NORAD supported project in MRRD covering
Capacity Building and Institutional Cooperation in the field of Hydrogeology for Faryab Province
Afghanistan

Hydrogeology 1.3
Well Drilling Methods

By Andreas de Jong
September 2013

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TOPICS TO BE COVERED

1. Introduction & Terminology
2. Well Location
3. Well Construction Methods
4. Well Drilling Methods
5. Well Completion & Development
6. Well Decommissioning
7. Cost Benefit Analysis
8. Drilling Management & Data Collection
9. Health & Safety

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PART 1 – Introduction & Terminology

1. Purpose of the course
2. Schedule
3. Definitions & Terminology

Purpose of the Course

1. Introduce participants to the theory of water well construction from considerations of site selection to well completion.
2. Introduce participants to the practical aspects of drilling supervision.
3. Emphasize Health & Safety issues.
4. Hold practical workshops to discuss key drilling issues in Afghanistan & propose possible solutions.
5. This is not a course for drillers.

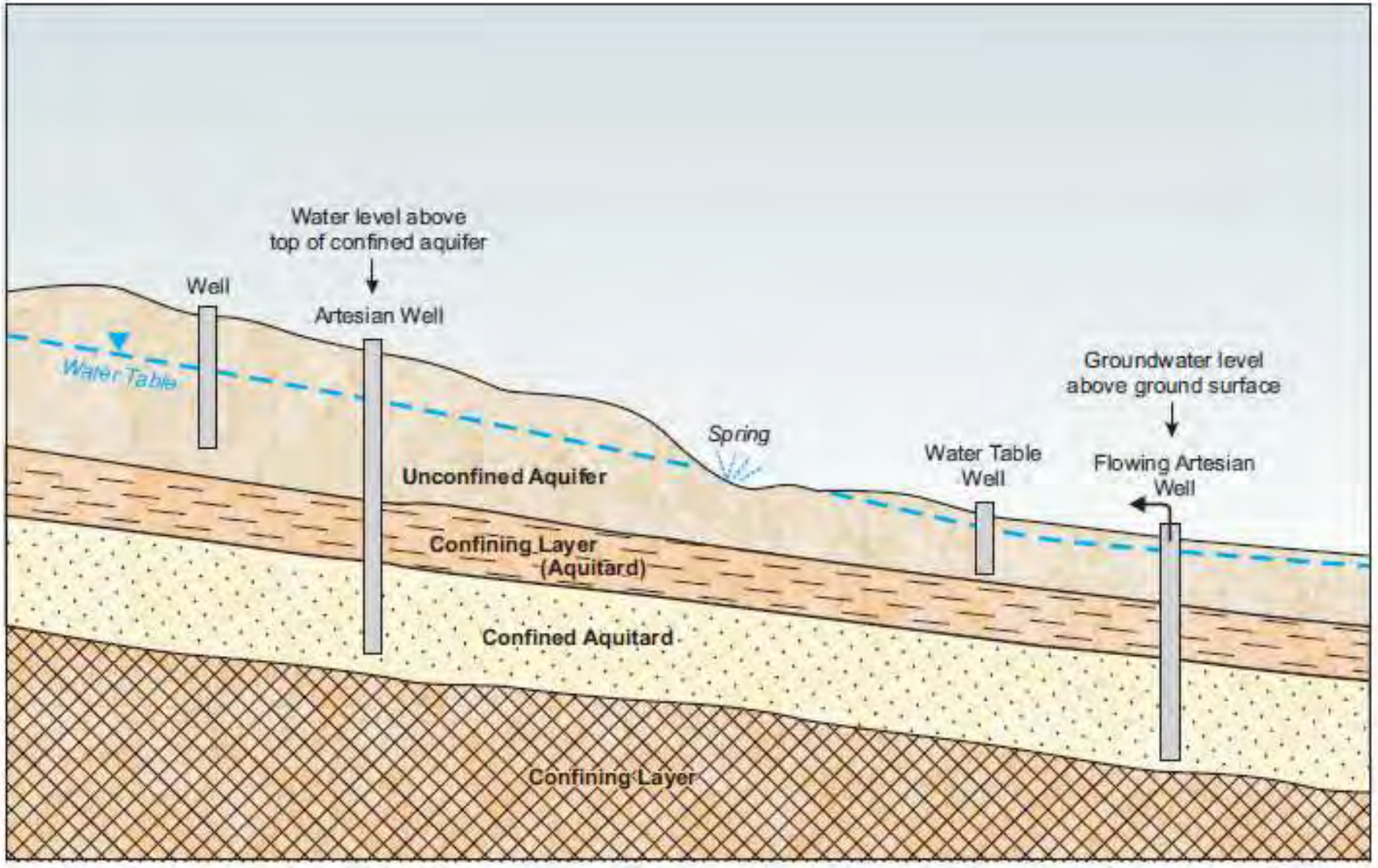
Schedule

Day	Date	Activity
1	Saturday 28/09/13	Opening & Introduction Lecture: Introduction to Well Drilling Methods
		Practical: Preparing for a Drilling Project
2	Sunday 29/09/13	Presentations by key hydrogeologists from MRRD, MEW, DACAAR & NCA on Drilling Issues in Afghanistan
		Practical: Workshop on Afghanistan drilling issues & recommendations for action.
3	Monday 30/09/13	Practical: MEW Laboratory in Wapeca Building, Airport road. Topics: Sieve analysis, core logging.
		Practical: MEW Drilling Center, Topics: Drilling Rig maintenance, spare part management, Health and Safety.
4	Tuesday 01/10/13	Visit to an active drill site within Kabul city.
		Final Course Workshop & Presentation of Certificates

Selected Definitions & Terminology

- **Water well:** Any hole excavated in the ground that can be used to obtain a water supply
- **Borehole:** A borehole drilled for the specific purpose of obtaining information about the subsurface geology or groundwater.
- **Drilled well:** A water well constructed by drilling. Synonyms are tubewell, production well or production borehole.
- **Hand-dug well:** A large-diameter, usually shallow, water well constructed by manual labour. Synonyms are dug well or open well.

Types of Wells – Aquifer Types



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PART 2 – Well Location

1. Water Resources Considerations
2. Water Quality Considerations
3. Other Considerations.

Well Location – Water Quantity

Every well should be located in an area that is:

- Has been studied by a hydrogeologist & is deemed to be able to provide sufficient quantities of good quality groundwater.
- Has been located in the field following a baseline survey of other existing water sources and a geophysical survey where necessary.

Well Location – Water Quality Considerations

Source: S. J. Schneider, 2012; Water Supply Well Guidelines for Use in Developing Countries, Second Edition.

Well Location – Other considerations (1)

Every well should be located in an area that is:

- Reasonably accessible to the beneficiaries if it is also the point of water distribution for individuals.
- Protected from contamination from wild and open-range animals and livestock.

Source: S. J. Schneider, 2012; Water Supply Well Guidelines for Use in Developing Countries, Second Edition.

Well Location – Other considerations (2)

Every well should be located in an area that is:

- Outside of floodplains and areas prone to regular flooding from surface rainwater drainage unless the well has a more extensive annular surface seal and its casing is extended above the highest known flood level.
- Close to power if the well is to be connected to an electric pump.

Source: S. J. Schneider, 2012; Water Supply Well Guidelines for Use in Developing Countries, Second Edition.

Well Location – Other considerations (3)

Every well should be located in an area that is:

- Reasonably available for future servicing of the well.
- Protected from vandalism.

Source: S. J. Schneider, 2012; Water Supply Well Guidelines for Use in Developing Countries, Second Edition.

Well Location Videos

6.1 Drill Safe, Drill Smart ... NGWA Press #V955.mp4

6.3 Well Stewardship July 17,2008.mp4

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Part 3 – Well Construction Method

