –DIESEL GENERATORS

concern that the intake lines for the skid mounted suction pumps would be too short for the fluctuating water levels.

In the end, six 8-inch submersible pumps operated for a week at a total cost of approximately $70,000. This price included the cost of the six submersible electric pumps, two diesel engine generators, HDPE piping from pumps to the downstream outlet channel (including fusion), all valves and fittings, and all mobilization, assembly, and demobilization. The price also included costs for providing two backup pumps and one backup generator.

<u>Findings</u>

Site constraints would not allow a siphon to function and left FIIP with pumping as their only option. Two different pump rental companies offered different pumping plans and related costs. Due to in-stream flow requirements, FIIP opted to go with the pumping plan that ensured continuous flow without requiring shut-down to move suction lines due to fluctuating water levels. It was also the less expensive option.

FIGURE 24 – PUMP DISCHARGE LINE

Stats

Dam: Earthen

Year constructed: 1936

County, State: Meagher County, Montana

Storage capacity: 490 acre feet (max.)

Reservoir surface area: 36 acres

Dam height: 33 feet

Elevation of dam crest: 5,181 feet

Elevation of reservoir level: 5,170 feet

FIGURE 25 – JACKSON LAKE DAM

Scenario

Through water storage in Jackson Lake, Jackson Lake Dam supplies irrigation water to a local ranch. During the summer of 1999, the gate stem sheared off leaving the gate in the closed position. The spillway did have capacity to pass storm events so danger to the dam embankment due to overtopping was not a concern. The damages to the gate stem, however, jeopardized delivery of irrigation water.

In order to maintain irrigation releases, a siphon was installed over the top of the dam using 80 psi PVC pipe. Soon after the siphon was primed, the siphon collapsed likely due to pipe material that could not withstand the vacuum pressures in the pipe. Another siphon was installed using stronger pipe material (120 psi PVC pipe). A vertical slide gate was installed at the downstream end of the siphon in the stilling basin.

FIGURE 26 – COLLAPSED PVC PIPE

The siphon served the needs of the irrigators through the growing season. In September of that same year, vandals opened the slide gate and the siphon flow was lost. The owner worked to re-prime the siphon and the siphon collapsed midway down the downstream face of the dam. The owner opted to wait until the spring to drawdown the reservoir to fix the gate stem.

Findings

Reviewing the elevation of the crest of the dam at 5,181 and considering that 1' of lift is lost for every 1,000 feet of elevation above mean sea level, this siphon could only theoretically lift water a total of 13.6 feet. The result is that the siphon would not work below a reservoir surface elevation of 5166.2 in best case conditions without risk of water vaporization. As the siphon drew the water surface level down, the vacuum pressures became greater and greater. It appears that the 80 psi PVC pipe was not strong enough to withstand the initial vacuum pressures and that the 120 psi PVC pipe only could withstand vacuum pressures to a certain point. It is speculated that the water surface elevation was too low when the owner tried to restart the siphon and vacuum pressures collapsed the pipe.

