# THE CRAWFORD DRILL

How it works and when it should be used.


ABSTRACT

This paper covers instructions for using, building and trouble - shooting the Crawford Drill Bar



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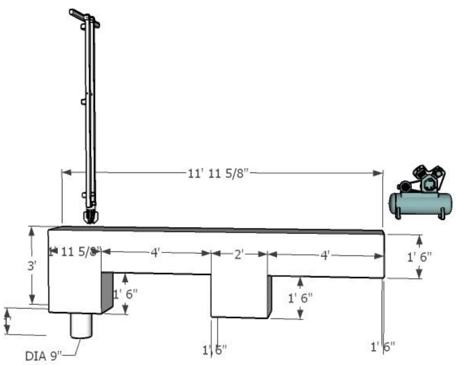
https://tinyurl.com/y9scsv5f

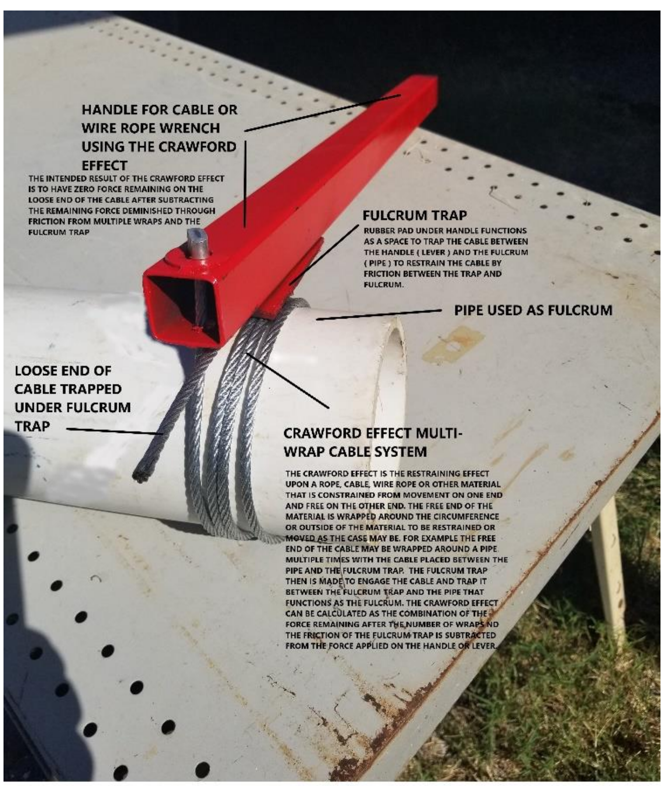
# WHEN TO USE THE CRAWFORD BAR METHOD

The Crawford Bar method can be used in any soil that can be hand drilled by any tool that will drill earth, sand, gravel, clay, or a combination of those materials. It will also drill in soft rock and in gravel that cannot be drilled by other methods. Typically, the Crawford Bar will drill where other hand methods cannot drill. For example, the Crawford Bar will drill where augers, direct circulation, jetting, hand percussion and coring are not successful because of cost or impossibility.




For example, none of the other drills will drill in large gravel below the water table. Because the Crawford system uses reverse flow air lift, it will drill gravel up to the diameter of the drill stem. Increasing the drill stem diameter increases the diameter of gravel it will drill.

The Crawford System is the only system available that will drill large diameter wells by hand below the water table. For example, one may drill below the water table with the 4-inch PVC drill stem using a 12- or 14-inch diameter bit in a single pass. No other drill can do that. When compared to jetting or direct circulation drilling, the reverse flow hand drilling process is the only process that will not ruin the aquifer. In direct circulation and jetting, the drilling fluid is forced into the aquifer under high pressure where the thixotropic clays stop up the aquifer and over time, ruin the well and aquifer.



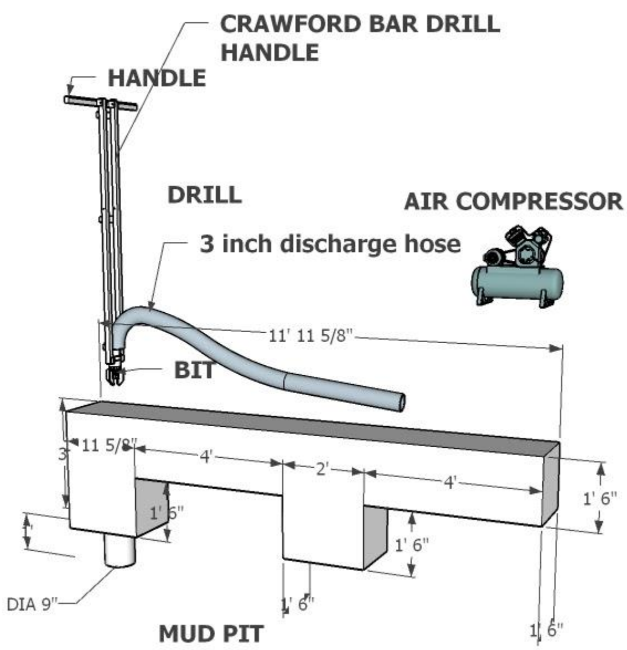

With the Crawford Bar System, the fluid at the bit is under negative pressure. Fluid pressure is decreased in the bottom of the borehole rather than increased as compared to other systems.