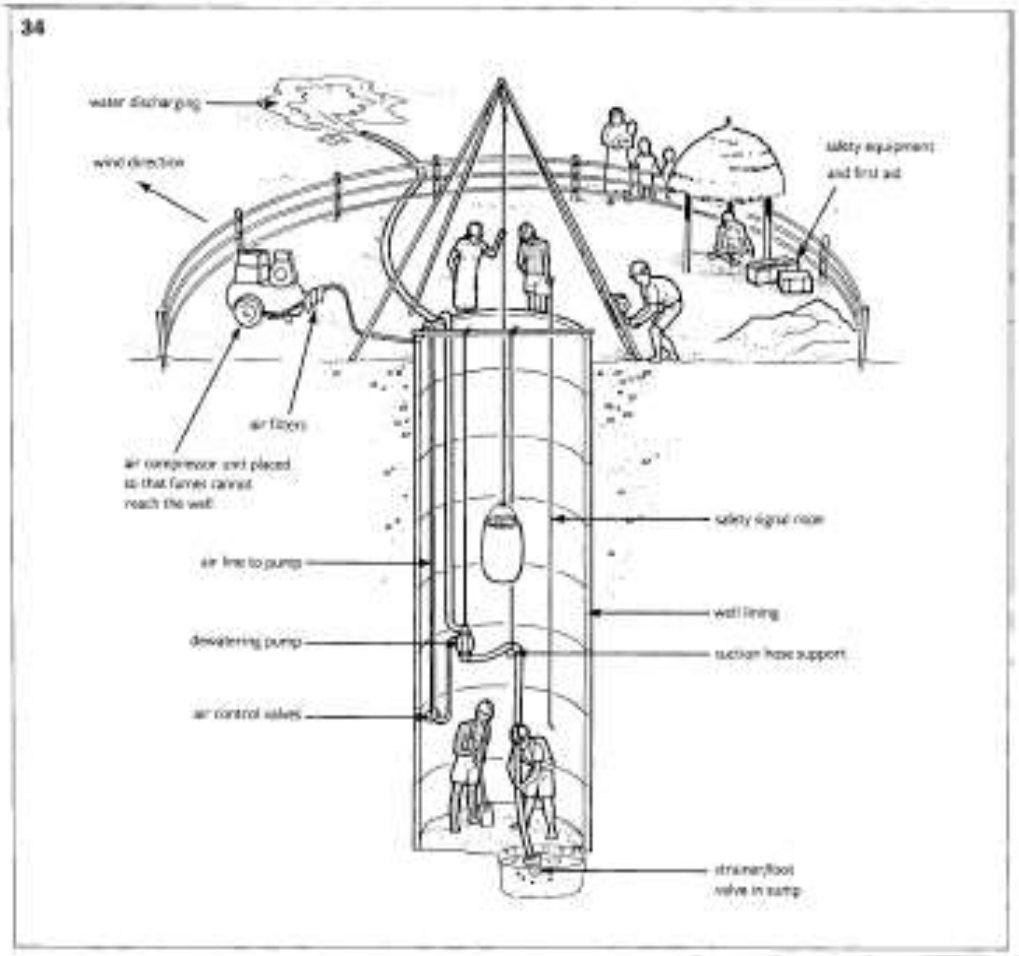
1. Hand dug well
2. Bored well
3. Driven well
4. Jetted well
5. Drilled well

Types of Wells – Hand Dug Well

Excavated by hand using picks shovels, spades or specialised digging equipment.

Source: http://www.redr.org.uk

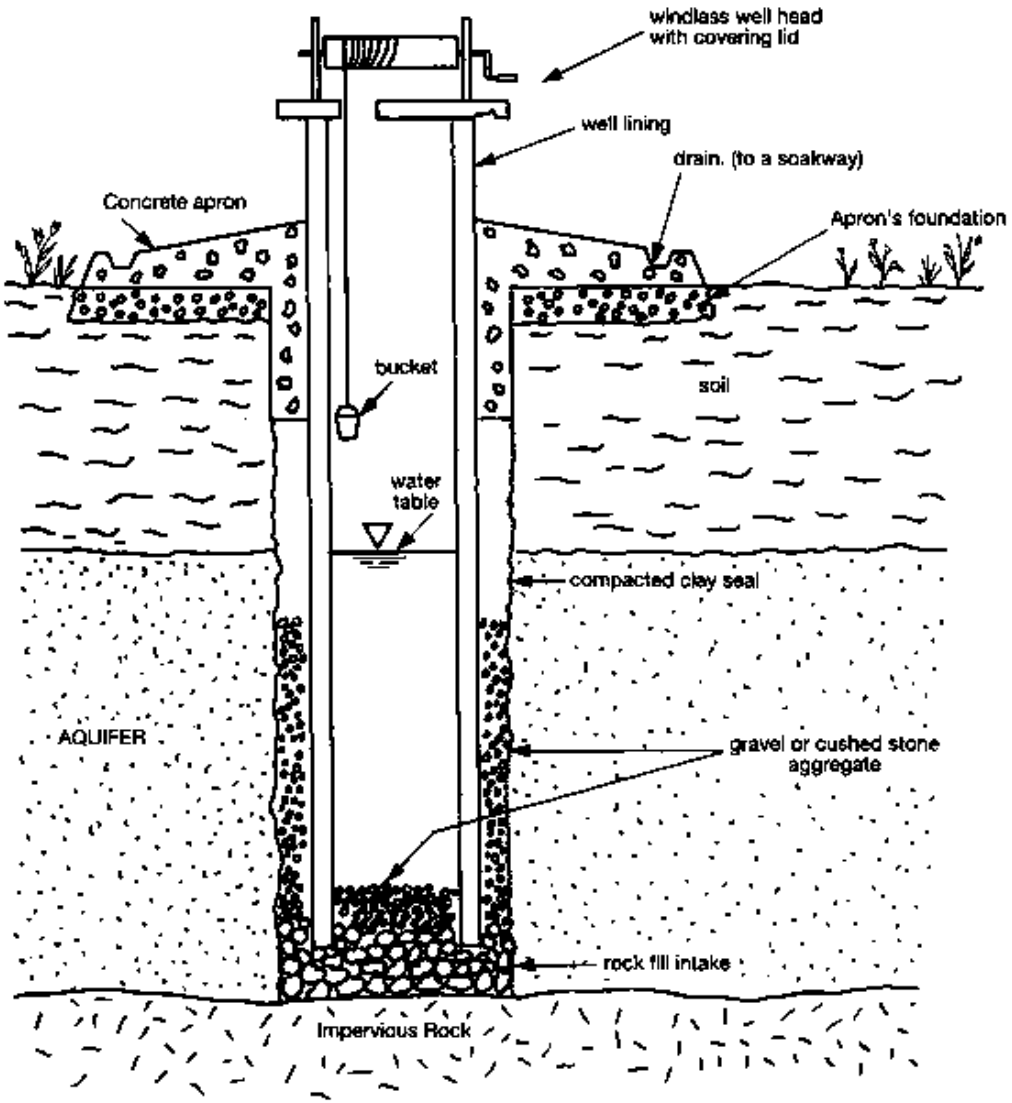
Lining of Hand Dug Wells



From Oxfam Manual on Hand Dug Well Equipment

Source: http://www.redr.org.uk

Lining of Hand Dug Wells



Source: http://helid.digicollection.org/en/d/Junr01/8.6.2.html

Hand Dug Well Completion

Simple open holes,
no protection from contamination

Sanitary surrounds with hand pump

Source: http://www.redr.org.uk

Hand Dug Well – Badris Province, Afghanistan

Source: MEW

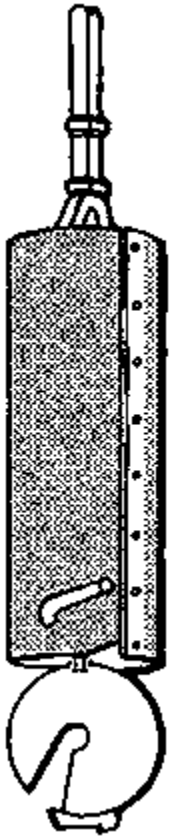
Types of Wells – Bored Well

- Excavated by using hand or power augers.
- Bored wells are usually narrow diameter (< 100mm diam). Constructed as tube wells.

