When I was younger my family and I moved to Cairo Egypt for four years. This was a wonderful time in my life and while I was there I got to see first hand the necessity of being able to efficiently move and transport water. There was plenty of water there, but unfortunately it was located in the Nile River. The river is always in the lowest part of the terrain. The land along side the Nile is mostly agricultural and no matter where you go you can find an efficient water distribution system. Along both sides of most streets were not sidewalks but irrigation ditches. Every street corner had a cement sluice box with 4 or more easily operated gates. Every house's yard could be flooded with the turn of a valve. Once a week our lawn was flooded to a depth of several inches to keep it green.

For thousands of years the Egyptians have distributed water from the Nile to their fields all of which are higher than the water source. To do this they employed a huge variety of methods. Near the town I lived in was a building on the Nile full of electrically powered water pumps filling the irrigation canals with water. You would think this was the norm now, but Egypt is a mishmash of new and old. Cutting through downtown Cairo, you can see the remains of a roman aqueduct and of the windmills used to raise the water to it. Go out into the farming areas and water is still raised from the ditches to the fields by the old methods. The two most common are the Archimedes screw and the Shaduf. Remembering what I saw in Egypt, I'm pretty confidant I can help the people at this farm.

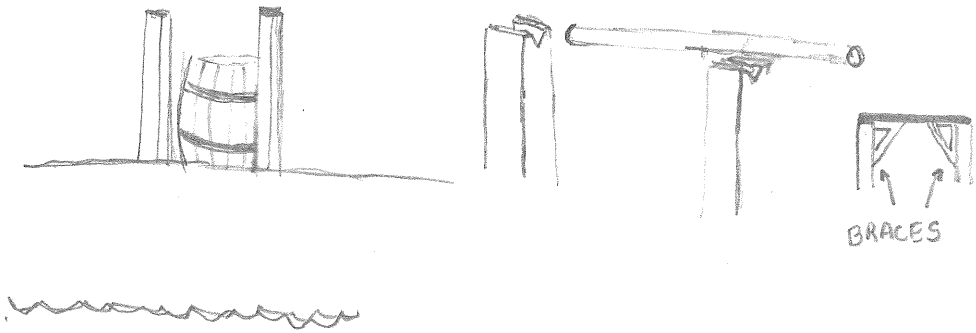
First lets go check out the barn and the farm equipment, If any of the equipment has a screw conveyor attached, we can use that as an Archimedes screw. A screw conveyor is used to lift dry material like corn or wheat to load a truck or silo. We could connect the 3 donkeys to turn one of the large tractor wheels mounted on a post. This in turn could be used to turn the screw conveyor to lift the water using ropes as drive belts.

Figure 1

If there is nothing like an Archimedes screw around, and since we are in a hurry lets set these people up with some Shadufs. We'll run around the farm and find some (3) used 4X4 posts, some assorted planks and boards and a few lengths of metal pipe, preferably longer than the width of the barrels. We can probably get most of this from the greenhouse, if not I'm not above borrowing from the barn. Oh and well need and some rope or strong wire and nails or screws.

Next on top of the bank of the pond we will set two 4X4s into the ground vertically just a bit wider apart than a barrel. The 4X4s need to be about 3 or 4 feet taller than the barrel. Use a hatchet to notch the tops of the posts so that a pipe can set horizontally across them. This pipe will have some weight put on it so it needs to be pretty strong. If it needs it you can brace it later.

Figure 2



Take your last 4X4 and drill a hole big enough to fit your rope through about 4-6 inches from the end of the board. Then drill another about 3 feet from the same end. This hole needs to match the diameter of the pipe. At the other end of the board drill two more holes about one about 4 inches from the end and the other about a foot from the end.

Pass the pipe through the pipe sized hole then mount the pipe on top of the vertical 4x4s.You have now created a arm that pivots on the pipe. You should strap down the pipes so it is attached to the tops of the 4x4s.