<u>Stats</u>

Dam: Sunrise Lake Dam

County, State: Apache County, Arizona

Owner: White Mountain Apache Tribe

Max surface area: 900 acres

Elevation of reservoir water: 9,200 feet

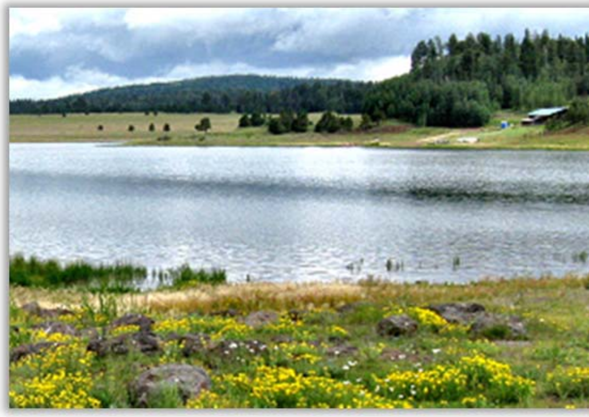

FIGURE 27 - SUNRISE LAKE

<u>Scenario</u>

Sunrise Lake was created by construction of Sunrise Lake Dam, an earth-fill embankment. The high-altitude lake is used as a recreational fishery. The original outlet through the dam was flawed and has not operated since the dam was constructed. Likewise, no water has passed over the spillway because water draining through a porous layer of volcanic rock on the north side of the reservoir prevents water from rising to the spillway elevation. With no discharge of water from the reservoir, all organic matter and other nutrients entering the reservoir accumulate in the deeper parts of Sunrise Lake where they eventually cause anaerobic conditions and biologic oxygen demand that depletes oxygen concentrations in the aerobic parts of the lake.

The process of eutrophication took place over decades due to the cold water temperature in the lake, but eventually conditions became adverse to the sport trout fishery in the reservoir. The White Mountain Apache Tribe obtained the services of a professional engineer to review the problem and recommend a solution. After hiring a fishery biologist to conduct vertical profiles of dissolved oxygen and temperature, to collect water samples from the vertical profiles and to prepare a bathymetric map; a siphon accompanied by a pipeline from a source of fresh water was recommended to restore the water in the reservoir to good conditions for aquatic habitat.

The siphon was designed to draw water from the deepest part of the reservoir with the intent that it would remove nutrients that were pooled in the bottom of the lake. A three-mile 10-inch pipeline was designed to divert fresh water from Becker Creek in order to provide fresh water inflow to Sunrise Lake to replace eutrophic water siphoned out of the lake. An issue with the siphon design was the ability to prime the siphon using a vacuum pump due to the low atmospheric pressure at 9,200 feet. This problem was solved by installing the siphon at an elevation below the top of the dam where enough vacuum could be generated to prime the siphon. A number of issues related to construction of the siphon were avoided by constructing the siphon in the winter, assembling it on the ice on Sunrise Lake, then cutting through the ice and lowering the siphon into position. The time and cost for the diversion of fresh water to the lake was minimized by utilizing 10-inch portable aluminum pipe to convey water from the diversion to the lake, a distance of three miles.

When the siphon was put into operation, anaerobic gray water was discharged from the bottom of the reservoir. Removal of the nutrient-laden water and replacement of it with fresh water during the winter months resulted in a tremendous improvement in dissolved oxygen throughout the reservoir by the following summer. The temporary operation of the siphon and portable pipeline for fresh water resulted in good conditions in the reservoir for the next three decades.

Findings

This site offered challenges due to elevation limitations and low atmospheric pressure at higher elevations. The solution included reducing the lift of the siphon by notching the dam crest at the siphon crossing. A siphon was a good solution to meet the objectives to restore the aquatic health of this lake.

ACKNOWLEDGEMENTS AND REFERENCES

ACKNOWLEDGEMENTS

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Munson, Young, Okiishi, *Fundamentals of Fluid Mechanics*, 3d ed., John Wiley & Sons, Inc.

Scott Bryant, PE and Douglas Jewell, PE, "Analysis of Siphon Lake Drain Performance for a Small Earthen Dam", Association of State Dam Safety Officials 1996 Conference Proceedings

Gordon Wind (Manager of Flathead Indian Irrigation Project), conversation with Molly Skorpik, September 7, 2012

