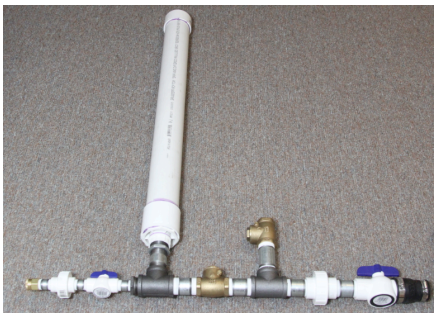
# How to build a Hydraulic Ram Pump

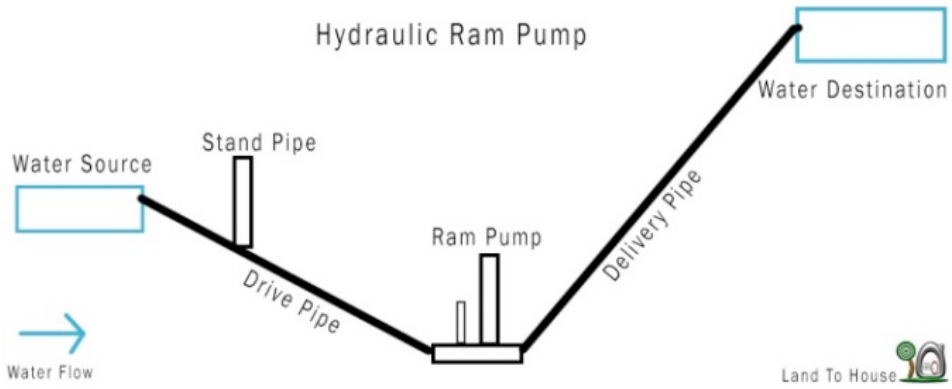
By Seth Johnson – Land To House™
Version 1.1



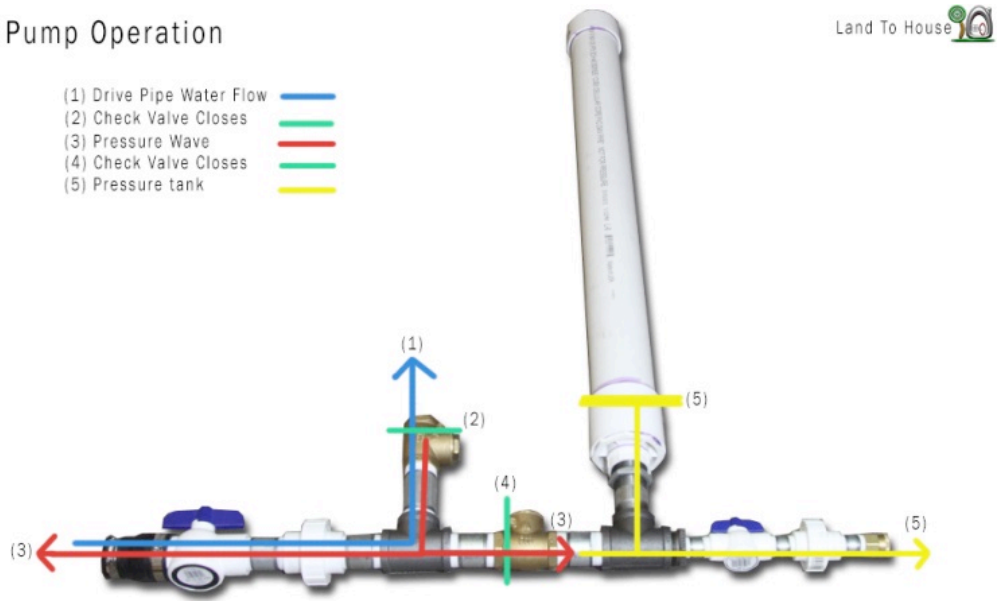
## History:

