Exhibit "F"

Fish Screens for Construction Dewatering

Habitat Program, Fish Screening Section

September 20, 2021

Purpose

A diversion device used for conducting water from a lake, river, or stream for any purpose shall be equipped with a fish guard approved by the director to prevent the passage of fish into the diversion device (RCW 77.57.010), even when the water is only temporarily removed.

This guidance is intended to give general direction to biologists and contractors when using water pumps at construction sites. Site specific conditions will dictate how this guidance is used. Pump screens sized to prevent fish entry may not be necessary if the supervising biologist determines that fish removal was adequate, that fish life is not at risk and there is adequately maintained work site isolation and fish exclusion mechanisms such as coffer dams, block nets, etc. in the work area.

Block net guidance is not included in this document because the size and configuration of block nets depends on location, channel morphology, species and size of fish expected to be present, debris likely to be encountered, etc. The local biologist should work with the contractor to determine appropriate block net mesh size based on the size of the smallest fish expected to be present and to ensure that the layout and sturdiness of the block net system is adequate to withstand expected water volume and velocity, size of debris, and other site-specific conditions that might impact the ability of the block net system to exclude fish.

This document may also assist biologists in assessing the compliance of fish screens; however, a more detailed compliance document is in development. A foot valve or backflow preventor is not an acceptable fish screen unless it is placed inside a screen that meets the other criteria listed below. When fish life may be present a fish screen must be used and the standard state screening criteria must be met, unless determined otherwise by the department.

To select an appropriate fish screen for your construction project you will:

1) Determine the area of the fish screen required using calculations provided below to ensure approach velocity criteria are met.
2) Determine the best fish screen design or configuration based on the screen area calculations and site-specific and other considerations.

Determine the screen area of the fish screen.

Use the equation below to calculate the required *Minimum Effective Screen Area*. Please note that the *Minimum Effective Screen Area* works in combination with other fish screen features to provide required maximum approach velocities that both protect fish life and prevent excessive debris occlusion.

$$Minimum\ Effective\ Screen\ Surface\ Area\ (ft^2) = \frac{Maximum\ Diverted\ Flow\ (cfs)}{Maximum\ Approach\ Velocity\ (0.33\ \text{ft/s})}$$

Where:

Minimum Effective Screen Surface Area – The total wetted screen area (the area of the screen submerged in the water) minus the area(s) occluded by major supporting structural elements of the screen. Screen size should be based on the maximum expected pumping rate and water volume/depth and is expressed in square feet (ft^2).

Maximum Diverted Flow (rate of flow, flow/pumping rate, or pump capacity) – The maximum volume of diverted flow over a given unit of time. For end of pipe or pump screens, it is the volume of water flowing through a pipe inside a particular time unit (e.g. cubic feet per second [cfs] or gallons per minute [gpm]). Formulas to convert flow rates between units are provided on page 9 of this document.

1. Determine the *Maximum Diverted Flow*. This can be done a few different ways, listed in order of preference:
    a. Get this information from the contractor.
    b. Determine the make and model of a particular pump and look up the rating curve or maximum pump capacity on the manufacturer's website. This information may also be available through various retail websites.
    c. Measure the outside diameter of the ports (pump intake and discharge). Typically, trash pumps have the same sized intake and discharge ports.

If you are unable to determine the exact maximum capacity of a pump, you can use information in Table 1 to determine the *Minimum Effective Screen Surface Area* required based on some common trash pump sizes/capacity. Trash pumps are commonly used for construction and related dewatering. Trash pumps can pass debris and 'dirty' water without damaging the equipment. Trash pumps are typically sized based on the diameter of the intake and discharge ports. Other types of pumps such as submersible, diaphragm, or other types of centrifugal pumps may be used for construction dewatering. This table is not intended for these pump types and instead you should refer to the manufacturers specifications or other resources to determine the pump capacity.

Table 1. Quick reference guide for common trash pump sizes used for construction dewatering and the *Minimum Effective Screen Surface Area* required. Please note that the screen sizes listed assumes a fully submerged and clean screen.