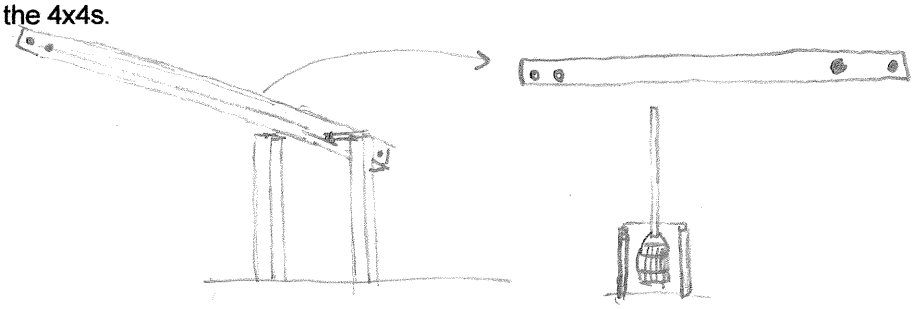


Figure 3

Hang a barrel from the short end of the arm using the hole you drilled in the end of the board and some rope. You might need to drill a few holes in the barrel. You want to hang the barrel so that when the arm is vertical the barrel is not touching the ground. To make the beam stand vertically put some dirt or rocks into the barrel (carefully! when it starts to swing upright it will really have some weight behind it)

Next we need to build a tray. It needs to be about 1 yard long x 18 inches wide by 1 foot deep. Make this out of the planks and framing. It doesn't need to be watertight because we can line it with plastic sheeting, but it needs to be able to support about 300 pounds. So use lots of screws and frame it well.

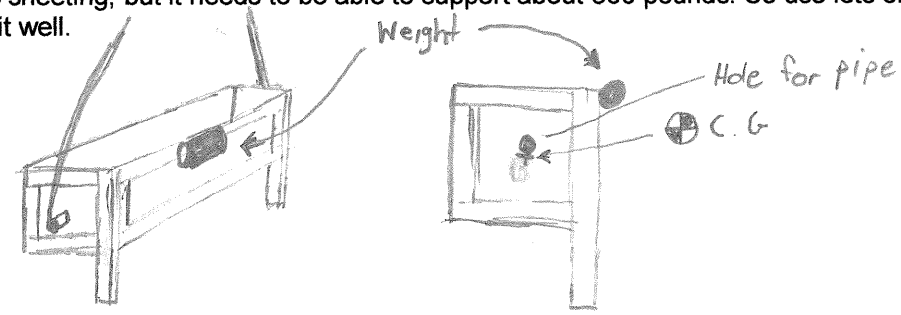


Figure 4

We want this tray to be kind of tippy, top heavy when its empty and just bottom heavy when its full of water. To do this, run a pipe end-to-end through the tray just above the center of gravity or halfway up the side. Then we can attach a weight to one side to make it top heavy when its empty. On the side with the weight we want to have two short legs hanging down, these will be used to tip the tray.

Now get some planks and build a U shaped wall a few feet in front of the vertical 4X4s. It needs to be about 1 foot tall and extend around the sides of the base away from the pond. This is a little cofferdam to keep the water from flowing the wrong way. It will also be used to "trip" the tray and dump the water.

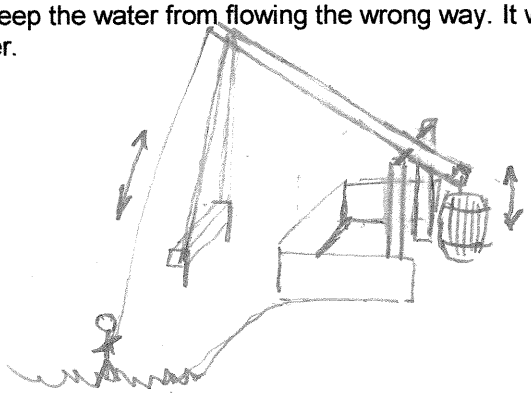


Figure 5

Thread a long rope through the unused hole at the end of the beam and tie it off. Then thread a rope through the other unused hole and let both ends dangle. These ropes should be long enough to reach the ground and still have extra slack when the pivoting beam is standing vertically.

Now using the rope that passes through the beam, hang your tippy tray at a level so that the legs hit the cofferdam but do not drag in the dirt. You want it so the tray passes above the cofferdam and the when the legs hit the cofferdam the tray tips and spills behind the dam.
Tie a couple of small lines to the tray from the rope so that the tray can only pivot 90 degrees. Actually if you balanced your tray well, these won't be necessary.