And cost is a major concern when choosing to drill by the hand drilling method. When compared to the capabilities of all other hand drilling methods, the Crawford Bar drilling method is by far the least costly method while at the same time it is the most efficient and fastest method of drilling below the water table. The main components of the drilling system are the drilling bar, drill stem, bit, air compressor and the mud pit. Those are the main components that are needed. To handle the drill stem, one can use the Crawford Wire Rope Pipe Wrench and Fork. Those are the only tools needed other than simple hand tools. The Crawford System is the least expensive method of drilling boreholes below the water table in order to hand drill water wells in developing countries. When drilling in soft rock one may supplement the normal PVC drill stem with a steel drill stem. Doing so allows for

the Crawford System to be used in hand percussion drilling using a tripod and pulley system with air lift reverse flow removal of cuttings. This method is superior to any other method of percussion hand drilling of water wells. When drilling below the water table it is the cheapest method of drilling and the only method that does not ruin the aquifer. It is also a method that can be built in any developing nation by local artisans.
Visit our web page at www.onemillionwells.info for more information.

# THE CRAWFORD BAR DRILL HANDLE

This is a brief description of the handle and its use. Construction of each element of the Crawford Bar and tools follows this introduction.




The key to using the Crawford Method of drilling reverse flow water wells and boreholes is to use the Crawford Bar Drill Handle. To drill with the handle, one attaches a drill bit to the bottom of the handle and attaches an air hose to the fitting on the bit and the air compressor. Then they fill the mud pit with drilling fluid. Next, one inserts the handle and bit into the starter hole at the bottom of the mud pit that is filled with water or drilling fluid. Once the setup is ready, a person may activate the air compressor in preparation to begin drilling. Once the air begins to flow into the bit and up the drill stem then the air mixes with the water inside the drill stem. The mixture of air and water inside the drill stem is lighter than the pure water outside the drill bit. Because the water + air inside the bit weighs less, the heavier water outside the drill stem is forced into the bit and drill stem from the bottom of the excavation. This sets up a circulation whereby the water inside the drill stem is continuously mixed with air, becoming lighter, and being moved up the drill stem by the entrance of heavier water entering the bit. Once circulation begins, one must move the handle of the drill a quarter rotation first in one direction and then return to the original position and then another quarter rotation in the opposite direction. This causes the bit that has blades at one quarter of a circle to overlap within the borehole. With weight on the bit the turning back and forth causes the bit to cut the soil at the bottom of the borehole. As the material is cut, the flowing water that is entering the bit and traveling up the drill stem picks up the cuttings and brings them within the drill stem to the surface where they travel down the discharge hose and enter the mud pit. The cuttings within the pit settle to the bottom of the pit where they are later removed. This process continues until the drill reaches full depth to the handle. Then the bit is removed from the Crawford Bar and attached to the first section of drill stem. The first section of drill stem and bit has the air hose attached at the air inlet that is 1 inch from the bottom of the bit. The drill stem is then placed in the borehole and held in place by a drilling fork or other device. The Crawford Bar is then attached to the top of the drill stem. The bit is placed near the bottom of the borehole. The air compressor is activated, and circulation initiated. The Crawford Bar handles are then turned back and forth and that causes the bit to cut and penetrate the earth and cuttings to flow into the mud pit. This drill stem is activated, and the drilling continues until the handles are near the ground.

The bit can remain in the hole and circulating until the borehole is clean and no more cuttings enter the mud pit. This continues by adding additional drill stem until a suitable aquifer is penetrated. Then the air is turned off and the process of removal is initiated.

The handle can be constructed to have one or two vertical tubes. The drawing shows a handle with two vertical bars and the photo shows a handle with a single vertical bar. The single vertical bar drill is segmented and can be shipped on an aircraft as luggage. The mud pit at the bottom has a larger settling pit at the end such that it requires less clean-out than a standard pit. The lower pit also shows the use of a poly liner in the pit. The liner is optional and can line all or part of a mud pit.

The drill stem should be designed for the conditions under which it will operate. In soil and clay and some gravel, the drill stem should be constructed of PVC as it is easily acquired and is easily purchased in most major cities in developing nations. The quality of the PVC must be the highest available and the wall thickness should be at least 5 mm or ¼ inch. Light weight PVC should not be used. The connections should be either pin connected with the holes for the pins placed with a template or the connections should be threaded. Experience has shown that if

high quality PVC threaded couplings are available, then threaded couplings should be used. The handles should be made from light walled steel tubing that is square. The handles can be of any convenient length. I prefer handles that are 7 ft long.

In boreholes that are likely to be shallow and easily constructed, I find that 12 ft. long handles are satisfactory.
When drilling, my preference is to use a threaded drill stem that is constructed of PVC. I have the most success when the joints are lubricated with a light grease or thread compound. I have found that cooking grease is sufficient as a lubricant. Vegetable oil is of some use as a lubricant if it is available.