Pump Size (in)	**Pump Capacity**		**Minimum effective screen surface area (ft^2)**
	gpm	**cfs**	
6	1,162	2.59	7.8
4	565	1.26	3.8
3	342	0.76	2.3
2	179	0.40	1.2

Maximum Approach Velocity – The water velocity component perpendicular to the screen surface (Figure 1). For construction dewatering, 0.33 feet per second (ft/s) is the *Maximum Approach Velocity*.

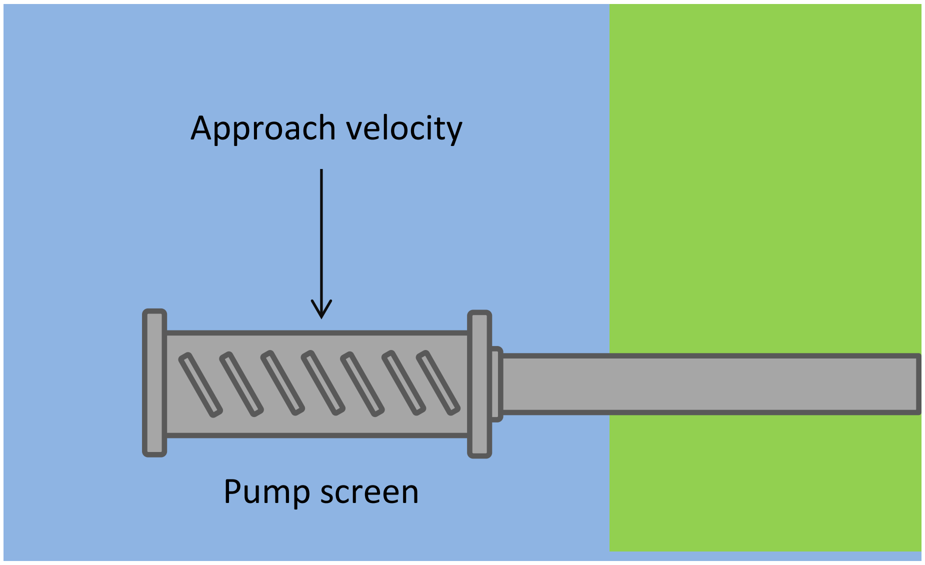

Figure 1. Simple illustration of approach velocity.

A note regarding screen approach velocities:

The size of the fish screen, the pumping rate and maintaining a clean fish screen are the most critical elements for maintaining appropriate screen approach velocities for construction dewatering. A correctly sized screen chosen following the guidelines in this document and an appropriate level of operational oversight and maintenance will, in most cases, result in appropriate approach velocities. In field application for construction sites, WDFW strongly recommends that contractors use a pump screen area that is sized considerably larger than the minimum required. Doubling, or even tripling the screen area will significantly reduce maintenance time and costs for the contractor while the additional fish screen costs will be relatively minimal. A screen designed to the absolute minimum screen area criteria will be rendered out of criteria with any amount of debris accumulation on the screen face.

Accurately measuring approach velocities at fish screens is difficult in field settings. Simply observing the area near the screen can help discover excessive approach velocities. Excessive debris accumulation on the screen, obvious swirling, and signs of debris being drawn towards the screen from further than 3 inches away from the screen can all be signs of excessive approach velocities. This problem can be exacerbated as water levels drop during dewatering and debris or sediment consolidate around the screen. Generally, cleaning the screen, adjusting the screen placement, or adjusting pumping rates can help alleviate excessive (> 0.33 ft/s) approach velocities.

If more precise documentation of excessive approach velocities is needed, any flow meter used for stream discharge may be used. However, the accuracy of these measurements depends on the exact device used. Please contact the fish screening section for more information on measuring approach velocities at fish screens.