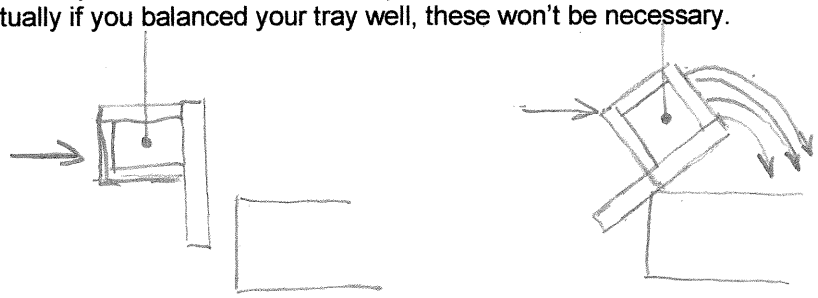


Figure 6

Almost done.
Pull down on the long rope the tray will swing out over the water hanging sideways because of the weight on the side of the tray. Continue to pull down on the rope until the tray submerges. Now, have someone lift the arm until the tray is just coming out of the water. This will be tough, as the tray now weighs about 300 pounds. Slowly fill the barrel with weight (rocks dirt, mud, whatever) until the counterweight is just heavier than the water-laden tray.
Let go of the arm the tray will soar out of the water and swing toward the cofferdam
The legs will hit the damn and the tray will spill its load of water all 127 liters.

Pull down on the rope until the tray submerges again in the pond. let go of the rope.
Congrats! you only have to do that 392 more times to irrigate your field.

Some thoughts on the rope, if you do not have enough available rope roll the plastic lengthwise and braid three lengths into a strong plastic substitute.

Given 1 Shaduf, lifting once a minute 1 guy could water the field in a little over 6 ½ hours. Except we have 3 barrels we can make 3 Shadufs and 3 people could water the field in 2.2 hours.

goal (liters)	bucket(liters)	Lifts	numshadufs	per shaduf	hours/day	lifts/shaduf/hour	Lifts/minute	seconds/lift	minutes/lift
50000	127	393.70	1.00	393.70	6.6	59.65	0.99	60.3504	1.00584
50000	127	393.70	2.00	196.85	6.0	32.81	0.55	109.728	1.8288
50000	127	393.70	3.00	131.23	2.2	59.65	0.99	60.3504	1.00584

Now the field is being watered but it still is taking 6.5 man-hours to accomplish. I'm sure these people have better things to do than stand in a pond pulling down a rope every minute.
So lets water the field and then improve things.

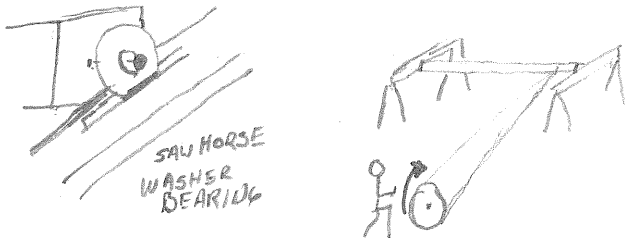
First we need to collect a bunch of pieces of wood, all uniformly thick, my preference is about a ½ an inch to an inch thick. Each piece should be about 6 inches wide and about a foot long. Then we need a long 4X4 or better yet a wooden rod about 3+ inches in diameter and 5 feet long, a sheet of plywood, 30 or so 1X1X5's, a bunch of 1 ½ to 2 inch screws, 3 big long nails, some sawhorses, a couple big thick washers and a bottle of Elmer's glue or something similar and not

water soluble. We will need a drill with a a large bore bit(same diameter as the rod), a bit to match the screws, a wood plane, a chisel, some of that plastic sheeting and the wheels off that tractor.

We can build an Archimedes screw that should have enough volume to water the field. If not build two and run them in tandem. Luckily we have all the time we need to build these because the Shadufs are working. The question comes up why build this if the Shadufs are working? The answer is we can use the Donkeys to power the Archimedes screws and they are more efficient and much faster, we can water the field much quicker.