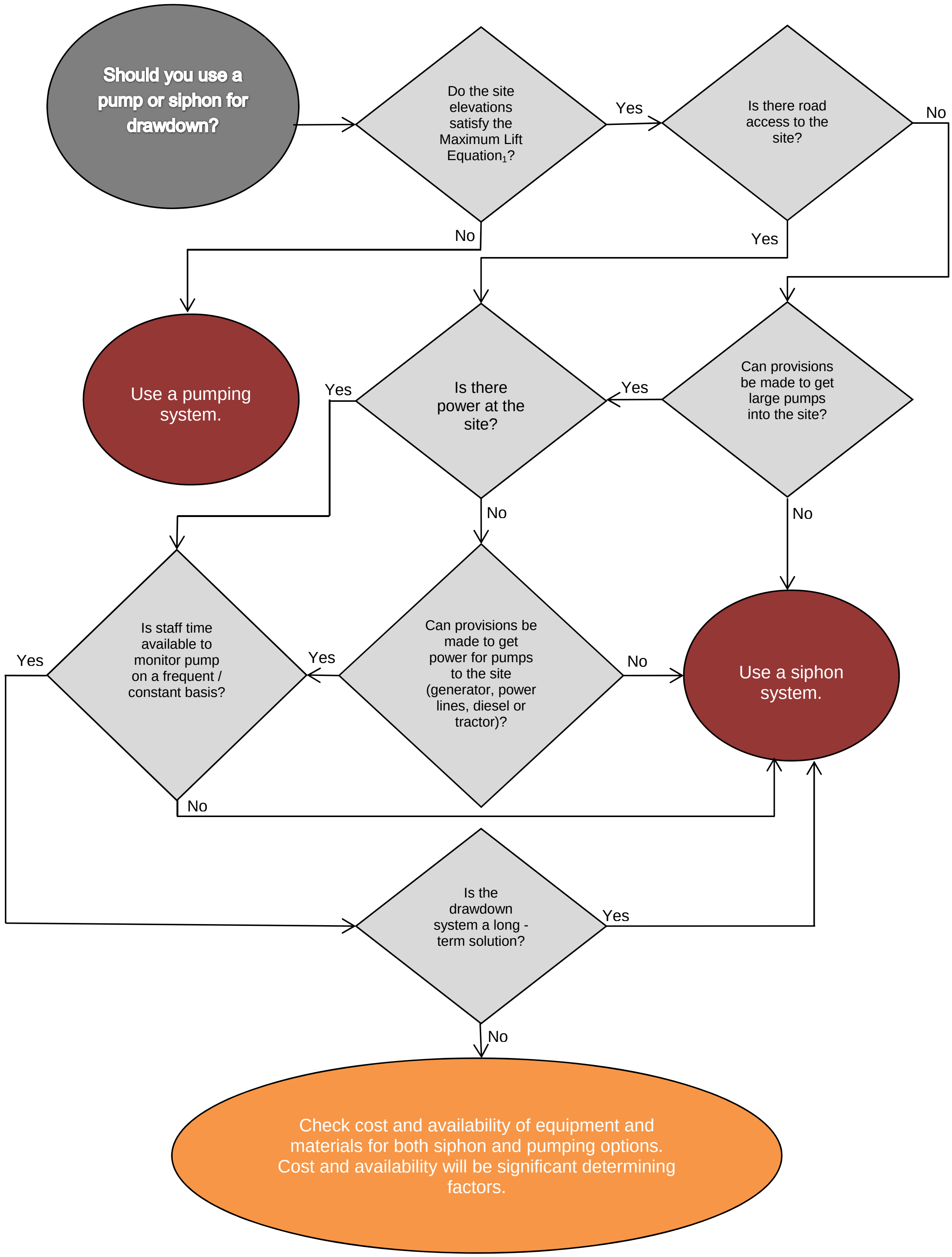
Michele Lemieux (Dam Safety Program Manager), conversations with Molly Skorpik June – September 2012

A Quick Guide to Siphons, Watershed News. 10/2004

Appendix A - Drawdown System Selection Flow Chart

Appendix A - Drawdown System Selection Flow Chart

Drawdown System Selection Flow Chart



Note:
1. Reference Siphon Overview Design Grade Considerations for Maximum Lift Equation.
2. Every site is unique. This Chart is a starting guideline. Your situation may warrant a different solution.