A note regarding trash pumps and capacity:

Table 1 was developed using the total pump capacity of approximately 30 different commercially available trash pumps at each size listed. The max capacity of each pump under optimum conditions was used to produce the information in the table. However, there are many variables affecting pump capacity, including but not limited to: the type of pump used (electric, gasoline, or diesel), the engine or motor size of the pump, the pipe or line diameter, debris load or silty water, altitude, and water temperature. The contractor will use the total head (sometimes called “lift”) required to dewater the site to choose the best pump for a given project. A simple illustration (Figure 2) and brief description of common pump terminology follows.

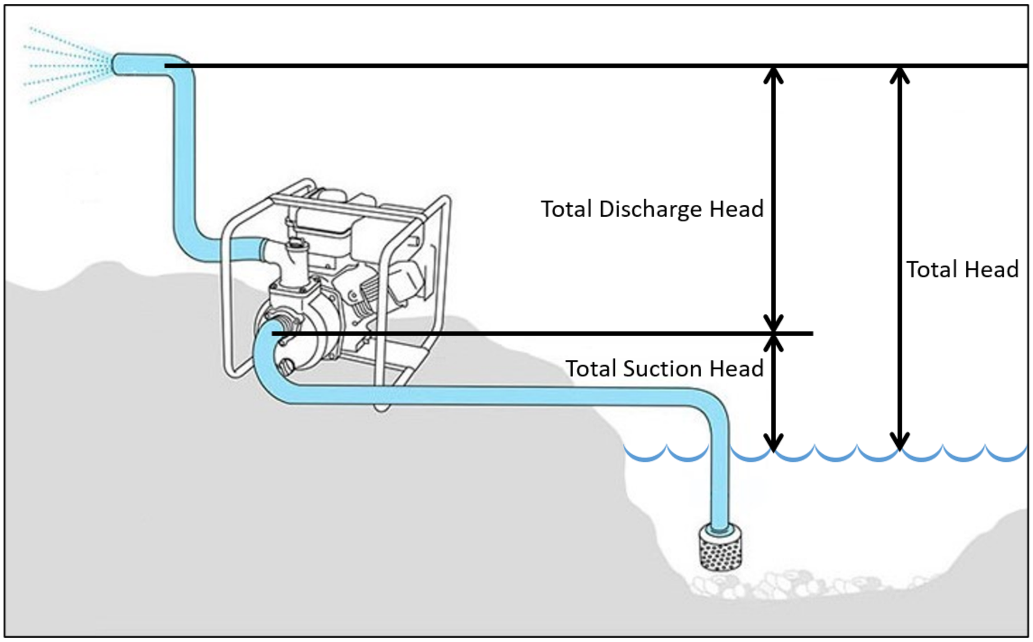

Figure 2. Simple illustration of trash pump and common pump terminology. Adapted from www.briggsandstratton.com

Head or Lift – Gains or losses in pressure caused by gravity and friction as water moves through a system. Depending on how the measurement is taken, lift and head may also be referred to as *static* or *dynamic*. *Static* indicates the measurement does not consider the friction caused by water moving through the hose or pipes. *Dynamic* indicates that losses due to friction are factored into the performance.

Total Suction Head – The static suction lift plus the friction in the suction line.

Static Suction Lift – The vertical distance from the waterline to the centerline of the pump suction line.

Total Discharge Head – The static discharge head plus the friction in the discharge line.

Static Discharge Head – The vertical distance from the discharge outlet to the point of discharge or water surface elevation when discharging into another body of water.

Total Head – The sum of the total suction head and total discharge head.

Determine the best fish screen for use on your project.

After determining the fish screen area needed using the methods above, you can choose more details about the appropriate fish screen based on site-specific and other considerations. Fish screens for construction dewatering may be off-the-shelf designs or custom fabricated. The fish screen must be sturdy enough to not compromise the integrity of the screen during pumping if the screen becomes clogged with debris. The goal is to find a fish screen that is sized to match your maximum pumping conditions and water depth. Typically, it will be difficult to find an 'off the shelf' screen that exactly matches your project conditions. It will most likely be a larger size than the minimum pumping capacity or flow rate. Again, a larger fish screen will require less maintenance and provide greater protection of fish life. Figures 3 and 4 show various fish screens used in construction dewatering projects and some examples of things that are not fish screens.