When drilling, the Crawford Handle uses both percussion and rotation for nearly all materials when PVC drill stem is used. When drilling soft rock, additional weight is sometimes needed on the bit. When additional weight is needed, I usually prefer to add it at the bottom of the drill stem by using a steel pipe drill stem attached directly to the bit. I have found that a short 5- or 10-foot section of drill stem can be used in most situations, however in some cases it is best to have solid steel all the way through. In those cases, the bit should be designed to use a small diameter drill stem that can break up the soft rock and move it inside the drill stem. Sometimes one must use a bit with a restricted entrance.

Remember that in nearly all cases the borehole you drill for your well will be in a location where the composition of the soil is entirely unknown. A driller should have on hand or within a reasonable distance, the ability to alter tool choice and method.
In addition to difficulty of the formation one must drill through, there are other problems that arise while drilling. While some of them are simple to resolve, others require considerable expense. For example, one may find that the required weight on the bit needs to increase dramatically in some soft rock. In weathered volcanic tuff, the drill stem may need to be solid steel pipe all the way to the aquifer. In that case one needs either a large crew that can lift the drill, or a lifting tool such as a tripod and pulley system or a pump jack system with a handle and lever. In those cases, one has the choice of
either drilling in a better location or tooling up with a tripod plus heavy drill stem and remaining in the same location.
Persons paying for water points can choose the location where they will drill.
Strong consideration should be given to locating water points in areas where there is sufficient certainty that one can drill a well/water point successfully in less than 3 days. In the early initiation of the introduction of this drilling system, it should be used in the areas where it is most efficient such that it serves the most people with water. For example, if one can drill in a location where the depth to water is less than 75 ft, then they can serve the most people with the least amount of money. And when one considers that using current tools and philosophy for locating water there has been abject failure to supply the most people - at the lowest cost- with suitable water, then we see the importance of using this tool in its most efficient manner. Currently used methods of drilling have simply failed. It has become clear that it is not only the drilling of wells

that needs to change but the location of wells that also needs to change. I strongly encourage the use of a local hydrologist to locate all water points. Accurate records should be kept in a local database and available to all who require information as to where water may be most efficiently obtained. The Crawford Bar drilling tool is the most efficient tool that produces the highest quality well and therefore should be used to its best advantage. There has never been a tool available that could resolve the water crisis, however if this tool is used in the correct locations then it has the ability to resolve the water crisis that no other tool has been able to resolve. The key to resolution of the water crisis is to drill in the “right places” with the “right tools”. Most of the time the “right tool” when drilling by hand or small powered drilling rig is the reverse flow system like used by the Crawford Bar and the Crawford Reverse Flow trailer mounted rig.

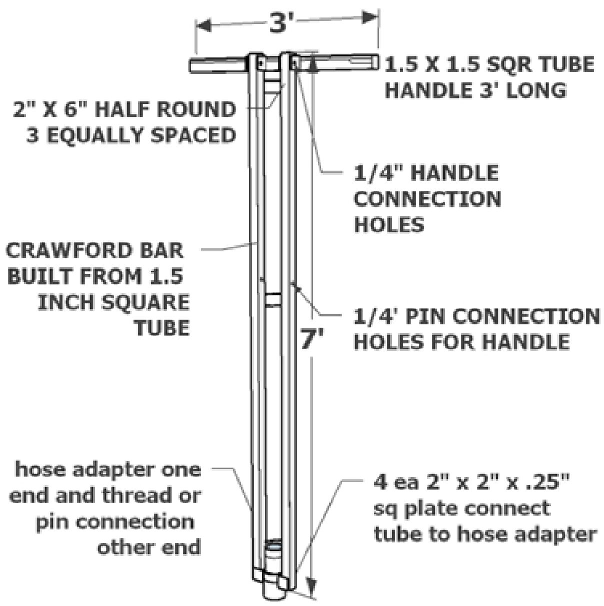
# Building the Crawford Bar and Components

The components that make up the Crawford Bar and drilling components are:

1. The Crawford Bar with integral coupling
2. The drill bit
3. The handle
4. The air compressor
5. The air hose and connectors
6. The discharge hose and attachments
7. The Crawford Wire Rope Fork
8. The Crawford Wire Rope wrench
9. And hand tools

Following are drawings and instructions about the building and use of the tools.

**The Crawford Bar** is shown in photos and drawings that do not contain exact measurements but instead show the relative positions of the components. Any measurements or the call out of any specification is for illustration only. Other sizes and materials that maintain the function of the tools and equipment is acceptable. The distribution of this document is worldwide, therefore including exact measurements when in fact the materials in different countries are not identical from nation to nation is not feasible. Because there are no universal units of measurement or quality specification there is no way to specify exactly the required materials.