Appendix B – Sources of Pumps

Sources of Pumps in Montana and Surrounding Areas

The following pump suppliers may offer pump rentals for reservoir drawdown. The list is not all inclusive and is not meant to preclude other pump suppliers not listed in this document. Pump suppliers serve areas outside of the Cities listed below. For areas outside of Montana, research pump suppliers on-line.

Billings, MT:

Champion Charter Sales & Service
2549 Enterprise Ave.
Billings, MT 59102
406-655-7828

Rain for Rent
1111 Monad Road
Billings, MT 59101
406-259-7216

Waterworks Industries
465 Moore Lane
Billings, MT 59107
www.waterworksind.com
Charley Stiles, Sales

Bozeman, MT:

Rain for Rent (pump rental)
1111 Monad Road
Billings, MT 59101
(406) 259-7216
Fax: (406) 259-7251

Dickinson, ND:

Rain for Rent
819 Implement Drive
Dickinson, ND 58601
(701) 225-7117

Glendive, MT:

SRS Crisafulli, Inc.
1610 Crisafulli Drive
P.O. Box 1051
Glendive, MT 59330
Phone: 800-442-7867
Or 406-365-3393

Helena, MT:

Godwin Pumps
3860 Helberg Drive
Helena, MT 59602
Phone: 406-495-1335
Andy Fitzhugh

Idaho Falls, ID:

Rain for Rent
3615 Ririe Highway
Idaho Falls, ID 83401
(208)-522-4500
Fax: (208) 522-4511

Windsor, CA:

Waterworks Industries Inc. (pumps)
930 Shiloh Rd., Bldg. 38, Suite D
Windsor, CA 95492
(707) 837-7900
info@waterworksindustries.com

Other:

____
____
____
____
____

Other:

____
____
____
____
____

Appendix C – Information for Pump Supplier

Information for Pump Supplier

The following information may be requested by pump suppliers. Use this worksheet to gather data that may prove beneficial to a pump supplier.

General Site Information: (Figure 1)

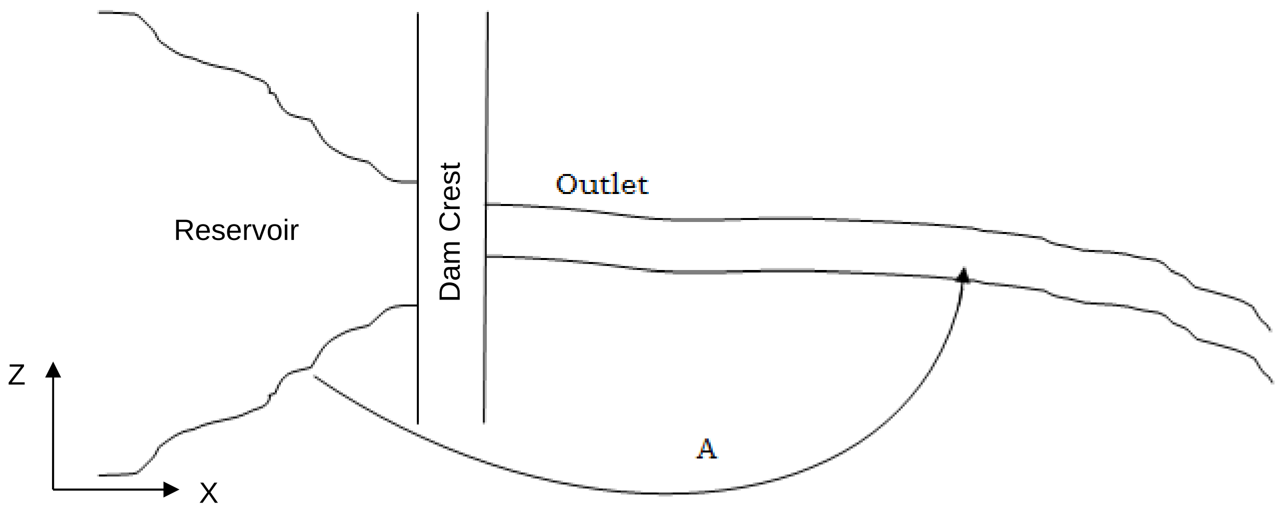


Figure 1: A plan view of a dam. 'A' represents the distance from the reservoir water's edge to the discharge location located downgradient of the dam.