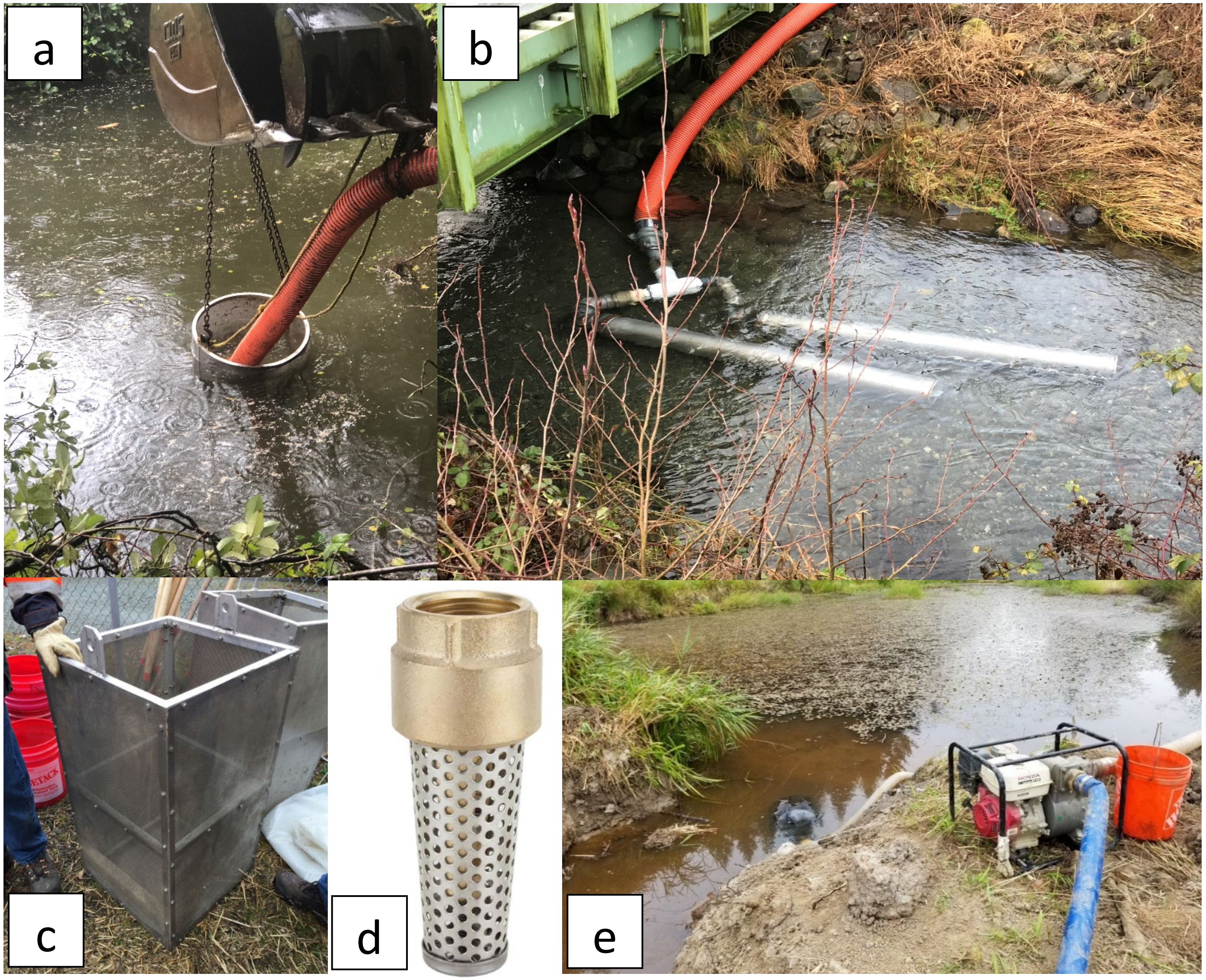

Figure 3. a) Custom fish screen barrel. b) Two off-the-shelf screens manifolded together. c) Custom fish screen box. d) Foot valve (not a fish screen), and e) Trash pump and slip-over style mesh screen. A and C are examples of custom screens where the pump intake (likely with a foot valve or backflow preventor) is placed inside the screen.