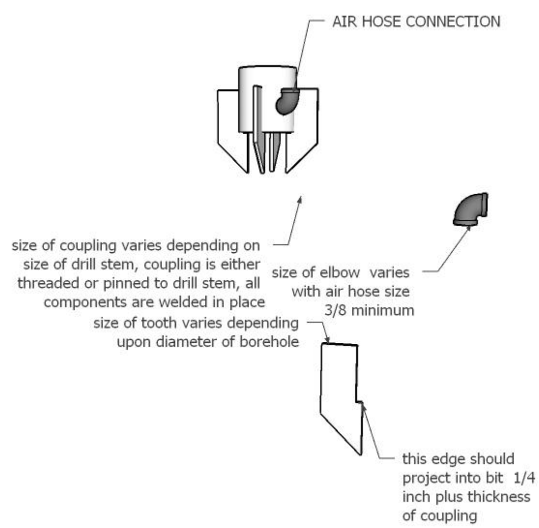

The Crawford Bar is a welded frame drilling bar with an adjustable pin attached handle and a removable hose. The bar is built with either a single or double vertical welded steel frame that forms a protective channel that is attached to a single hose adapter that is either threaded or pinned to a drill bit and discharge hose. At the top of the bar is attached a handle that has attachment arms with holes that fit matching holes in the vertical frame. The attachment holes are in the vertical steel tubes that make up the frame and are spaced about 3 feet apart or at a distance that is comfortable for the drilling crew. The frame and the detachable handle are welded steel that is light in weight. The strength of the handles is proportional to the strength of the tubing from which it is made, and the strength of the half round braces. The weight of the Crawford Bar is an important consideration in its use in a specific location. In areas of hard drilling the bar should be built with material that is heavier than that used in areas of easier drilling. At a minimum the strength of the tubing should be heavy enough to allow welding with an electric welder. The minimum metal gage for the tubing could be 12 gauge to ensure that proper welding can occur. The wings that attach the handle to the tubing should be heavy enough to minimize the load on the ¼ inch pin that attaches the two parts. The suggested size is 2 inches square by ¼ inch thick. At the bottom of the tubing, on the opposite end of the handle attachment, is the adapter between the discharge hose and drill stem. This adaptor

should be strong enough to withstand the impact loads and torque imparted by use of the drill as intended. The attachment plates from the two tubing bars should be 2-inch square plates at least 3/16 inch thick. The hose adapter to drill stem connection may be either threaded or pin connected. The adapter should be heavy enough to be welded to both the attachment plates as shown in the drawing and the hose adapter.

# Drill Bits

There are a great number of borehole drilling designs that are specific to different drilling conditions. In most of the areas where this drilling system is designed to operate, a multifunctional drill bit is the best. For an initial bit that is simple to fabricate, a simple design with an open throat and straight cutting blades is best. If you are a beginner with reverse flow, then I suggest that you use the design below.

The first photo is of a bit designed to drill primarily in areas with large amounts of clay. It makes good penetration and will bring up “cores” of clay which means you do not have to cut and pulverize most of the material you drill through. The key to building the bit is to have the exterior blades extend at least 1.5 inches from the inlet housing and to have the interior of the inlet to be cut allowing for a path for circulation of water with cutting the core. The bit should protrude at least ¼ of an inch to the interior and up to ½ inch. It is best to leave as much uncut area as is possible so that should you encounter gravel or cemented clay, it can pass through the middle of the bit and up the drill stem into the pit. The intent of the design is to allow for the flow of water around the core and have enough room for the cuttings from the bit to pass by the core.




In the drawing on the right, the bit is built directly on a coupling and the air inlet is welded directly to the coupling. The teeth of the bit protrude a little over a ¼ inch into the inlet of the portion of the bit that attaches to the drill stem. In most instances the bit can protrude even more, however, the more it protrudes the less room there is should the bit need to pass gravel or broken laterite.

In the bits below the intent of the design is to drill small amounts of clay and to primarily drill unconsolidated sand, silt and gravel. The designs allow for the breaking up of the materials and keep the mouth of the bit open as much as possible such that large gravel may pass into the drill and be removed from the borehole. On one or two teeth, it is helpful to have a protrusion that is removable such that if a small amount of clay is encountered, the protrusion will break it up and keep if from plugging the inlet of the bit with solid clay. If the protrusion is not needed it may be easily removed.

## Discharge Hose

The discharge hose is sized to fit the mud pit and bit. Normally the mud pit will be 12 to 15 feet long in order to have enough capacity to furnish water and store the spoil from the drilling process. The hose is normally constructed out of water pump suction hose and has been

available in every country where I have worked. Sometimes it must be imported from a major city within a country. If one is drilling with a certain diameter drill stem, then the discharge hose should be the same interior diameter as the drill stem. The ideal situation is to connect the discharge hose with a connector that is the same size as

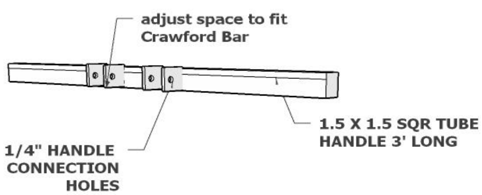
the outside diameter as the drill stem to hose adaptor section of the steel handle. The photo at the left shows the use of a “Fernco” rubber outside coupling that connects the outside diameter of the hose to the outside of a 3-inch steel pipe and the outside of the discharge hose. One could also use a PVC coupling on the outside of the hose and pipe that is restrained by the U-bolt at the handle. All connections that are made between the hose and the pipe should have a connection as well to the Crawford Bar with a U-bolt to keep the joint from accidently disconnecting. The connection of the discharge hose to the Crawford Bar should be easily removable.