1) Material to be pumped: ________________________

2) Horizontal distance from reservoir to the discharge location in feet, A (see figure 1: Dam Plan):____

3) Any debris in the water? If so, describe (size in feet).

4) Any information about an existing power source:____

5) Location & Access: ____

____

6) Description of the system and situation, pictures if necessary:____________________________

7) Any solids in the water?

Circle or check all that apply:

Spherical Pulpy Gritty Hard Soft

Maximum size (in): ______________________________

Flow and Elevation Information: (Figure 2)

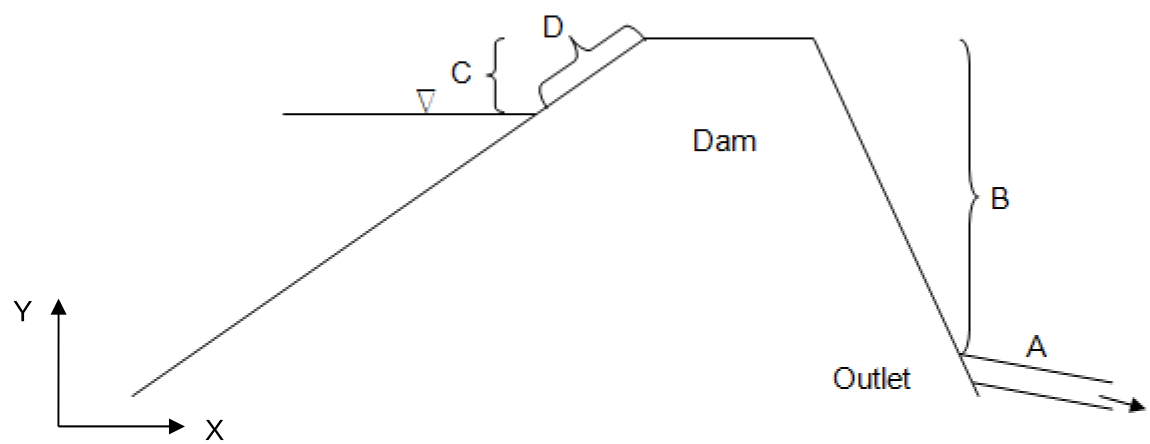


Figure 2: A profile view of a typical dam.

8) a. Required flow rate, **A** (cfs):__________________________ (See figure 2: Dam Profile)

b. Dam Height, **B** (ft):__________________________________

c. Maximum elevation change from crest or dam to lowest water surface elevation desired, **C** (ft):_________________________

d. Slope distance from lowest water surface elevation to crest of the dam, **D** (ft):__________

Pump Information:

9) Pipe diameter (in):_____________________________

10) Pipe material:_________________________________

11) Water drawdown time (days): ______________________

12) What is the configuration/style do you want? Please circle or check:

Trailer-mounted portable: _________

Vertical configuration (stationary/permanent): _________

Hydraulic pump for: portable use _____ stationary use_____

Submersible electric for: portable use _____ stationary use _____

13) Frequency of pump use (check one): _____ Continuous _____ Intermittent

Appendix D – Sources of Siphon Materials

Sources of Siphon Supplies in Montana and Surrounding Areas

The following pipe suppliers may offer pipe materials for reservoir drawdown using a siphon. The list is not all inclusive and is not meant to preclude other pipe suppliers not listed in this document. For areas outside of Montana, research suppliers on-line.