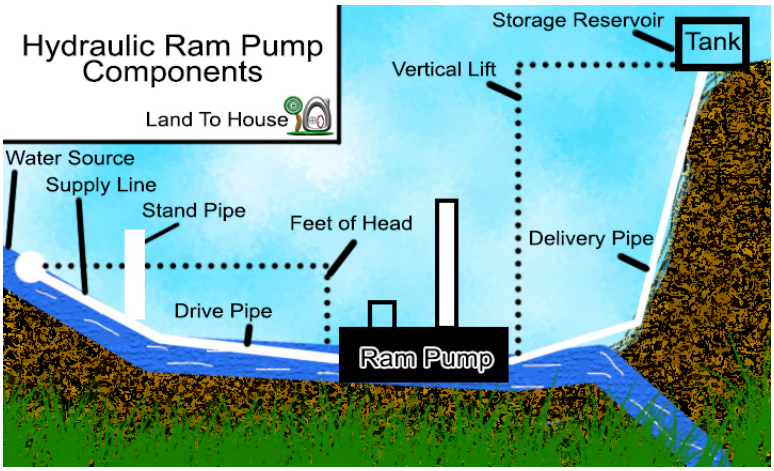
A man named John Whitehurst first created the Hydraulic Ram Pump in 1772. That means that this ingenious little pump is over 240 years old at the time of this writing. Several design improvements have been made over the years but the basic concept has stayed the same.

## Technical stuff (what makes the pump work):




The hydraulic ram pump works because of a pressure wave that builds up and then passes. Two moving parts called one-way valves or check valves create this pressure wave. Water moves through a pipe known as a drive pipe to the pump system and flows out of the first check valve until the pressure reaches a value that causes the check valve to slam close. A burst of water is sent back up the pipe creating the pressure wave. When the valve closes a small percentage of water is forced into the second check valve. A pressure tank located behind the second check valve forces the water out a pipe known as the delivery pipe. This pipe is what carries water to the desired destination.



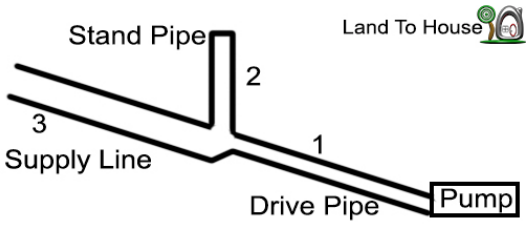

The pressure wave that is needed to get the system working correctly will not work well if the drive pipe is less than 15 feet. The pressure wave is sent back up the pipe and then out the end, thus the system does not work well or at all. This means that the drive pipe must be longer than 15 feet.

**StandPipe:**

Depending on the distance that the water needs to travel to achieve the desired drop (feet of head) it might be necessary to add what is called a standpipe. Basically the standpipe brings the water source closer to the pump. Because there will be a shockwave in the system that travels up the drive pipe, the drive pipe cannot be more than approximately 100 feet long. If the drive pipe is longer than that, the shockwave will be reduced because of the pressure of the water in the pipe and the distance that the wave has to travel. If the feet of head that you need cannot be achieved in the 100 feet of drive pipe then place a standpipe at the 100 foot mark from the pump system. Make sure that the pipe stands to a height of one foot above the height of the source intake. Adding this pipe at the end of the suggested drive pipe range will let the shockwave travel up the standpipe and not be

dissipated out the length of the drive pipe. If the shockwave were allowed to continue up the pipe it would take so long to return to the pump system that it would not be an effective pump. If you have the required amount of feet of head to reach the pumping destination within 100 feet of drive pipe then you will not need a standpipe.

When installing a StandPipe you will need to use a pipe size ratio for best results. This ratio is a 3, 2, 1 ratio. The supply line that comes from the water source will need to be the largest pipe. For instance a 3" pipe. Next you will need a StandPipe that is smaller than the supply line in the example 2". And lastly the drive pipe should be the smallest pipe 1" in size. What this dose is allow the water to be supplied without any loss to the pump. The water in the StandPipe will be acting as the source and will have the pressure wave acting on it.