## Stow the Hose

When changing the drill stem or any time the Crawford Bar is withdrawn from the borehole, the hose should be stowed within the gap between the bars that form the bar. It should be placed above the half round brace ash shown in the photo so that is out of the way of those working on joints or attachments.

With the shorter bars, the handle should be removed from the bar before it is out of reach of the workers while changing drill stem or working on the pipe fork. When shipping the bar, one may attach the hose directly to the handles or tie it in place.

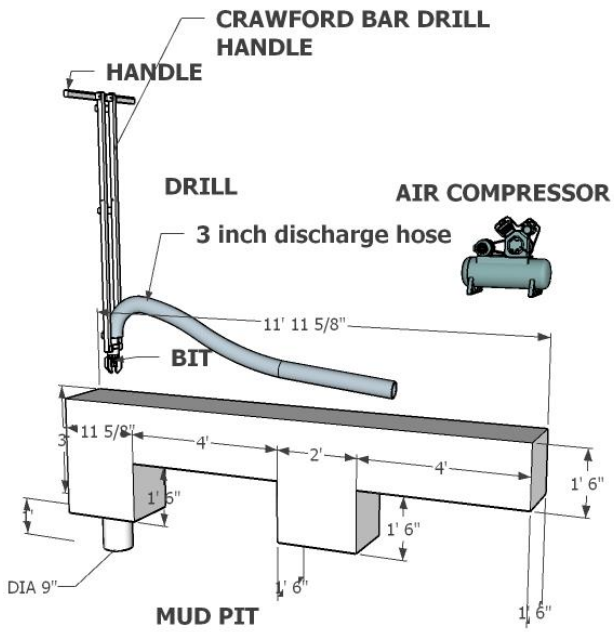
## Handle




The turning handle for the Crawford Bar should be designed to fit the crew and tool it is to service. I suggest that the handle be constructed out of 1.5 x 1.5-inch square tubing and the connecting lugs be 2 inches square. The handle should not be manufactured until the Crawford Bar has been built. Then the handle should be mounted on the bar at the locations where a person intends to use the bar and the holes can then be drilled in perfect alignment. I find it best to pin each connection as I drill through the tubing. That way one is certain that the handle will fit at each point where it is designed to fit. I also suggest that several sets of ¼ inch pins be purchased and shipped with the bar. It is common for drillers to have wet muddy hands while removing and replacing the pins. Therefore, it is not uncommon to drop a pin down the well or into the mud pit. So spare pins are a necessity.

## Site set-up

Setting up the site with all the equipment needed should be done with considerable planning. The location of the mud pit, air compressor, tools and drill stem is very important. For example, the air compressor should be located in a place where the noise and heat from the compressor will not cause discomfort for the drillers. The compressor should also be on flat and hard soil. Loose soil will allow the compressor to sink and possibly turn over as the compressor vibrates.




Consideration should be made to the location of the air compressor as it relates to the anticipated depth of the borehole and the length of the air hose. If the borehole is to be about 75 ft. deep and the hose is 100 ft then the compressor should be within 15 ft. of the borehole so that there is plenty of hose to spare when laying the Crawford Bar on the ground away from the mud pit. If the depth of the borehole is unknown, then spare hose should be on hand in case it is needed.

The mud pit should be at least 1’6” deep and should be 1’6” wide. There should be at least one settling pit that is an additional 1’6” square. If the borehole is to be deep or of a large diameter it is wise to add another settlement pit at the end of the mud pit. I have found that the minimum starting hole depth should be 4 ft. deep and at least 9 inches in diameter to accommodate the hose and Crawford Bar. If there is an auger or post hole digger available, it is best to drill as deep as you can with the starter hole. If the starter hole is to be dug with small hand tools, then it should be done as shown in the drawing above. The hole should be hand dug to the size in the drawing so that a worker can perch within the bottom of the pit and dig the 9-inch starter hole at the bottom. The starter hole should be at least 1 ft. deep. The deeper the starter hole is, the easier it will be to make fast progress drilling. Keep in mind that the slowest drilling is at shallow depth. Hand digging as deep as is reasonable is suggested. It should also be remembered that when starting the borehole, higher discharge out of the hose is achieved by lifting and dropping the Crawford Bar since it greatly increases the flow out of the hose.