Belgrade, MT:

Northwest Pipe Fittings Inc.
360 Floss Flats Road
Belgrade, MT 59714
406-388-2093
Fax 406-388-2093

HD Supply Waterworks Ltd
5240 Jackrabbit Lane
Belgrade, MT 59714-9061
1-406-388-5980

HD Fowler Co.
401 E Main St
Belgrade, MT 59714
1-406-388-1169

Billings, MT:

Ferguson
1734 Lampman Dr.
Billings, MT 59102
(406) 655-0010

Utilities
1723 Lampman Dr.
Billings, MT 59102
(406) 252-0528

Northwest Industrial Supply
1819 2nd Avenue North
Billings, MT 59107
406-248-1151
Fax 406-252-8835

Billings, MT (cont'd):

Northwest Pipe Fittings Inc.
33 South 8th Street West
Billings, MT 59103
406-252-0142
Fax 406-248-8072

Bozeman, MT:

Ferguson
188 Pronghorn Trail
Bozeman, MT 59718
(406) 587-8855

Anderson Precast & Supply Inc.
80 E Valley Center Rd
Bozeman, MT 59718
1-406-586-5087

Butte, MT:

Northwest Pipe Fittings Inc.
1901 Meadowlark
Butte, MT 59701
406-494-2120
Fax 406-494-3767

Gillette, WY:

Utilities
1209 Energy St.
Gillette, WY 82716
(307) 682-0748

Great Falls, MT:

Ferguson
905 River Dr. S
Great Falls, MT 59405
(406) 761-8957

Northwest Pipe Fittings Inc.
404 17th Avenue N.E.
Great Falls, MT 59404
406-727-9843
Fax 406-454-1743

Helena, MT:

Contech Construction Products
PO Box 5478
Helena, MT 59604
406-442-1012
www.contech-cpi.com
Dennis Dirks

Kalispell, MT:

Ferguson
2435 US Hwy 2 E
Kalispell, MT 59901
(406) 756-7630

Waterworks – Water & Sewer
1093 Rose Crossing Dr.
Kalispell, MT 59901
(406) 755-9242

Northwest Pipe Fittings Inc.
1780 Highway 35
Kalispell, MT
406-752-6562
Fax 406-752-6553

HD Supply
1093 Rose Crossing Dr.
Kalispell, MT 59714
406-755-9242

Missoula, MT:

Ferguson
3843 Brooks St.
Missoula, MT 59804
(406)251-4341

Waterworks- Water & Sewer (HD Supply)
7372 Interstate PI
Missoula, MT 59808
(406) 728-7336
George Whittaker, MT District Manager
Michael Richards, Product Specialist

Northwest Industrial Supply
2304 West Broadway
Missoula, MT 59802
406-543-2982
Fax 406-543-1982

Offers full service siphon set-up:

Godwin Pumps
3860 Helberg Drive
Helena, MT 59602
Phone: 406-495-1335
Andy Fitzhugh

Other:

____
____
____
____
____

Other:

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____
____
____
____

Possible list of Equipment for PVC siphon:

- ✓ Plain end PVC pipe, schedule 80, dam crest length
- ✓ Plain end PVC pipe, schedule 40, dam embankment slope lengths
- ✓ Rubber sleeve connectors
- ✓ Flat band clamps
- ✓ Two 22.5 degree elbows
- ✓ One 90 degree elbow
- ✓ Two valves
- ✓ Trash guard for inlet, if needed
- ✓ 3” tee tap with an air tight plug
- ✓ Pump and hose to fill the pipe with water
- ✓ Trailer to haul equipment

Appendix E – Information for Siphon Materials

Information for Siphon/Pipe Designer or Supplier

The following information may be useful when ordering siphon supplies and/or when deciding if a siphon is feasible. Use this worksheet to gather data that may prove beneficial when making these decisions.