**Pressure tank:**
The size of the pressure tank is important in the operation of the pump. If you have a tank that is to small then the pressure that is built up will not be great enough to achieve the output that is expected. In this build for a 1-1/4" system you will need to use at least a 3" pvc pipe for the tank. This tank needs to be at least 3 feet tall so that you will have the needed air volume. You can use a 4" pvc pipe for the pressure tank and you can reduce the height of the pipe to 2 feet tall.

**Snifter Valve/Bike Tube:**
The Pressure tank builds pressure but also has a tendency to fill with water if the pump runs to long without the delivery pipe open. When the tank fills with water the system loses some or all its ability to pump water. Two things can be done to prevent water from flooding the tank. **1.** The first is that a small hole can be drilled in the lower section of the tank connectors. The bushing is a good place for this. This small hole is called a Snifter valve. On every cycle of the pump a small stream of water is shot out of the snifter valve and a small portion of air is taken in. This small gulp of air floats to the top of the pressure tank and keeps the tank from filling with water. **2.** The second option that can be done to keep the tank from filling with water is place a bike inner tube in the tank and fill the tube partially with air. This will make sure that there is always some air in the tank that can be pressurized. I recommend using one of these methods to keep the tank free from water so that you can run the pump continuously.

**Feet of Head / Ratio:**
The pump can only move water up hill within its limits. For every foot of head that falls into the pump system seven feet of lift can be achieved. For instance if 5 feet of water falls into the pump then the water will lift 35 feet high. The rate of flow will increase as the feet of head increases. There are several equations that will help you determine the results that you can expect from your pump but this "how to" does not cover them. Check below to see a chart of results from this build. To find out more results from this pump check out the videos under: http://www.landtohouse.com/?p=307

## Notes:

A couple notes before we start building the pump:

- You have to have a water supply for this pump to work. Obviously without water there is no need to have a water pump.
- For the pump to work, water must drop from some height into the system. This water drop is known as "feet of head". For instance if water falls 2 feet than the feet of head would be 2 feet. Without this drop the pump will not work.
- This pump works with a pressure wave. If the Drive Pipe (pipe that brings water into the system) is to long it will cut down the pressure wave and the pump will not work correctly. If the Drive Pipe is to short the pump will not work correctly either. There are workarounds for both of these problems discussed later. To ensure that the pump works as desired make sure that the Drive pipe is at least 15' long and not more than 100' long.
- You can build this pump with several dimensions of components but it is important that the Drive pipe and the first check valve have the same dimensions. For example in the component list below the drive pipe and the two check valves are 1-1/4" diameter.
- Starting the pump will be discussed in detail later but it is important to have a backpressure on the Delivery pipe to allow the pump to operate at its full potential. Without this backpressure the pump will stop pumping. To create this backpressure simply run the Delivery pipe uphill 15' or more above the pump.

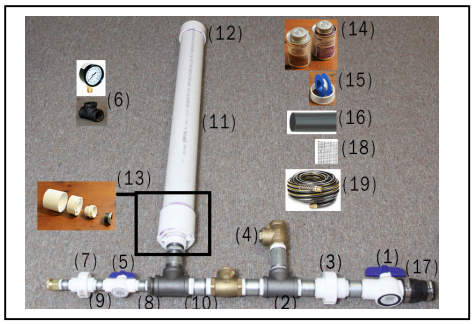
## Cost:

The Cost of the pump will depend on a couple of things. The length of pipe that is needed for both the drive pipe and delivery pipe will affect the cost. Your local plumping store should sell 1-1/4" flex tube for $1 a foot. For the delivery pipe a garden hose can be used with a cost of $40 for a 100foot section. For the pump parts, your total will be between $140 and $200 depending on what parts you need and where you purchase your parts. Some large stores such as Lowes and Home Depot may not have the check valves that you need. Try your local plumbing store or shop at http://hdsupplysolutions.com for these parts. Ace Hardware will run about $40 more for the pump than your local plumbing store.