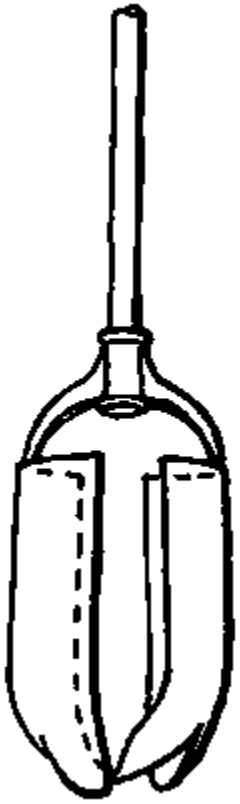



Source: http://www.redr.org.uk

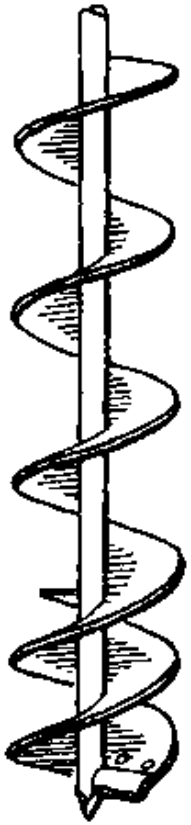
Auger Tools



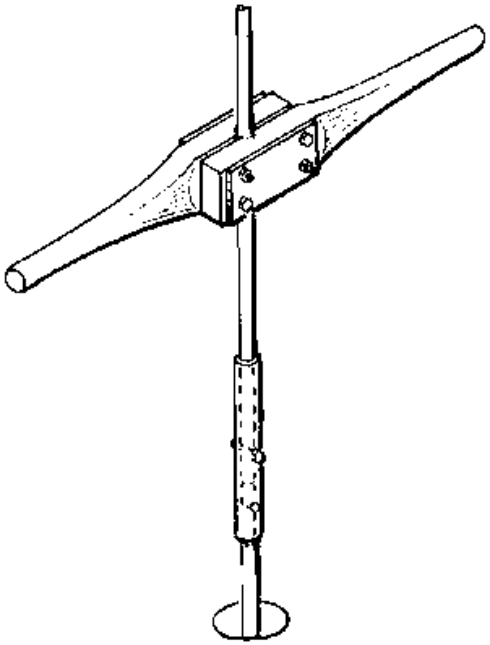
Cylindrical bucket auger



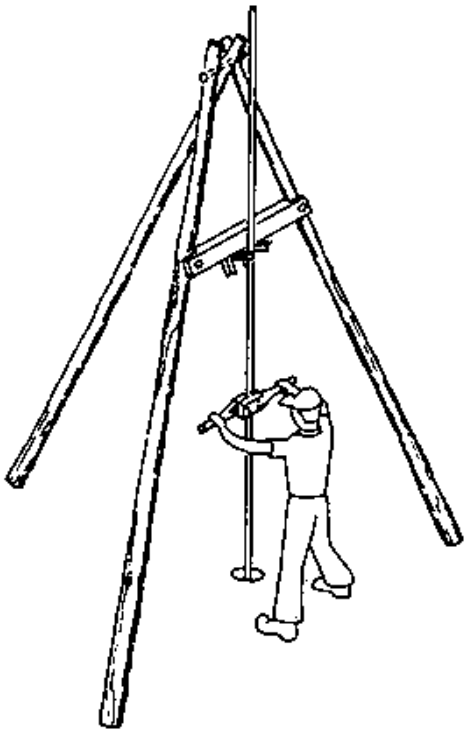
Two-bladed auger



Helical auger



Auger extension and handle



Tripod used to support long auger extensions during drilling

Source: http://www.fao.org/docrep/x5567e/x5567e05.htm

Bored Wells Videos

1.1 Using AMS Augers.mp4

1.2 Affordable Water Well Drilling in Sierra Leone - Fresh Hope .mp4

1.3 Well Drilling Brazil 2009.mp4

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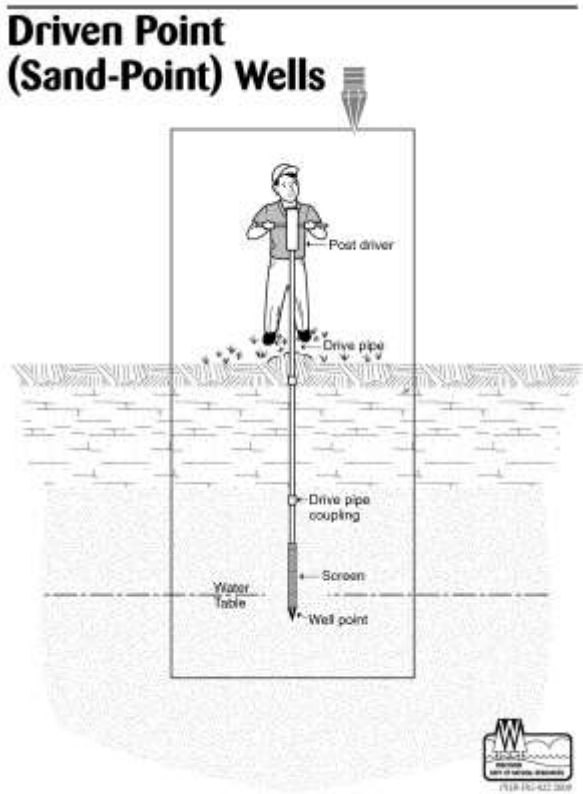
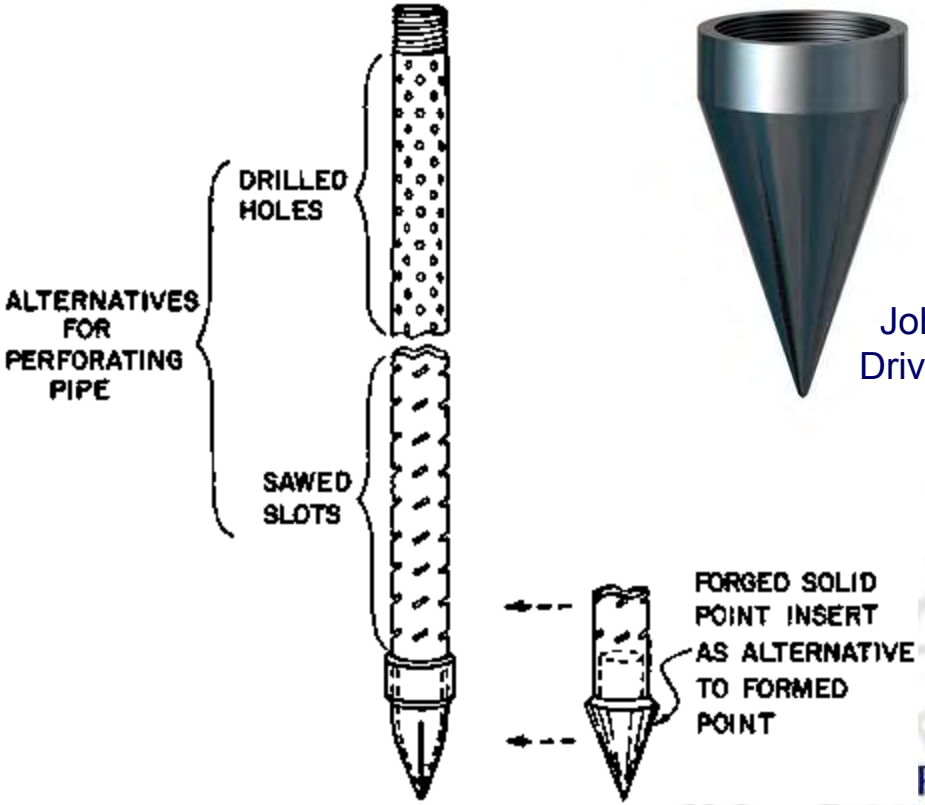
Types of Wells – Driven Well

Driven well: constructed by driving a pointed screen (drive point) into the ground. Casing and screen are attached to the drive point as it is being driven into the ground.