Figure 4. a and e) Custom fish screen boxes. b, c, and d) Custom fish screen barrels. f) Foot valve wrapped in wire mesh (not a fish screen).

Site-specific and other Considerations:

1. *Screen shape and geometry* – Standard screen shapes are a barrel, cylinder, or box (Figure 5). While screen shape may not matter, site specific conditions may favor one screen shape over another for both protecting fish and removing water. For example, a small diameter screen may be necessary for dewatering in shallow water where no sump is used or needed.

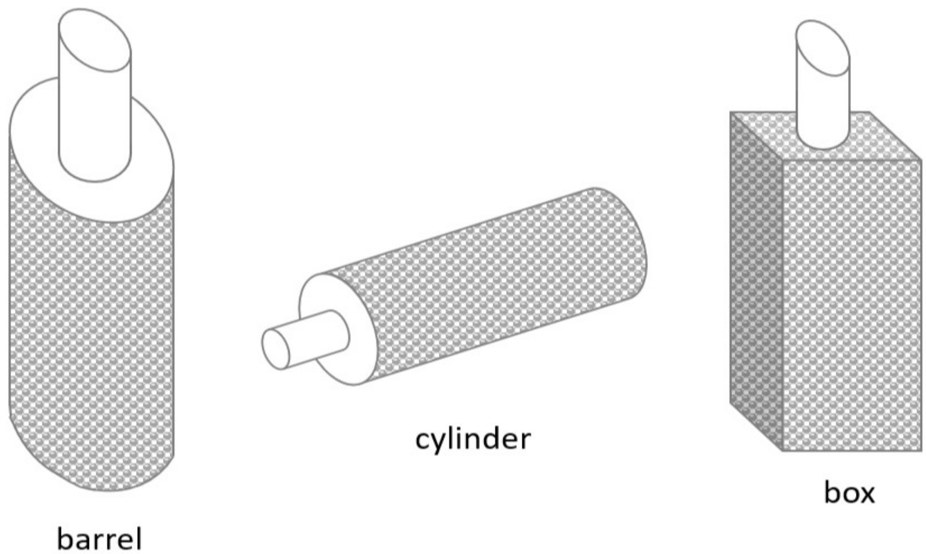

Figure 5. Some typical screen shapes.

2. *Cleaning* – Fish screens for construction dewatering do not need to have an automated cleaning system; however, an operator must regularly check and clean the screen during the entire pumping operation to prevent the screen from becoming occluded with debris. As water levels decrease, the screen must continue be monitored for fish that may not have been rescued during fish removal and site isolation. Again, a larger screen will require less maintenance and will provide a greater level of fish protection.
3. *Uniform flow* – Screens should be designed to draw water relatively uniformly over the entire screen area to prevent excessive debris occlusion and to prevent fish impingement. If site conditions allow, screens should be elevated or suspended off the stream bed to ensure the full use of the screen area. Please note that sections of the screen that are occluded or blocked by the stream bed, screen structural components or any other natural or constructed features does not count towards the *Minimum Effective Screen Surface Area*.
4. *Screen Material*
   a. Screen material must be corrosion-resistant and sufficiently durable to maintain a smooth, uniform surface over the course of use. Screen surfaces must be smooth to the touch, with the openings punched through in the same direction as the water flow ('smooth' side out). Screen materials commonly used include stainless steel, aluminum, or durable plastics (not PVC).
   b. The screen material must have a porosity (open area) of at least 27%. The maximum screen opening allowed is based on the shape of the opening.
5. *Screen Opening or Hole Size* (Figure 6). These are the maximum sizes allowed unless there is site-

specific biological rationale for doing so.

a. Square and circular openings must not exceed 3/32 inch (0.094 inch or 2.4 mm). Measure square openings on a diagonal.

b. Slotted screen face openings must not exceed 0.069 inch (1.75 mm). Measure slotted openings in the narrow direction. Slotted screens should be oriented vertically.