(Print this page for the build components)

## Parts list:

This project does not require many parts and even fewer tools to complete. You can get these parts at your local plumping or hardware store. Parts labeled (6) are for installing a pressure gauge and they are not needed for basic operation. The option a. in part labeled (13) can be hard to find. If this happens look for option b. This involves more parts but gets the job done.




**Tools Needed:**

2 Pipe Wrenches
Screw Driver- flat head

**-The Ram Pump:**

(See figure for visual)

(1) 1-1/4" ball valve (With threads)
(2) 1-1/4" metal or PVC tee (With threads) (buy two of these)
(3) 1-1/4" PVC union (With threads)
(4) 1-1/4" brass swing check valves (With threads) (buy two of these)
(5) 3/4" ball valve (With threads)
(6) 3/4" Metal or PVC tee (With threads) and pressure gauge – Both Optional
(7) 3/4" PVC union (With threads)
(8) 1-1/4" x 3/4" bushing (With threads)
(9) 3/4" x 2" nipple (Buy three of these)
(10) 1-1/4” x 3” nipple (Buy six of these)
(11) 3" x 36" PVC pipe
(12) 3" PVC glue cap
(13) Get a. or b. but not both:
  a. 1-1/4" to 3” bushing threaded on the 1-1/4” end and glue end on the other.
  b. Or a 1-1/4” to 1-1/2” threaded metal bushing and a 1-1/2” to 2” bushing threaded on one end and glue end on the other. One 2” to 3” bushing or reducer. Then a 3” coupling
(14) PVC Cement and Primer
(15) White pipe tape / teflon tape. (Buy 3 rolls of this)
--You may add a pressure gauge if you would like to find out what pressure you have at the pressure tank. Just add a 3/4” tee after the pressure tank and place the gauge here.

**- Drive Pipe**:

(16) 1-1/4” Pipe of required length Flex, PVC, Steel
(17) Rubber pipe connector 2” to 1-1/4”
(18) Screen or hardware cloth (To prevent debris from entering the pipe)

**Delivery Pipe**:

(19) 3/4” Pipe of required length to reach destination Flex, PVC, Steel, Garden Hose
  (If you are using a garden hose you need to get an adapter to go from the threaded pipe nipple to garden hose thread. If you will be using flex pipe you will need a rubber pipe connector that will attach to the 3/4” union.)

## Lets start the Build:

(**Warnings:** Use PVC primer and cement in a well vented area! The fumes are strong and can cause health problems. If you need to cut PVC pipe be sure to use gloves and eye protection.)

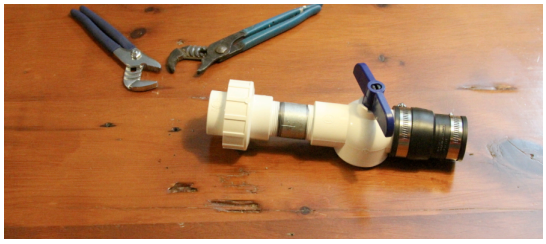
Each step listed has a corresponding figure or figures to help you with the build.

1. First take the 2" to 1-1/4" rubber pipe connector and place it on the end of the PVC ball valve. Place the 2" end next to the ball valve. Use a screwdriver to tighten this component on securely.

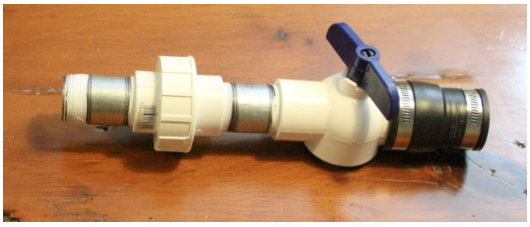
2. Gather the white pipe tape (teflon tape) and all the pipe nipples. That should be six 1-1/4" and three 3/4" pipe nipples. Place at least four winds of the white tape on the threads of each nipple. This will allow connections to be secure and water tight.