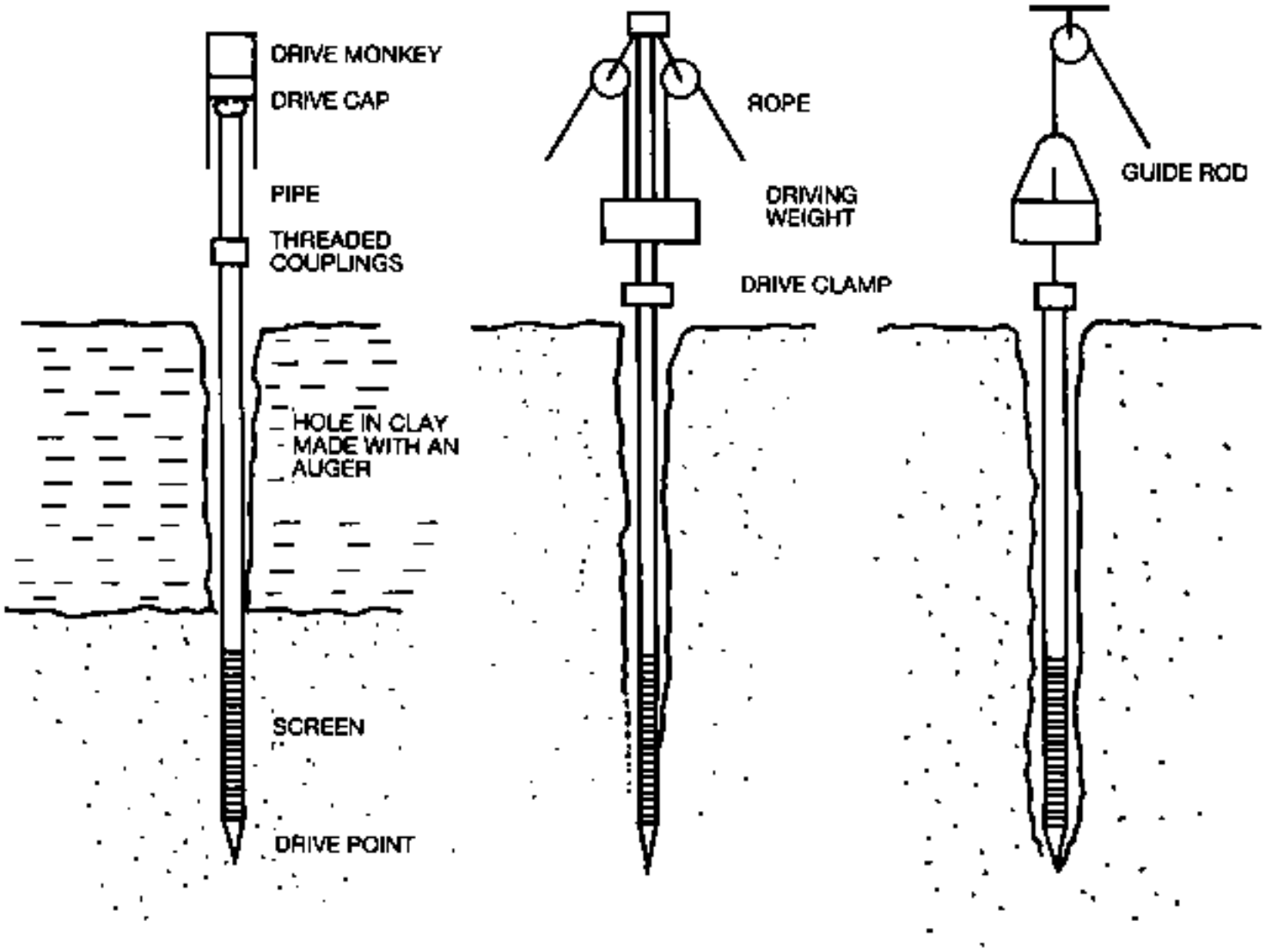




Johnson Drive Point

Source: http://www.fao.org/docrep/x5567e/x5567e05.htm

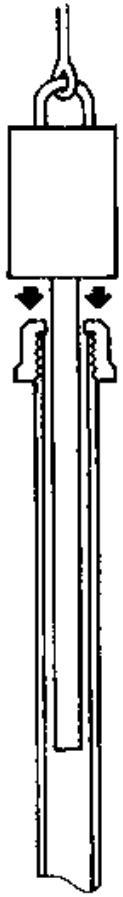
Well Driving Techniques



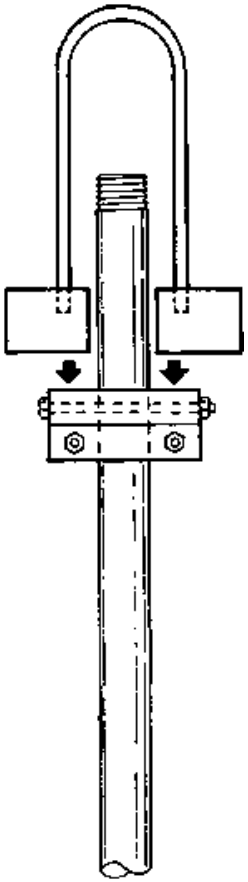
Source: http://helid.digicollection.org/en/d/Junr01/8.6.3.html

Driven Well Tools

Guided on outside of pipe



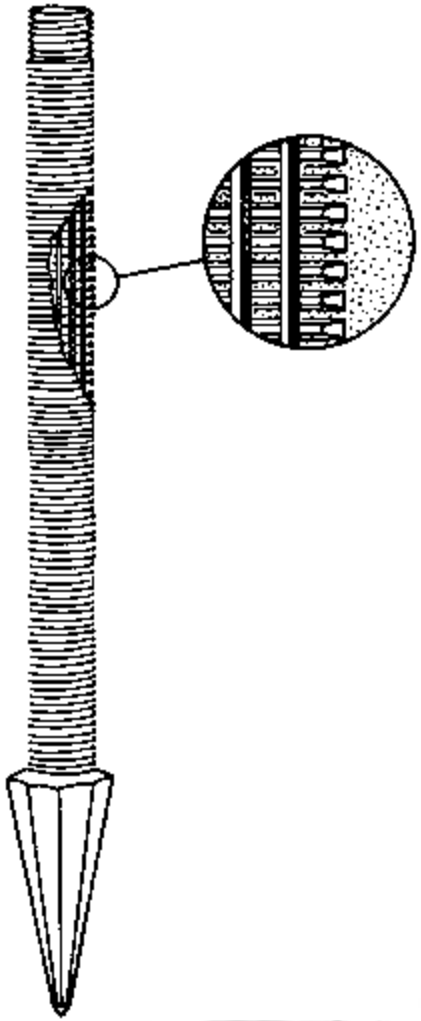
Guided on inside of pipe



Driving on clamp

Driving on inside of point

Perforated pipe with screen



Spiral trapezoidal wire

Source: http://www.fao.org/docrep/x5567e/x5567e05.htm

Driven Wells Videos

2.1 Manual well drilling, WFA method.mp4

2.2 Senegal file-80861575.mp4

2.3 Hand drilled well in Dhaka slums.mp4

2.4 www.waterforallinternational.org Low cost drilling rig..mp4

Types of Wells – Jetted Well

Excavated using a high velocity jet of water.