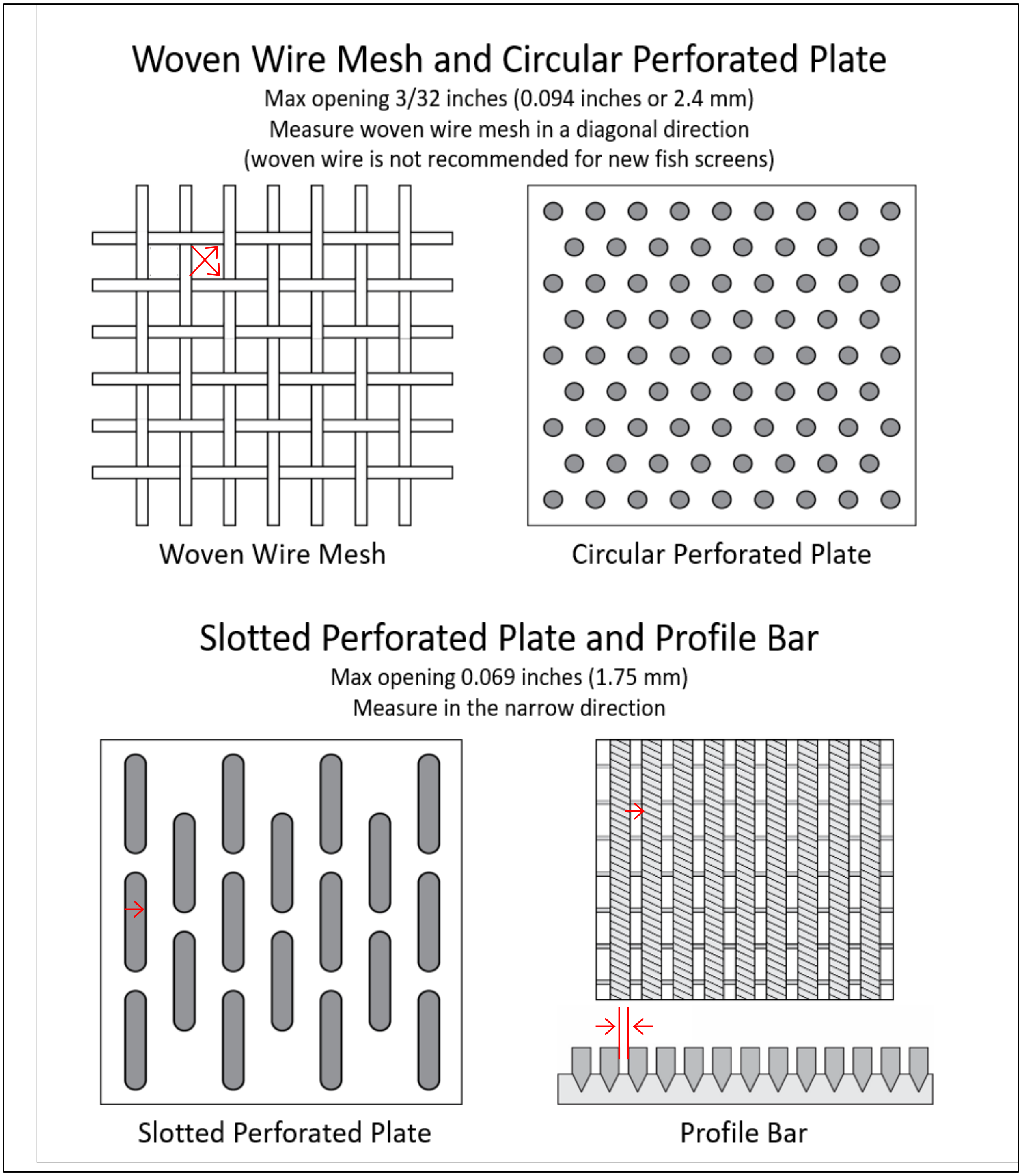

Figure 6. Screen mesh sizes and the direction to measure them.