## Air Compressors

The sizing of air compressors is especially important. Most commercial compressors are vague as to the actual volume of air that they will produce. For that reason, purchasing a compressor is a risky proposition. I find that a compressor that is manufactured by a known trade name is the least risky to purchase. I try to find a compressor that has a quality rating by users online. If that is not available, then I ask local people what compressor they recommend. For a 2-inch drill stem I suggest a 3 to 4 CFM compressor. For a 3 inch I suggest a 7 to 8 CFM compressor. For a 4-inch drill stem I suggest a 12 to 14 CFM compressor. A larger compressor is not always a good thing. For example, if a person rents a 100 CFM compressor, it will not work well with a 2- or 3-inch drill stem. The compressor will produce more air than water, and it is the mass of the water and change of pressure within the drill stem that causes the circulation. So, having too much air is not good.

## Closing

These instructions should enable a person to construct a working model of the Crawford Bar and to use it to drill a well in any location where the tool is appropriate. I am also linking to my OneDrive file that has several videos and photos that can also help in understanding and using the tool. https://1drv.ms/f/s!AglCyzMf1rkIgaVphWaMDUpGNzSaOQ

There will are rough 3D drawings that are available. Please contact me at rccrawford@swbell.net if you need more information. I also have a great number of videos online in YouTube and at www.onemillionwells.info .

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# Troubleshooting

There are many other instances where drilling can be difficult, these are the problems that must be resolved and the suggested method of resolution:

1. If there is hard clay, sand, or soft rock there are several resolutions. We suggest that first one should use a hard-faced drill bit with drilling wings at least ⅜ inches thick and the teeth should be sharpened. The bit should be attached to the drill stem with a stiff steel coupling. The drill stem should be lifted more than a meter off the bottom of the borehole and dropped sharply forcing the teeth of the bit to hammer into the formation, breaking it by impact. Once each impact is completed, the drill stem should be turned to the area between the impact zone of the first blow and lifted and dropped into that location just as in the first drop. When the area under the bit is crushed sufficiently, the drill stem should be turned a half turn in each direction to “sweep” the cuttings into the drill bit and remove them from the excavation. This can be a slow process and penetration rates can be as low as an inch an hour. In many instances a person will start off in soft rock and the rock will increasingly become more difficult to drill. If it is anticipated that such conditions will be encountered, it is advised to add at least 5 feet of steel drill stem on the bottom of the handle and have a steel to steel connection between the bit and drill stem as soon as possible. If difficulty continues then one must choose to continue at a slow rate or increase the weight on the bit and the complexity of drilling. We have been in several situations where we needed to use a tripod or pump jack lever set up to drill. In some

soft or medium rocks, one cannot even drill by hand. Keep in mind that if there is some progress, and there is proof of water in the location, it is well worth the time it takes for difficult drilling and expense. However, the cost of furnishing water to only a few people at great expense can lead to a lack of having the capacity to furnish several wells for the cost of the single well you are drilling. Be wise and you can save the most life for the least money.

2. If there is sticky clay that is difficult to drill, and it has not been anticipated then one must judge whether it is better to shut down and re-tool or to continue drilling. My suggestion is to continue drilling using the methods explained here if some progress is made, and drilling is at least at the rate of 2 ft. an hour. If while one is drilling, they encounter low flow out of the discharge pipe, it is a sign that the bit is becoming obstructed by soft clay. Sometimes all one needs to do is to hold back on the handle taking weight off the bit and continue drilling. The rocking motion of the bit will sometimes un-lodge the stuck clay. If that does not work, the next thing to do is to lighten the load on the bit --- including not lifting the drill off the bottom and dropping it to impact the clay. If the clay has already stuck to the bit and wings of the bit, then one may try lifting the bit with a jerking motion while turning it in a reverse direction. It should then be allowed to fall back down without letting it hit the bottom of the borehole. Try that several times. Then hold the bit off the bottom of the excavation and turn the air off. Let pressure build up in the tank until the tank is completely full under high pressure. Then turn the air on, while lifting and lowering the drill stem. This will often un-lodge the blockage. If this does not work then one may try changing bit design, using additives in the drilling fluid, or simply taking the extra time to remove bit, clean it and replace it in the borehole. Usually if there are only a small number of wells in the sticky clay, it is best to just keep drilling and move though the soft clay at a slow rate. In such a case the drilling conditions should be noted clearly and used to plan for the next borehole in the same area.
3. There are other causes for low drilling fluid discharge from the hose. Most importantly, every borehole drilled will have low discharge when the depth of the borehole is shallow. In such situations it is suggested that the percussion method be used in all shallow drilling and when the discharge from the hose is low. The correct method is to lift the drill off the bottom of the borehole at least 1 meter and drop it to the bottom of the borehole letting it softly impact the bottom. Do not jam the bit into the bottom unless the drilling is difficult, and the bottom is hard. When one lifts the bit, it allows the borehole to fill with an equal volume of the bit and discharge, and then when it drops it must displace that volume. To displace the volume, the drilling fluid must flow up the drill stem and mix with the air that is injected. The reason it moves in that direction is because the fluid going down the borehole has velocity under the force of gravity, whereas the fluid going up the drill stem is already moving against the force of gravity. The least resistance to flow is to travel up the drill stem. As a result, the flow increases dramatically up the drill stem and out the discharger hose. This action should be the first action taken when the discharge of the hose appears to slow. The higher the drill stem is moved up the borehole, the faster the discharge will be into the mud pit.
4. Another cause of low discharge velocity from the hose is found in the nature of the material being drilled. If one is drilling through some shales or clays, then some of those materials are naturally expansive when in contact with water. Some clays can expand to nearly twice their normal volume. In those clays, as the bit moves through the clay it is exposed to water. Once the bit is past the expansive clay, it swells, and the swollen material tends to block the flow to the drill stem. With some shales the materials can swell or simply break apart once exposed to water. In that case the shale can collapse against the drill stem to block flow or it may come off in chunks that are too large to pass within the borehole. If one encounters either of these conditions, one must “re-drill” the