3. Now take a 1-1/4" pipe nipple with white tape on it and screw it into the 1-1/4" ball valve. To make this connection secure you can use two pipe wrenches but don't over tighten because the threads on the PVC can strip.

4. The other end of the pipe nipple will now be connected to the end of the 1-1/4” Union. The functional purpose of a union is to separate so when you are installing it make sure that both parts of the union are connected together to prevent pieces from getting out of order.



5. After the union place a 1-1/4” pipe nipple into the other end of the union.



6. Now place the 1-1/4” threaded tee on the other end of the pipe nipple. Tighten this down so that it is secure but make sure that the 90 degree angle is facing up. This will be important later.

7. On the two remaining sections of the tee, screw 1-1/4” pipe nipples securely.

8. Up from the top of the tee, screw a 1-1/4” check valve. The direction of the water flow will need to be facing down on the check valve. There is often an arrow on the check valve that will indicate the flow direction. This arrow needs to face down. As long as the whole system is facing upright, it does not mater what angle the check valve is facing as you tighten the threads.

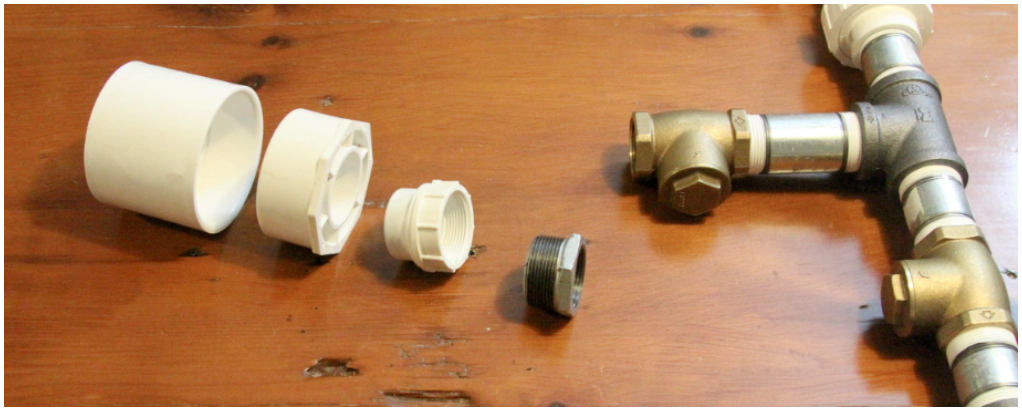
9. Place the second check valve on the other end of the tee. The direction of the water flow needs to be going out of the system. Make sure that the arrow points away from the first valve. Because gravity pulls the valve flap down it is important that the angle of the valve be upright so that the valve can remain closed naturally. What does this mean? The hinge that the valve swings on needs to be at the top of the component.

10. From this check valve, install another pipe nipple.

11. The next component is another 1-1/4” threaded tee. Make sure that this tee has the 90 degree angle facing upward.

12. From the 90 degree bend of the tee, place another 1-1/4” pipe nipple.

13a. If you are able to find a 1-1/4” to 3” bushing then screw the 1-1/4” to 3” bushing onto the 1-1/4” pipe nipple. Make sure that this is tight and secure because this will be the base of the pressure tank. If you are unable to find this part, see 13b.
13b. Because the 1-1/4” to 3” bushing is sometimes difficult to find it might be necessary to find an alternative to this part. In this build I have used a 1-1/4” to 1-1/2” metal bushing that connects to a PVC 1-1/2” threaded to 1-1/2” PVC Glue end. This simply adds the needed pipe step-up to allow for a 1-1/2” to 3” bushing or reducer. This is the most complicated section of the build and there are several modifications that can be made to get the pressure tank connected. It is also acceptable to use a 4” pressure tank if that makes it easier to find a single bushing to make the 1-1/4” to 4” bushing.