How to Measure Screen Opening Size.

Screen opening size can be measured using a taper measuring gage with metric or imperial graduation marks. A tool with an imperial measurement range of 1/32 to 5/8-inch measurement capacity with 1/64 Inch graduation and metric with a range of 1 mm to 15 mm long with 0.10 mm graduation readings is preferred. A 3/32" drill bit can also be used as an inexpensive sizing gage.

Relevant Calculations and Formulas:

Converting flow rates

Converting from cfs to gpm: cfs x 448.83 = gpm

Converting from gpm to cfs: gpm ÷ 448.83 = cfs

Calculating Surface Areas.

Formulas for calculating surface areas (Figure 7) are generally intended for closed shapes. However, most fish screens will likely have some ends blocked off, open, or not otherwise count towards the *Minimum Effective Screen Surface Area* requirement. An example of a blocked end would be a screen side placed in direct contact with the streambed or any other obstruction. Therefore, these formulas must be modified to measure the *Minimum Effective Screen Surface Area*.

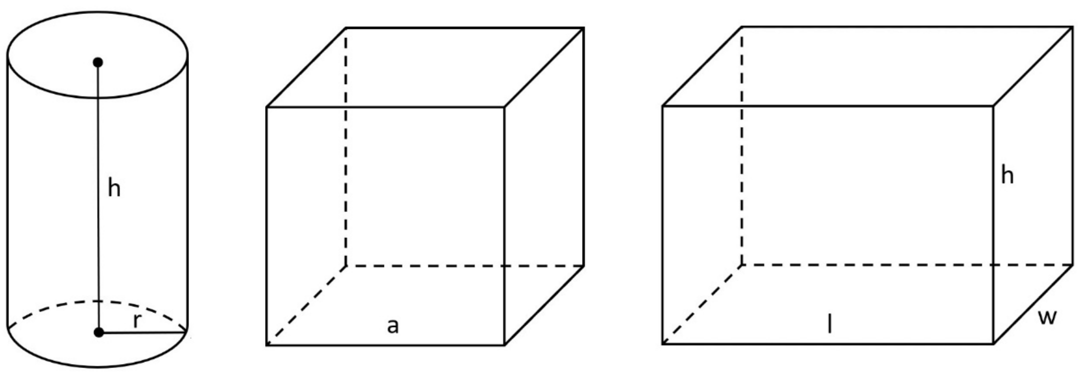

Figure 7. Illustration of different shapes and how to calculate area.

Surface Area of a Cylinder.

The formula for calculating the surface area of a closed cylinder is: $2\pi rh + 2\pi r^2$, where r = radius and h = height. Do not count blocked areas or open ends towards the *Minimum Effective Screen Surface Area* requirement. Therefore, the formula to calculate the surface area of a cylinder excluding the ends is: $2\pi rh$.

Surface Area of a Cube.

The formula for calculating the surface area of a closed cube is: $6a^2$, where a is the length of the side of each edge of the cube. Do not count blocked areas or open ends towards the *Minimum Effective Screen Surface Area* requirement. Therefore, the formula to calculate the surface area of a cube is like calculating the surface area of a square. To calculate the surface area of a square fish screen, multiply the number of screened sides by a^2.

Surface Area of a Rectangle.

The formula for calculating the surface area of a closed rectangle is: $2lw + 2lh + 2wh$, where: l=length, h=height, and w=width. Do not count blocked areas or open ends towards the *Minimum Effective Screen Surface Area* requirement. To calculate the surface area of a rectangular fish screen, omit the blocked or open side of the screen from the formula. For example, if the larger rectangle is open on the top, and the screen is placed on the stream bed the formula would not calculate the top or bottom of the rectangle. In this case the formula would be: 2lh + 2wh.