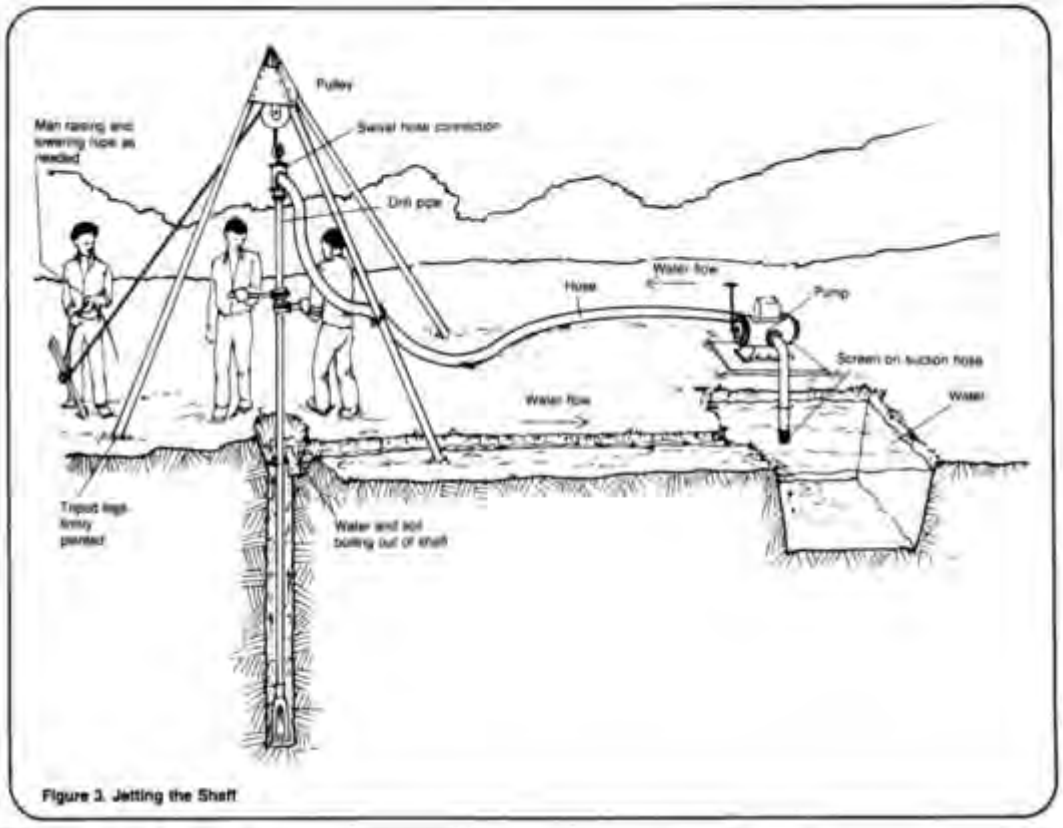


Figure 3. Jetting the Shaft

20m deep jetted well near Vermasse, Timor Leste

Source: http://www.redr.org.uk

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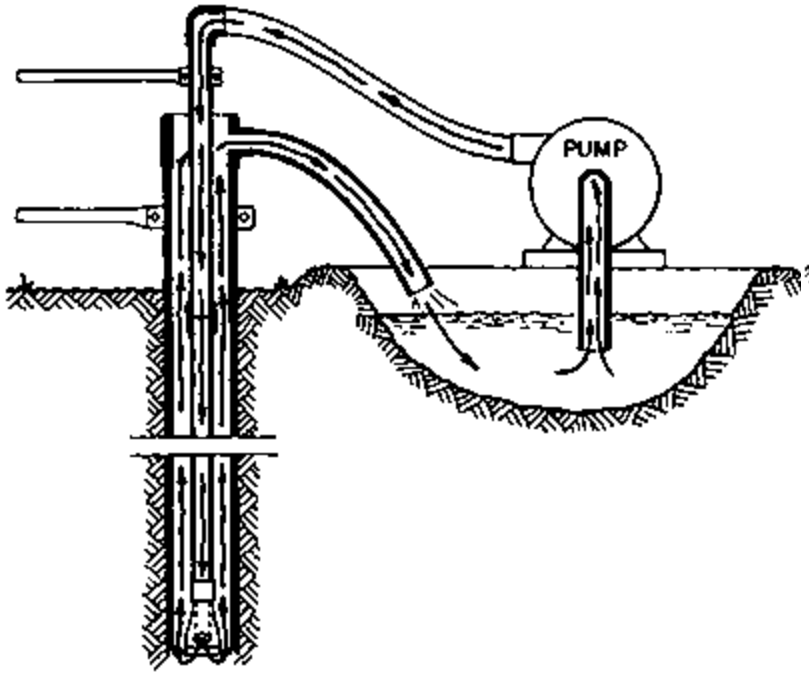
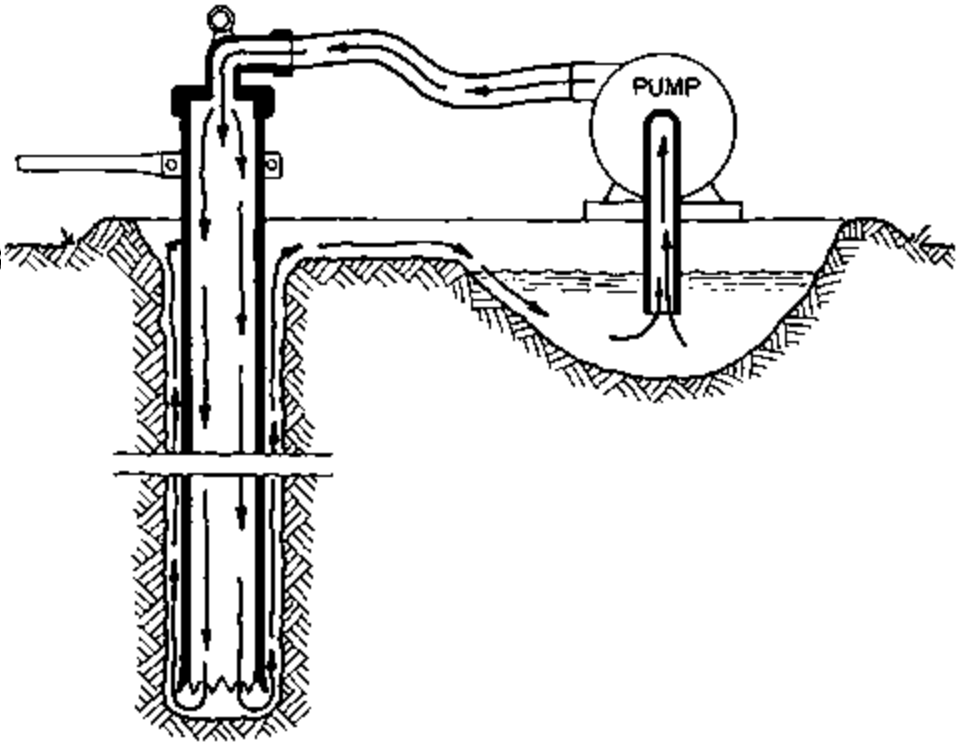
Types of Wells – Jetted Well



Well jetting using jetting tube



Well jetting using jetting in casing

Source: http://www.fao.org/docrep/x5567e/x5567e05.htm

Jetted Wells Videos

3.1 How To Drill A Well In Your Own Backyard_.mp4

3.2 Do It Yourself Well Jetting Part 1 Rig Parts.mp4

3.3 Do It Yourself Well Jetting Rig Part 2 Jetting.mp4

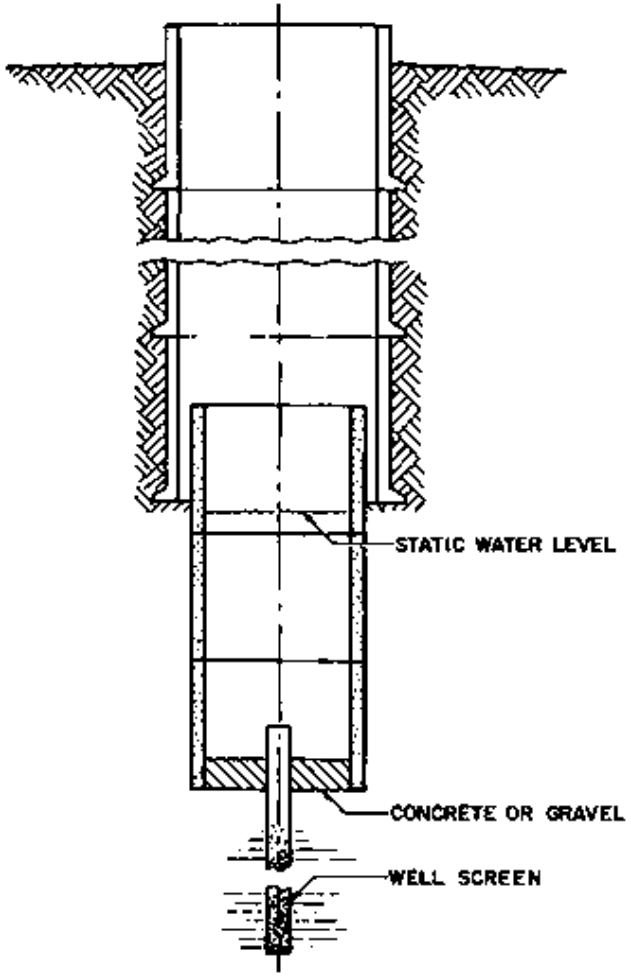
3.4 Do It Yourself Well Jetting Part 3 Well Point Installed.mp4

Types of Wells – Drilled Well

Drilled using percussion or rotary rigs. The excavated material is brought to the surface by means of a bailer, sand pump, suction bucket, hollow drill tool, or hydraulic pressure.

Source: http://www.redr.org.uk

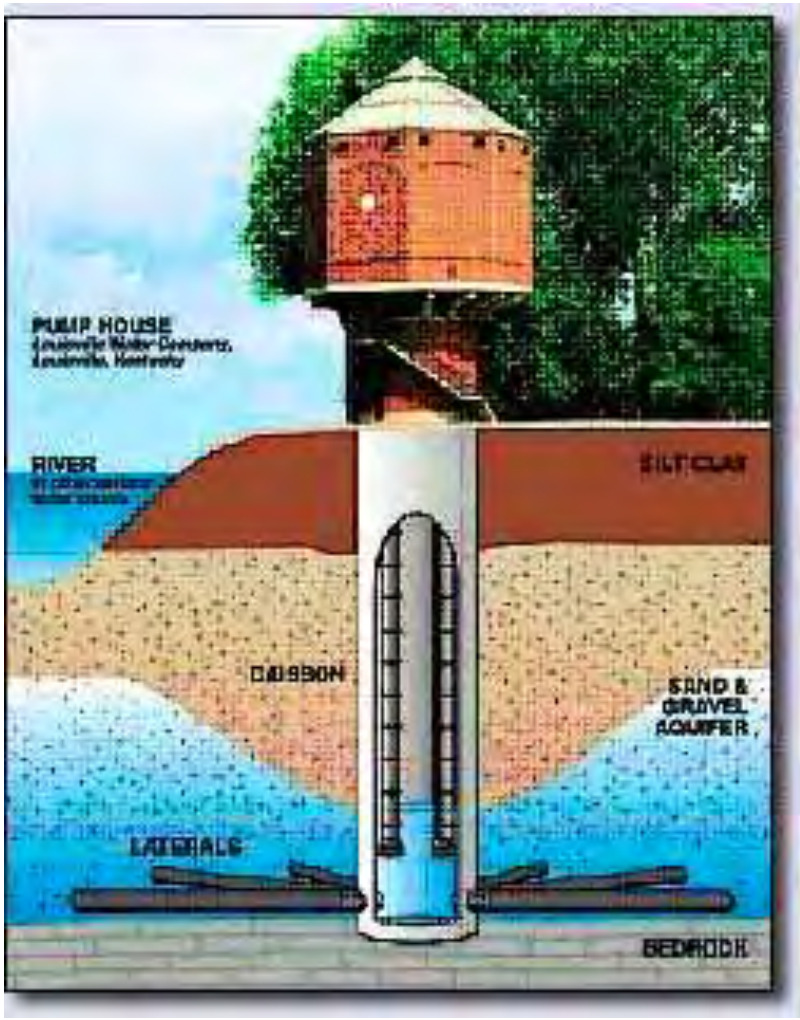
Hybrid Wells – “Well-cum-bore”