Maximum Siphon Lift Equation:

$$DCE - RWS \leq 20' - \frac{RWS}{1000}$$

Dam Crest Elevation (DCE)= ______________________________

Reservoir Water Surface Elevation (RWS)= ______________________________

General Site Information:

1) Horizontal distance from reservoir to the discharge location in feet:________________

2) Discharge Channel Type (choose one): Stream Ditch

3) Any debris in the water? If so, describe (size in feet).

4) Location & Access: ____

____

5) Nearest Town: ____

6) Description of the system and situation, pictures if necessary:______________________________

7) Any solids in the water?

Circle or check all that apply:

Spherical Pulpy Gritty Hard Soft

Maximum size (in): _______________________________

Maximum Siphon Lift Equation:

Flow and Elevation Information: (Figure 1)

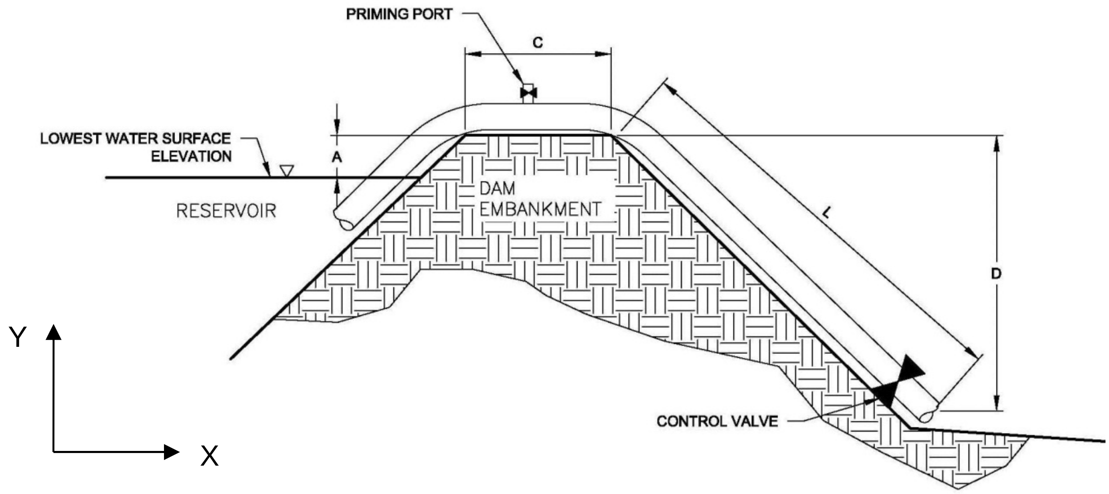

Figure 1: A profile view of a typical dam with simple siphon.

8) a. Required flow rate, (cfs):________________________ (keep in mind multiple siphons are often easier to operate than a single large siphon)

b. Maximum Lift Height, **A** (ft):____________________________(See figure 1: Dam Profile)

c. Dam Crest Width, **C** (ft):________________________________(See figure 1: Dam Profile)

d. Dam Face Slope Length, **L** (ft):__________________________(See figure 1: Dam Profile)

e. Dam Height, **D** (ft):______________________________(See figure 1: Dam Profile)

f. Predicted Siphon Flow Rate Equation: (see text)

Q (cfs)
H=D-A (ft)
L= total length of pipe ordered (ft)
K (see text)
D=pipe diameter (in)
N= Manning's n coefficient (see pipe supplier info)

$$Q = 0.0438 D^{2.5} H^{0.5} (12\,fL + KD + D)^{-0.5}$$
$$f = 425\left(n^2 / D^{0.33}\right)$$

<u>Pipe Material Information:</u>

9) Pipe diameter (in):________________________

10) Pipe material:___________________________

11) Water drawdown time (days): ____________________

12) Negative Internal Pressure Capacity (psi or ft): ______________________________

13) Allowable Bend Radius (ft): ___________________________________

14) Valve Fitting Connection Configuration: ____
____

3011 Palmer Street | Missoula, MT 59808 | 406.542.8880

www.m-m.net