14. Use the pipe primer to coat all connections of PVC pipe. Including both ends of the 3” pipe, end cap, coupling, 1-1/2” to 3” bushing, and 1-1/2” glue bushing. These pipe sections will be glued together.

15. Use PVC cement to glue together the 3” pipe to the coupling. Then glue together the coupling to the 1-1/2” to 3” bushing. Now glue the 1-1/2” threaded to 1-1/2” glue end into the 1-1/2” to 3” bushing. Then glue the end cap to the 3” PVC pipe on the other end.

16. Set the pressure tank aside. The tank is large and cumbersome so it will be installed once the rest of the pump is assembled.

17. Screw the 1-1/4” to 3/4” bushing to the other end of the threaded tee.

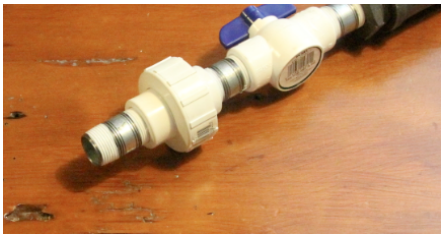
18. Connect a 3/4” pipe nipple into the bushing.

19. From the 3/4” pipe nipple connect the 3/4” ball valve. When tightening, try to keep the cutoff handle upright to make it easy to use when needed.

20. Place another 3/4” pipe nipple onto the 3/4” ball valve.

21. Make sure that the 3/4” union is connected together. Screw it onto the 3/4” pipe nipple.

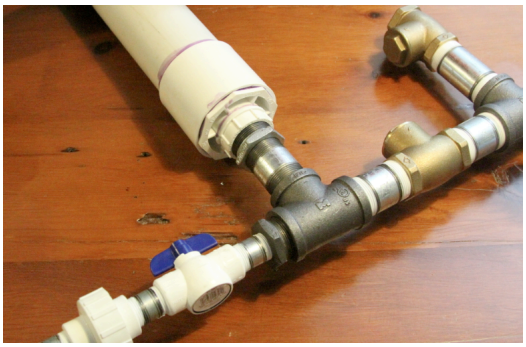
22. Connect a 3/4” pipe nipple into the union.



23. If you are using a garden hose as the delivery pipe, you will need a garden hose thread connector placed on the end of the last 3/4" pipe nipple.

24. Connect the 1-1/4" to 1-1/2" bushing to the 1-1/4" pipe nipple that is coming out of the second threaded tee.

25. Screw the pressure tank to the 1-1/4" 1-1/2" bushing.



26. The basic parts of the pump are now assembled. If you are going to use a flex tube then you will need to use a rubber connector that will connect to the end of the union. If you are using a garden hose then use the connector in step 23.

## **Installing the pump**:

Select a place that has a flat surface that the pump can rest on. It can be on dry ground or in the water as long as the first check valve is out of the water. Because the pump has the force of a pressure wave that closes the check valves repetitively, it is important to secure the pump in place to keep it from falling over. Do this by anchoring with screws to concrete or cover the pump with rocks. (It does not really matter what you use to keep it from moving as long as it is secure.) The pump has two moving parts, the Check valves, and needs to be upright. This will allow gravity to open the check valves when the

pressure behind them is decreased or forced open by the pressure wave. Also the shockwave that is created will hammer the system and cause it to move back and forth. By securing the pump in place the shockwave will not be reduced by a moving pump.