Large diameter well
with vertical casing and screen

Source: http://www.fao.org/docrep/x5567e/x5567e05.htm

Hybrid Wells – Ranney Well

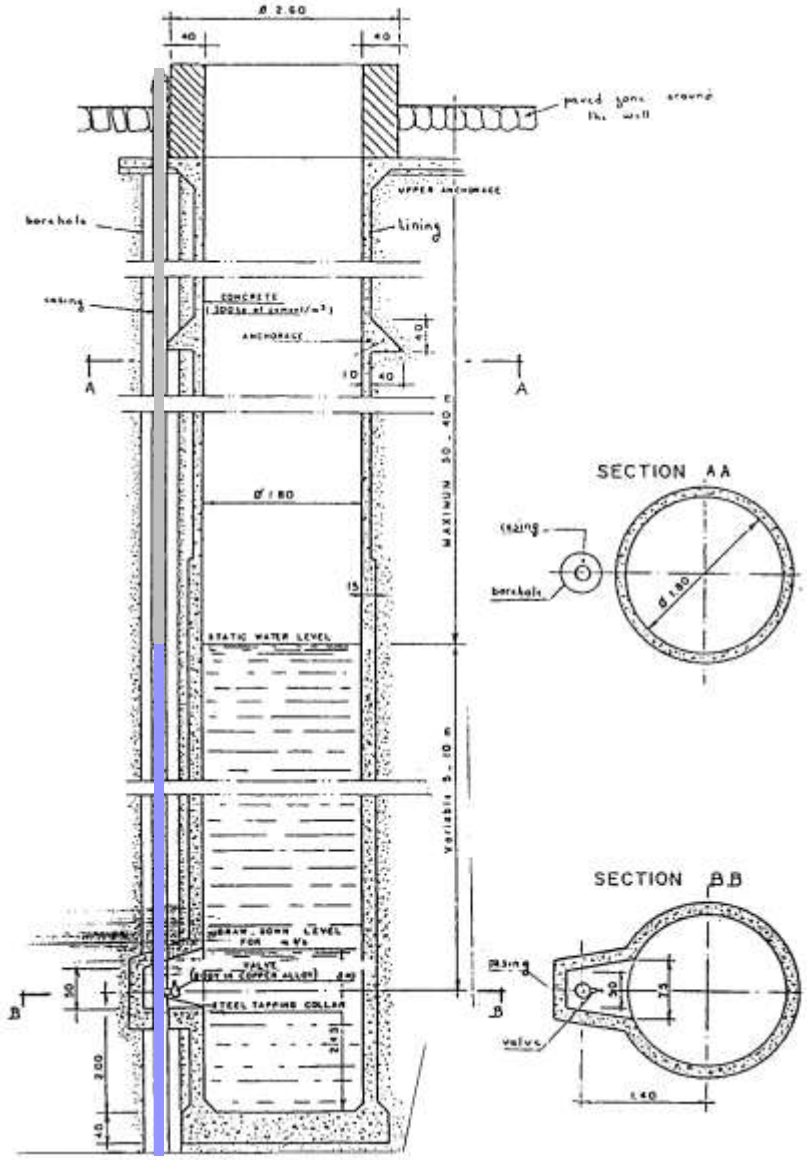


Large-diameter well with radial well points

Source: Unknown

Hybrid Wells – Well cistern & drilled well

A large diameter lined well is used to extract, with traditional drawing methods, water coming from a nearby drilled well connected with the large diameter well.



Suitable technique when:

a. the aquifer is confined and cannot be exploited by dug wells because it is too deep (more than 80m) or because water is under pressure;

b. the water bearing formation consists of hard rocks in which water flows through fissures and from which bigger discharge can be obtained by drilled wells tapping a deeper aquifer section than dug wells.

Source: http://www.fao.org/docrep/r7488e/r7488e07.htm

Advantages

Advantage	Dug, bored, driven & jetted wells	Drilled wells
Small equipment requirements	X	
No need for skilled personnel	X	
Easy penetration		X
Easy construction		X
Safeguarding against pollution		X
Deep wells		X
Economical	X	
Portable equipment	X	

Disadvantages

Disadvantage	Dug & driven wells	Jetted wells	Drilled & bored wells
Limited yields	X		
Slow construction in tight formations	X		
High wear & tear on equipment	X		
Limited to shallow depths		X	
Cannot penetrate hard formations		X	
Bulky & costly equipment			X
Need skilled personnel			X

Summary of Well Construction Methods

Method	Materials	Depth (m)	Diameter (m)	Yield (m^3/day)
Bored	Unconsolidated	10-25	5-90	15-500
Driven	Silt, sand	15	3-10	15-200
Jetted	Silt, sand	15	4-8	15-150
Percussion	All	450	8-60	15-15000
Direct rotary	All	450	8-45	15-15000
Reverse rotary	Unconsolidated	60	40-120	2500-20000
Air rotary	Consolidated	250	15-45	2500-15000

Adapted from U.S. Soil Conservation Service 1969. *Engineering Field Manual for Conservation Practices.* Department of Agriculture, Washington D.C. 995 p.

Source: JW Delleur,1999; The handbook of groundwater engineering

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PART 4 – Well Drilling Methods

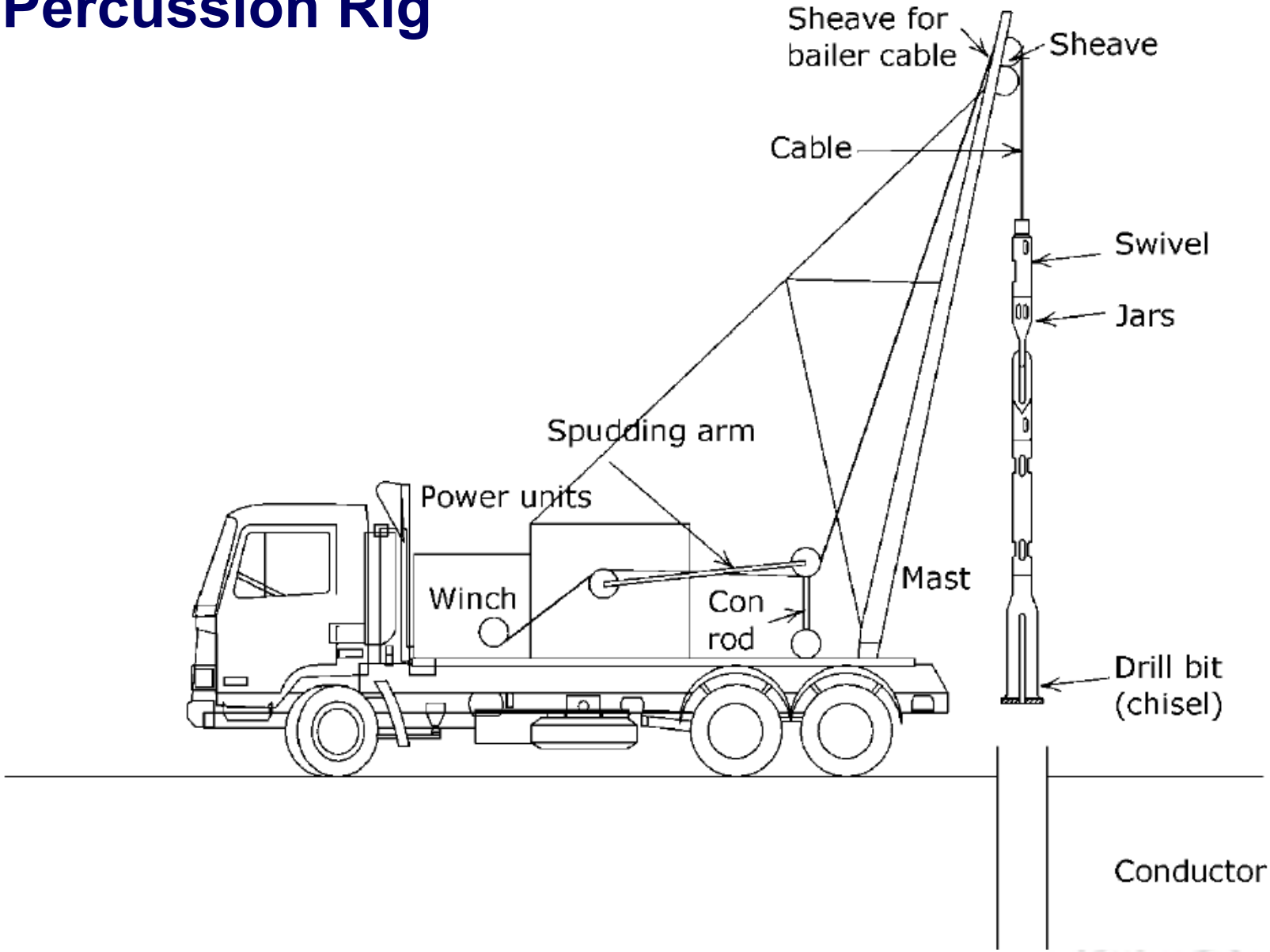
1. Non-circulation Methods
   - Cable-tool/Percussion drilling
   - Bucket-auger drilling
2. Direct Circulation Methods
   - Air & Mud rotary drilling
   - Down-the-hole hammer drilling
   - Reverse Circulation drilling
3. Borehole drilling fluids

Non-Circulation Method – Percussion Drilling

- Drills by lifting & dropping a drill bit into the borehole on a length of cable.
- Suitable for unconsolidated and soft formations.
- Relatively slow.
- Cheap, and “low-tech”.
- Easy to repair when things go wrong.
- Drill depth limited by weight of drill stem and cable (90 – 500m max)