area where the clay swells or the shale collapses. I usually note where clay or shale are encountered while drilling. Then I can raise the bit to that elevation in the borehole and re-drill the borehole maintaining the flow until the circulation is maintained. Sometimes all one needs to do is continue drilling until they hit a solid formation and the velocity of the water through the borehole will erode the sidewalls thus making more room for water circulation.

5. Another common cause of low discharge is simply that the air hose has become kinked or the valve on the compressor is not open sufficiently.
6. Also, low flow can be caused by insufficient pressure in the air tank. One psi of air pressure will displace 2.13 feet of water in a borehole. So, when a person is drilling 100 ft. deep it requires at least 100 ft of water divided by 2.31 psi or 43 pounds of pressure to force the air below the water. So if the flow is low one can check the air pressure gage and tell if there is enough pressure simply by dividing the depth of the drill bit below the fluid in the mud pit and tell if there is enough air being delivered to the bit. As a rule of thumb, the deeper an air lift reverse flow drill penetrates the earth, the greater is its efficiency. So, if you are getting low flow and the air pressure is high enough for the depth you are drilling it usually means that the bit is stopped, clay has expanded in the borehole or shale has caved. If you are drilling below 250 ft deep, then sometimes it is good to move the air discharge up the drill stem instead of having it discharge at the bit. One may also choose to use a compressor that is capable of pumping air at a higher pressure. To drill 300 ft deep, one must have a pressure of 130 psi.
7. Another possible cause of low discharge is found when using too small of an air hose. If the air hose is less than 3/8 inches in diameter and the length of the hose is long, the hose may restrict the air as it moves through the hose. I suggest that one should always use at least a ⅜ hose made of light plastic materials. The use of a heavy rubber hose can cause the hose to sink in the borehole under its own weight. I normally look for the lightest weight hose that is usually constructed of PVC or some other plastic. The lighter hoses will usually have at least a neutral buoyancy. Some will even float in the drill fluid. Floating is the preference.
8. Another common problem is found in the tendency of the airline to become blocked with sand at the bit and hence restrict the flow of air from the bottom of the drill stem. This usually occurs when the air is shut off at the compressor during the addition of the drill stem. For example, one may drill down, shut off the air, disconnect the Crawford Drill Handle and add a new drill stem. Sometimes when the air is turned on after the change, the air hose at the bit is clogged with sand or silt and will not let the air circulate. That is usually an easy problem to solve. Almost every incident like this stopping of flow can be resolved by drilling as deep as possible with the handles of the drill and then lifting the drill stem off the bottom before turning off the air. One should not disconnect the air hose allowing water to enter the hose. Instead keep the air hose full of air and off the bottom of the excavation where the sand is located. Using a backflow valve at the bit usually causes as many problems as it saves. So that is not as efficient as simply keeping the air hose up and out of the sand.
9. Slow drilling and hard turning of the drill stem can occur. The usual cause of hard turning and slow drilling is using an incorrect method of turning the bit. The bit on the end of the drill stem is constructed of 4 equally spaced wings / teeth that are 90 degrees apart. The hole that is being drilled is round and thus the soil below the bit presents as a circle. Because the bit has four wings at 90 degrees one must turn the bit in such a way that the entire circle at the bottom of the borehole is covered by the turning teeth. At a minimum the handles should be turned 90 degrees to have the teeth cover the entire area of the bottom of the borehole. However, it is best to have the bit turn more than 90 degrees. If one does not turn the bit sufficiently, then a block of soil remains uncut and

when turning the bit beyond the point where the block is located there is great difficulty. I usually suggest that the drillers turn the bit between 100 and 180 degrees so that the teeth cover the most area between the changing of directional rotation. That way the least energy is expended in the changing of rotational direction.