There are several ways to install the drive pipe. Flex pipe is easy to use for waterways that have lots of bends and obstacles. Every curve and bend in the Drive Pipe will cause friction and will slow the water inside and this will reduce the efficiency of the pump. Using a Drive pipe that is rigid, such as PVC or Steel, will allow for better flow and higher efficiency. If you are using Flex pipe place the water entry point of the pipe out of the water and make sure that it is not submerged while installing the rest of the pipe. (When the pipe is empty it is easier to move.) As you install the pipe cover it with rock or heavy objects to keep it from flowing away with the moving water. Use the 2" to 1-1/4" rubber connector to connect the Drive pipe to the 1-1/4" ball valve. Once the Drive pipe is connected to the Ram Pump securely, place a screen or Hardware cloth on the water entry end of the pipe, and secure it so that it will not wash off. You can do this with rocks or zip ties. Place the pipe in the water and make sure that it is fully submerged and secure.

The Delivery pipe can be flex pipe or garden hose. If you are using a garden hose, use a connector that allows 3/4" threads to garden hose from the end of the pump. If you are using a 3/4" flex pipe as the Delivery Pipe than use a 3/4" to 3/4" rubber connector. Place the Delivery Pipe up hill at least 15' to maintain backpressure. Without setting the delivery pipe to 15' or more the pressure in the tank will be dissipated and the pump will stop.

## Starting the pump:

Now that the pump has been built and installed it is time to make it work. Make sure that the drive pipe is submerged in the water. Make sure that the delivery pipe is 15' or more above the pump to keep pressure in the tank. Close the delivery pipe ball valve so that no water exits. Open the drive pipe ball valve to 90% open. (This value might change depending on the flow and feet of head you have) Press the first check valve and hold it open to let water rush out of the valve. Let this water run until all the air bubbles are out of the drive pipe. Depending on the length of the pipe this might take 30 seconds to over a minute. Once the air is out of the drive pipe, press and release the first check valve so that water flows up and out of the valve. If all of the air is out of the drive pipe then the pump will start to pulse on its own. Once the pump has started to pulse allow it to do so for 30 seconds. (This is building pressure in the pressure tank) After the pump has been working for 30 seconds on its own, open the delivery pipe ball valve 10%. If the pump continues to work, open the delivery pipe ball valve more until it's fully open. If opening the delivery pipe ball valve stops the pump, then repeat these instructions but allow more than 30 seconds of operation before opening the Delivery pipe ball valve. When the system is operating on its own then open the Drive pipe ball valve all the way.

## Operation Results:

Here are some results from the operation of the pump built in this "How To"

| Fill 1 Gallon @ 5' Head | Delivery Height | Time | Rate |
|---|---|---|---|
| | 10 Feet | 20 Seconds | 3gpm |
| | 20 Feet | 80 Seconds | .75gpm |

To arrive at these results a 1 Gallon container was used to collect water as it fell from the delivery pipe. As the water filled the container a timer was set. The drive pipe that supplies water to the pump system has a total of 5 feet of head. You can see from the results that the pump can supply a reasonable amount of water to both 10' and 20' heights and can do so in a short amount of time. As the height increases the volume of water flow decreases. The main determining factor on the height the water can reach is the feet of head that enters the pump. The build in this "how to" has a feet of head value of 5' so it will stop pumping at approximately 35' in the air. This means that the pump has a 1/7 ratio of pumping potential. For every foot of head there is a 7 foot lift. The Hydraulic Ram Pump has a greater potential for water lift than 35' but for this build 35 feet is sufficient. To see more results of the pump: http://www.landtohouse.com/rampump

## Cleaning the pump:

The system often cleans itself during the normal operation but if it does not clean itself then it must be cleaned. The screen or hardware cloth on the water inlet of the drive pipe should be cleaned when it becomes clogged. Often leaves and sticks will gather on the screen and block the flow of water. Remove and shake the screen in the water and allow the debris to fall away. If large debris, such as rocks, enter into the delivery pipe it will travel to the rubber connector before the 1-1/4" ball valve and it will clog the ball valve entrance. If this happens first remove the flex pipe water inlet from the water to stop the flow and relieve the pressure. Then remove the 2" to 1-1/4" Rubber connector and pull out the debris that has entered into the ball valve. If small debris has entered into the pump it will often get stuck at the 1-1/4" x 3/4" bushing. If this happens, first stop the water flow by pulling the flex pipe inlet out of the water. Next unscrew the two unions and lift the Ram Pump out of the water. Because the debris is behind the second check valve it might be necessary to hold open the valve to allow the debris to fall out toward the 1-1/4" end of the pump. At times the first check valve will be held open with leaves and twigs. To clean this check valve first close the large ball valve to stop the water from flowing. Hold open the valve and use a finger to remove the debris. You can turn the ball valve half way open to allow the water to flush the debris out.