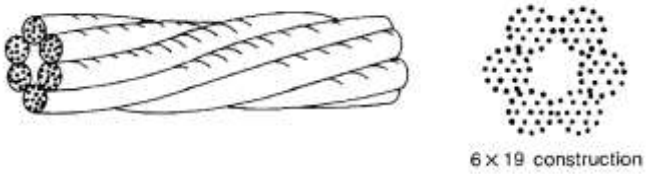
http://www.blogigo.co.uk/Afghanistan/DRILLING/8/

Percussion Rig

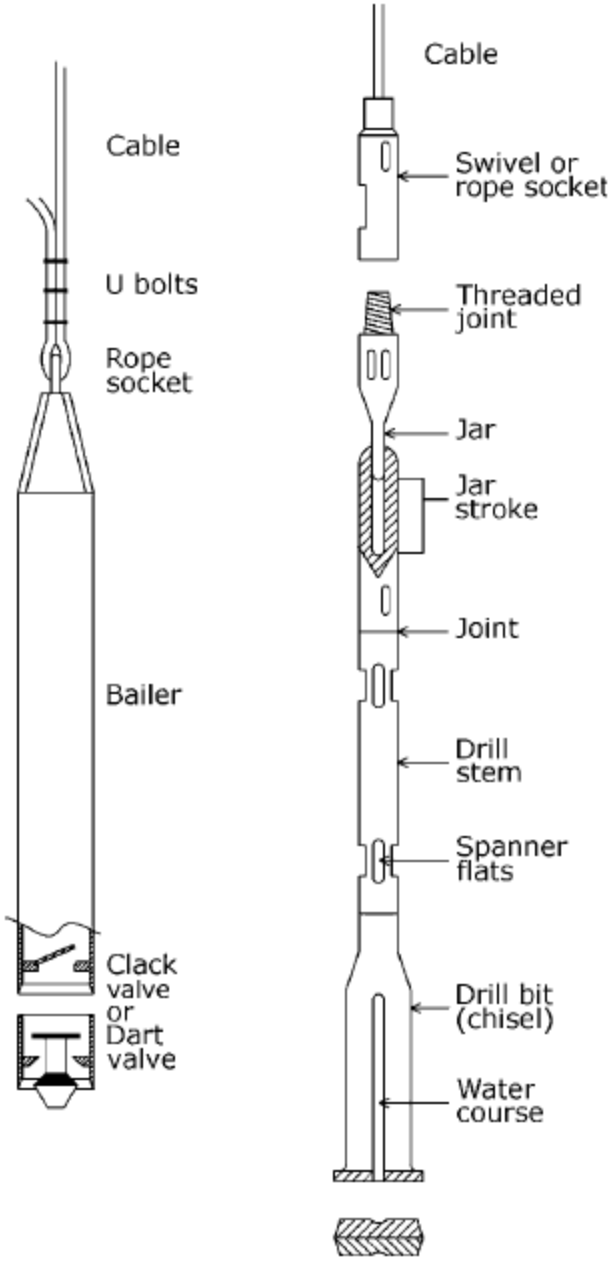


Source: B. Misstear, David Banks & L. Clark, 2006; Water Wells and Boreholes

Percussion Tool String For Hard Rock

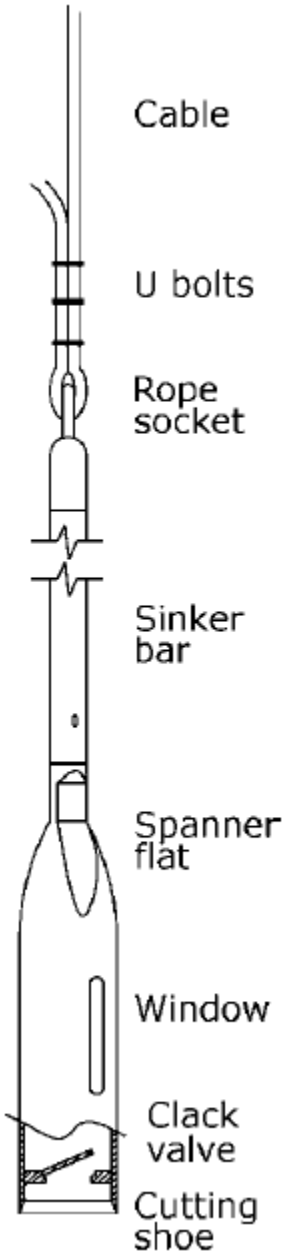


Left-lay cable for percussion rig



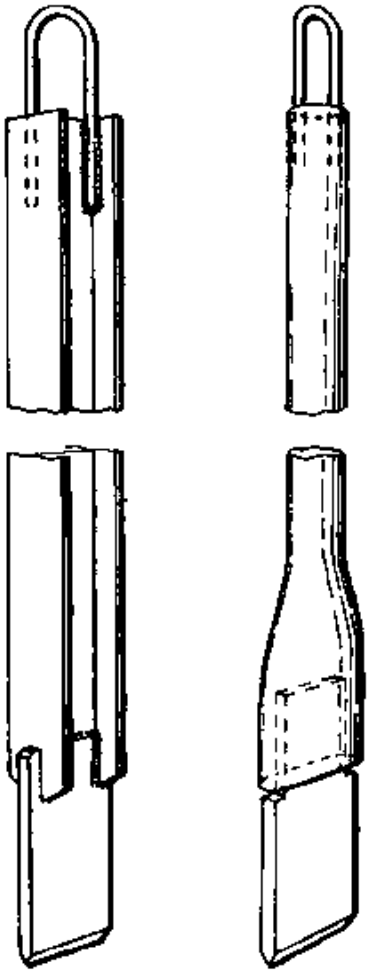
Source: B. Misstear, David Banks & L. Clark, 2006; Water Wells and Boreholes

Percussion Tool String For Soft Rock

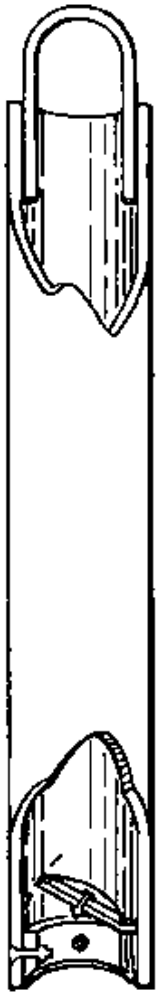


Source: B. Misstear, David Banks & L. Clark, 2006; Water Wells and Boreholes; WILEY ISBN: 9780470849897

Percussion Tools



Percussion bits,
locally fabricated



Bailer,
locally fabricated

Source: http://www.fao.org/docrep/x5567e/x5567e05.htm


25/05/2012 09:57

Percussion Drilling Videos

4.1 Cable tool Drilling Method.mp4

4.2 Cable Tool Drilling- Starting A Hole.mp4

4.2 Philippines_ Drilling Deep Well.mp4

Non-Circulation Method – Bucket-Auger Drilling

- Material is excavated using large diameter bucket auger.
- Water wells of 18” – 48” possible, though generally to shallow depths.
- Primarily used in clay formations that do not cave.
- Drilling in sand is difficult, unless the hole stays open.