10. Another problem one will encounter is in keeping the hole plumb. A plumb and straight borehole is the best product a driller can provide. In order to keep the borehole straight, one must not advance the hole too quickly, keep the drill stem vertical, drill slowly through obstructions that can "kick" the borehole off plumb and use a heavy and large diameter drill stem when accuracy is more important than speed. For example, if a certain area requires a more accurately placed borehole then precautions should be taken as needed to align the borehole. One may use a rigid steel pipe to drill the borehole all the way to completion or to drill only the top of the borehole. In addition, one should use a level to center and plumb the drill within the mud pit. It is important during the drilling process not to allow the drill to "wave" back and forth while drilling. This can be accomplished by placing one hand on the drill stem holder and the other on the handle while rotating the drill. It is also good to have two persons on the drill at the same time with both having one hand on the drill stem and the other on the drill handle.
11. Another problem is found when one fails to maintain enough water in the mud pit. The standard pit holds about 300 gallons of water or about 1135 liters of water if completely full. Normally one would expect for the pit to have about half that amount of water. If the water in the pit can fall too low, the material that forms the bottom of the mud pit can erode and enter the borehole. In such a case the flow of the water in the pit would continue to erode the bottom of the pit, and the water would drop within the borehole. The drilling fluid / water in the borehole is what keeps it from collapsing, so if the level in the mud pit drops, the borehole is likely to collapse. if that occurs while the drill in in the borehole, then the drill and bit can be lost while drilling.
12. Another problem that can become serious is the breaking of tools within the borehole. One of the best ways to limit the number of broken tools lost down a borehole is to maintain equipment in a responsible manner and to purchase materials that are of high quality. For example, one should purchase the highest quality PVC pipe available that is within their budget. It is often more expensive to try and save money buying low quality materials than it is buy high quality materials. The materials that are purchased should be inspected frequently for breaks or signs of wear. No matter how meticulous a person is when purchasing and maintaining equipment, at some point one will break a drill stem, bit, or air hose and need to recover it from the bottom of the borehole. The first thing that a person should do is determine how deep the joint, bit or broken piece is below the ground. One should always have on site a fishing tool that is suitable for removing a lost drill stem. Normally one will have at least a hook, spear, or sleeve tool that can be used to engage the lost tool and remove it from the borehole. It is best to have a tool that is light enough that it can be handled by hand. The most useful of the tools for removing casing or drill stem is the spear type of fishing tool. A spear is constructed on a piece of small diameter pipe that will fit within the casing or drill stem. It has at least 3 prongs that are welded to the tube and are sharply pointed on the ends. I normally use 3 pieces of rebar that is ¼ to ⅜ inches in diameter and 4 inches long. They are placed equally around the pipe and welded to the pipe with about ½ inch long welds. The welded rods are sharpened pin sharp and bent to engage the pipe. After manufacture, the spear is tested by inserting it within a test piece of pipe the same size as the drill stem or casing. When pulling, the rods should engage the pipe and should become tighter as it is pulled harder. Usually the pipe that holds the spear has a coupling to connect to other pipes that serve as the handle for the fishing tool. The points on the rebar are aimed such that they will grab into the PVC pipe when inserted within the interior of the pipe

lost within the borehole. In use the spear is inserted within the borehole to the level of the broken drill stem and then within the drill stem. After inserting the spear, one pulls upwardly until it is locked tight within the pipe. The pipe can then be removed from the borehole. The hook is like the spear, but it has only a single tooth and it is designed to hook onto a coupling, bit wing, tooth or air line to attach to the lost tool. The sleeve is designed to go over the outside of the pipe and have teeth that engage with the outside of the pipe rather than to the inside. 90 percent of the time whatever is lost within the borehole can be recovered using the spear. In some unusual situations, persons have hand dug a well next to a lost drill bit and removed the bit once the hand diggers reach the correct depth.

13. With other systems of drilling, caving of the borehole is a large problem. With reverse flow, caving is rare, but it can still occur. As a rule of thumb in all types of drilling if the static water table is less than 7 ft. below the surface from which one is drilling, there is a high likelihood that caving will be a problem. With air lift reverse flow the normal course of drilling does not require manufactured drilling mud. However, if the water table is high and there is no clay in the borehole, mud can be required. Even then, there is only one way to assure that the borehole will be stable. Build a berm of soil high enough that it is 10 ft above the static water table and then drill from that elevation. The trick is to keep hydrostatic pressure on the sidewall of the borehole. As a last resort one may try to use a thick and heavy bentonite slurry for drilling mud. The heavier the mud the more likely it is to stop the caving.
14. Flowing wells can also cause a problem when drilling through impermeable overburden. With flowing wells, it is often possible to get the well drilled but it is difficult to seal the well and stop the flow such that the well is useful. The best way to control weak flow is to prepare a casing with a threaded adaptor on top connected to the screen and set it as deeply within the borehole as is possible. The screen should then be backfilled with gravel above the slots at least a meter, allowing the water pressure to be relieved through the screen up the casing and out of the well and away from the well. Then a layer of bentonite should be dropped to the bottom of the borehole on the outside of the casing and about a foot thick. After that  a tremie pipe should be placed to the top of the bentonite seal. The pipe should be filled with a mixture of bentonite and cement to the surface of the borehole and the cement should have dowels set in it while the cement is wet. Then while the water pressure in the well is diverted away from the well a thick cement cap 4 ft. square should be placed on top of the cement around the casing. The cement should be allowed to set for at least 48 hours. Then a valve sufficient to sustain the pressure should be attached to the adapter at the top of the casing. The valve can then be closed, and the well will be under control if the pressure in the aquifer is not excessive.