If we couldn't find a wooden rod (a big wooden curtain rods would work) we need to lathe one out of a 4X4. Get some Saw horses and cut a groove in them to hold the washer vertically Stick a large nail in the center of the end of a 4x4 with about 1/2 inch left out. Then suspend the 4x4 between the sawhorses by sticking the nails through the washers. You then need to spin the 4x4 along its access, to do this use a wagon wheel or even the tractor wheel as a flywheel and use a rope to go from the large wheel around the 4x4 to spin it. (Even a stationary bike would work to power this, Remember Gilligan's Island!) Use the chisel to turn the 4X4 into a rod. You want the diameter to match the large Drill bit you have – say 3 inches...

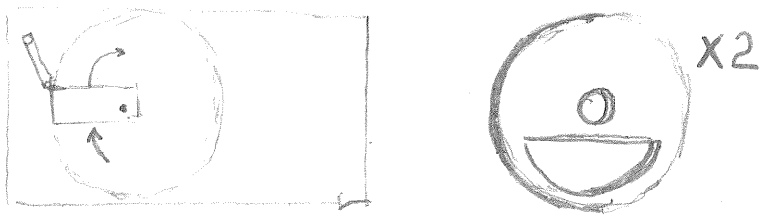
Figure 7



Ok that was the tough part.

Now get one of your 6"X1' pieces of wood and mark a spot in the lower right corner that would be where you would center the bit if you were going to drill a 3 inch hole leaving ½ from the edges (2 inches from the bottom and right sides) pound a nail through that. Using that as a center stick the nail into the plywood. and using the board draw a circle (using the upper left corner of the board as your scribe) Do this twice so you have two circles. Cut the circles out of the plywood (leaving the line) then using the large bit drill out the center of the circles using the nail mark as the pilot hole. In both circles cut out a large half circle hole as shown.

Figure 8



Now grab your drill and the big bit, and all but one of your 6"X1' pieces of wood bore out a hole in them to match where you stuck the nail in the last piece (2 inches from the bottom and right sides)

Now take the last 6"x1' and cut it diagonally lengthwise so you have a 6"X1'X6 inch triangle. You can use this to keep the angle of the screw uniform.

Take the rod leave about 6" from the end and put the 6"X1' over it. Using the glue and a screw (be sure to drill a pilot hole for the screw- you don't want to split your rod!) affix the piece to the rod. Do it again but offset the angle of the piece of wood using your triangle as the guide. (glue

the two pieces together as well as gluing the new piece to the rod.) Remember to make your screw spiral counter clockwise, so that when you spin it clockwise it pumps uphill. Keep making your spiral until it is long enough to raise the water 1 meter –1.5 to 2 meters is plenty. You want about a foot of rod left over.

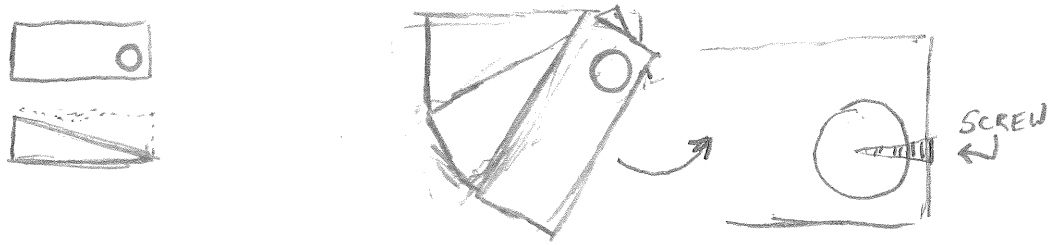


Figure 9

Put the plywood circles over the each end of the rod (you probably want to grease the holes of the plywood first.) Now you are going to make a cylinder by attaching the long 1"x1" strips. To make them fit tightly you will need to take your wood plane and bevel the 1X1s so their crossections look like keystones. Get them as tight together as possible. When they get wet they will swell up. and we can also wrap the whole cylinder in plastic to help make it watertight.

Attach a drive wheel to the top end of the rod, stick the lower end in the water and power it with the donkeys going around a windlass. Once its started every revolution of the screw will deliver about 4 liters of water at 60 rpm the Screw will lift enough water to irrigate the field in 3.5 hours. If you build two screws you can halve that time.

My work here is done.