## **Problems with operation**:

There are several factors that could effect the operation of the pump. Let's take a look into a few things that can be done to fix problems. Starting from the beginning and moving down the line.

Is water reaching the pump? The drive Pipe can become blocked very easily when in water that has debris flowing around freely. Make sure that the pipe is submerged in water and able to pull in all the water it needs. If the pipe is stopped up then remove all the debris that is blocking it. If the water is not deep enough and the pipe is not fully submerged then locate a place that is deeper that will allow the pipe to be fully submerged. If you must have the drive pipe in this location and it is not deep enough you might try digging deeper. Also you can use a bucket or some form of catch basin to trap water for better intake. Walk down the pipe and make sure that it does not have any kinks that would cause the water flow to be slow or reduced. Press out any kinks so that the pipe is smooth and open. Read above for how to clean out the pump if there is debris in the pump itself.

In order for the pump to work correctly the two check valves must be the same size as the drive pipe. If these two components do not correspond in diameter size, the pump will not start and maintain the pumping motion. The pump that is built from the component list above uses a 1-1/4" drive pipe and a 1-1/4" check valve combination. Also the delivery pipe must be smaller than the drive pipe and the check valves.

The length of the drive pipe can effect the operation of the pump. Because the water in the pipe is being affected by gravity and is being forced down to the pump it is "heavy". The shockwave that is required for the operation of the pump can only counter act so much force from the drive pipe. When the pipe is to long the shockwave is reduced and the pump does not work as it should. Also, a drive pipe that is to long will cause the pressure wave to take a long time to return to the pump system, and pressure will be lost. Look above for standpipe information. A drive pipe that is to short also can be a factor in the pump not working. If there is not enough water pressure behind the pump, the shockwave is not effective at keeping the pump going. A length of more than 15 feet is recommended.

The pump is designed to be upright with the first check valve swinging up and down and the second one swinging backwards and forwards. If the system is leaning to the side the check valves will be affected and they will not be able to swing properly. So make sure that the pump is not leaning to the left or right. This will allow the pump to be more efficient.

All of the air must be removed from the drive pipe before the pressure wave will flow freely. Hold open the first check valve and let the water run out until all of the air trapped in the pipe has been released. Depending on the length of the pipe this might take a 30sec to a couple min.

The first ball valve can be used to control the amount of water that enters the pump. The drive pipe and the check valves are a set size and cannot be changed, so by changing the amount of water that is allowed in by moving the ball valve you can fine-tune the operation of the pump. Also if the pump is not starting you can use the ball valves to adjust the amount of water that enters the system to match the size of the check valves.

A backpressure is needed on the system to keep the flow of water moving out the delivery pipe. This backpressure is built by the height and distance of the delivery pipe. By using a pipe that is at least 15 feet above the pump a sufficient backpressure is built to keep the system pumping.

*I am learning something new about the Ram Pump everyday.*
*Build one for yourself and go have fun!*

## About the Author:

**Seth Johnson**

I am an Engineer from East Tennessee State University. I also have an associates in electronics from Mayland Community Collage. I have always enjoyed working with my hands. Tinkering with electronics, Testing alternative sources of energy, Making fun videos, and building water pumps are just a couple things that occupy my time. If you would like to learn more about me please check out my blog on Land to House:

http://www.landtohouse.com/category/seths-blog/

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