http://www.blogigo.co.uk/Afghanistan/DRILLING/8/

Non-Circulation Method – Bucket-Auger Drilling

Source: http://www.griffindewatering.com/about.html#.UkG9lz-ziJY

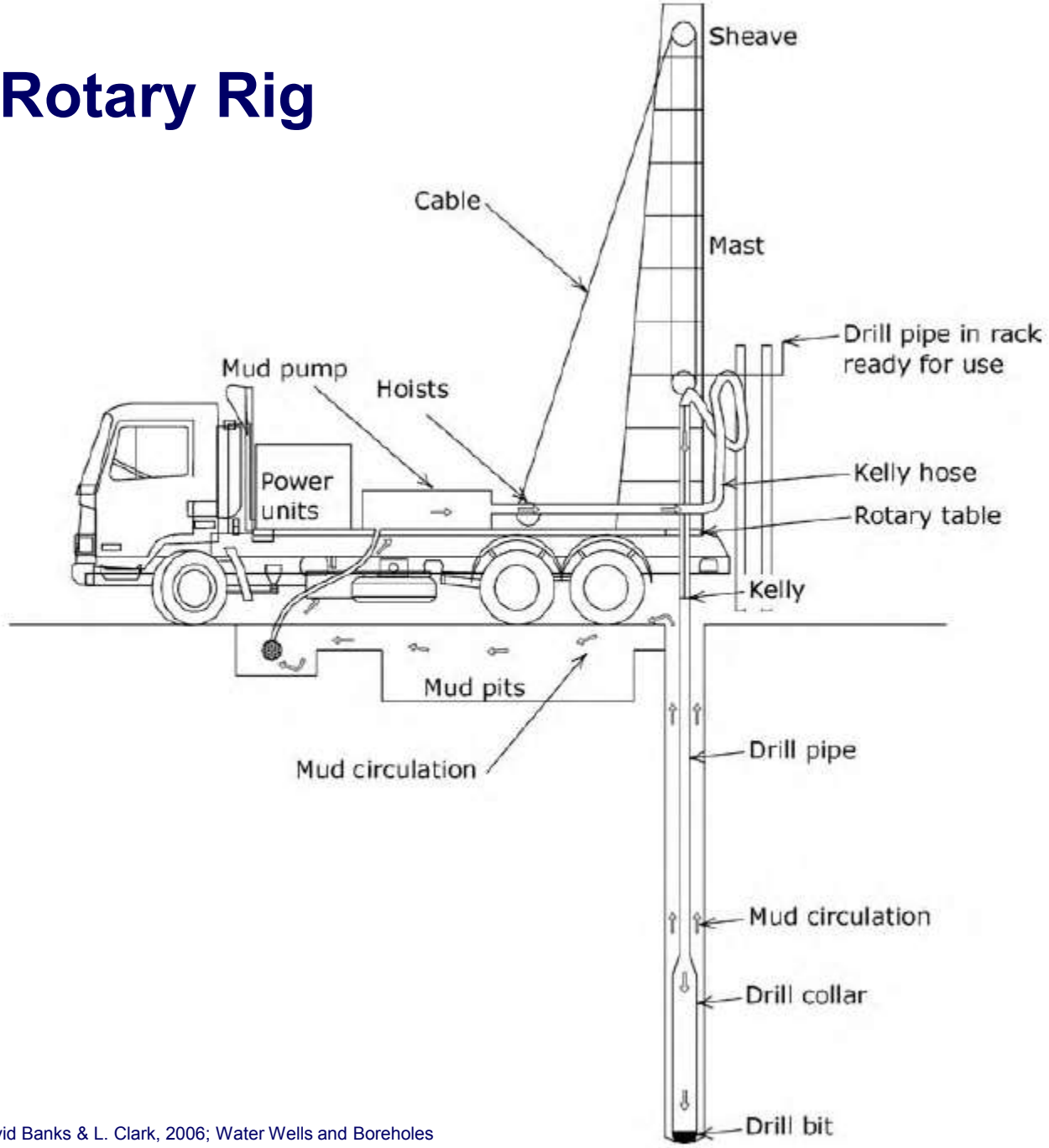
Bucket-Auger Drilling Video

5.1 Bucket auger drilling method.mp4

Direct Circulation Methods – Air/Mud Rotary

- Developed to increase drill speeds and drill depths.
- Borehole is drilled by rotating a bit at the bottom of a string of drill pipe.
- Cuttings are removed by continuous flow of drill fluid up the borehole.
- The cuttings are removed at the surface and clean drill fluid is recirculated down the borehole.

Direct Rotary Rig

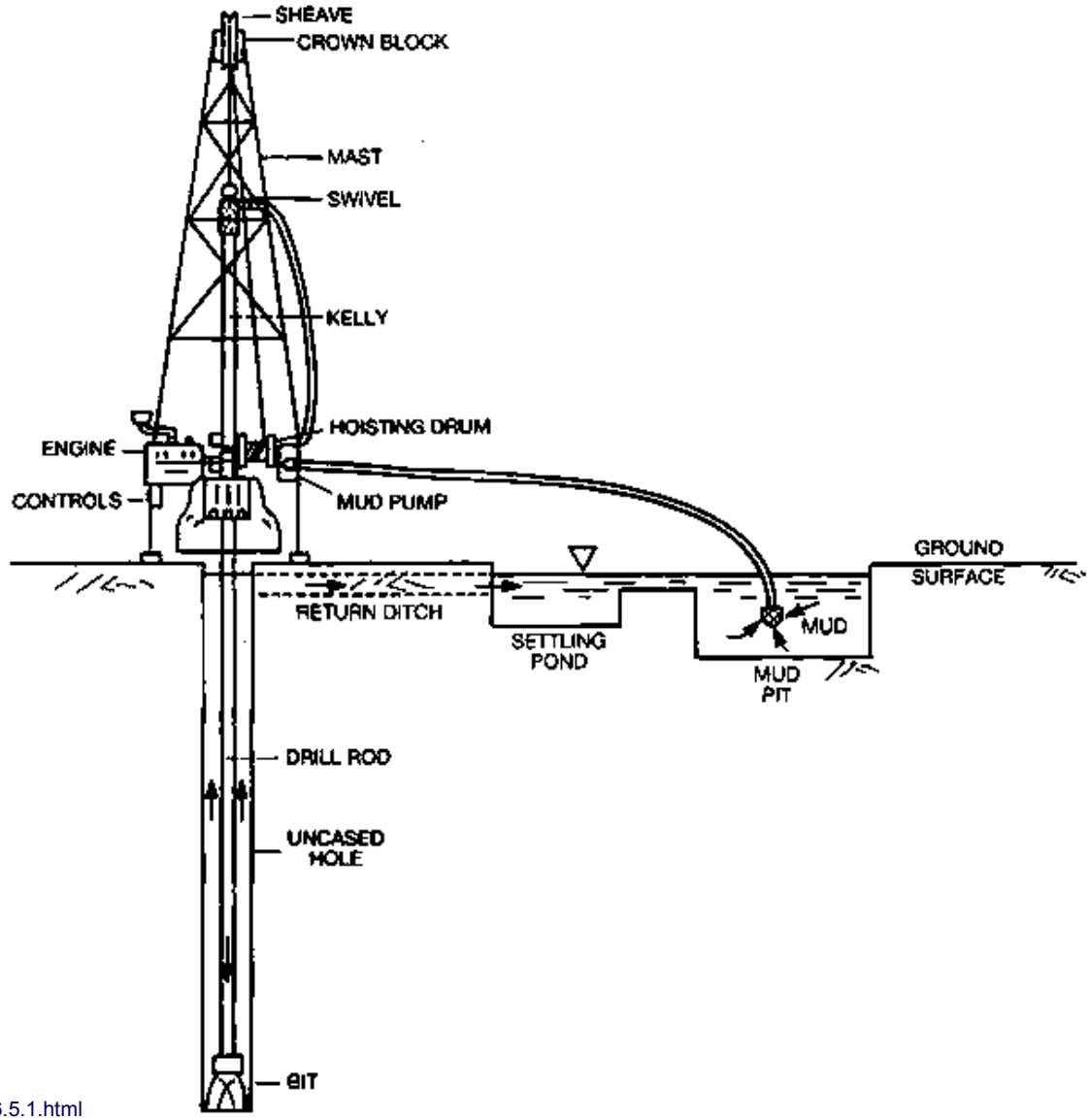


Source: B. Misstear, David Banks & L. Clark, 2006; Water Wells and Boreholes

Rotary Rigs

- **Table-drive Rig**
  - ✓ Power is supplied to drill pipe via a kelly bushing located on the tabel.
- **Tophead Rig**
  - ✓ Rotation provided by a hydraulically driven gearbox, which travels up & down the mast.
  - ✓ Drill string is connected to the rotation unit, so kelly is not required.

Table-drive Rig



Source: http://helid.digicollection.org/en/d/Junr01/8.6.5.1.html

Tophead Rig

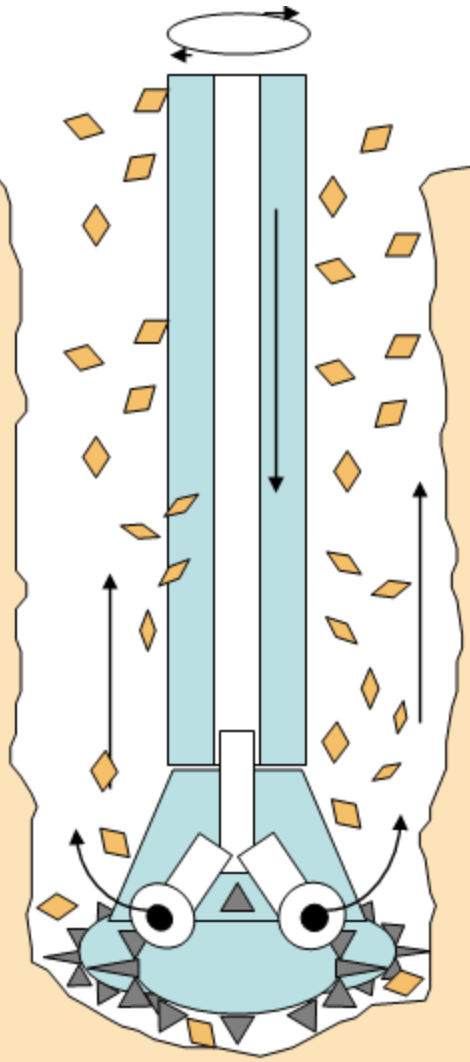
Schramm
T450MIIA

Source: http://www.schramminc.com

Rotary Mud Drilling Method

The drill string is turned at surface, which turns the bit at the bottom of the hole.

The teeth on the drill bit grind the rock into fragments, or "cuttings".

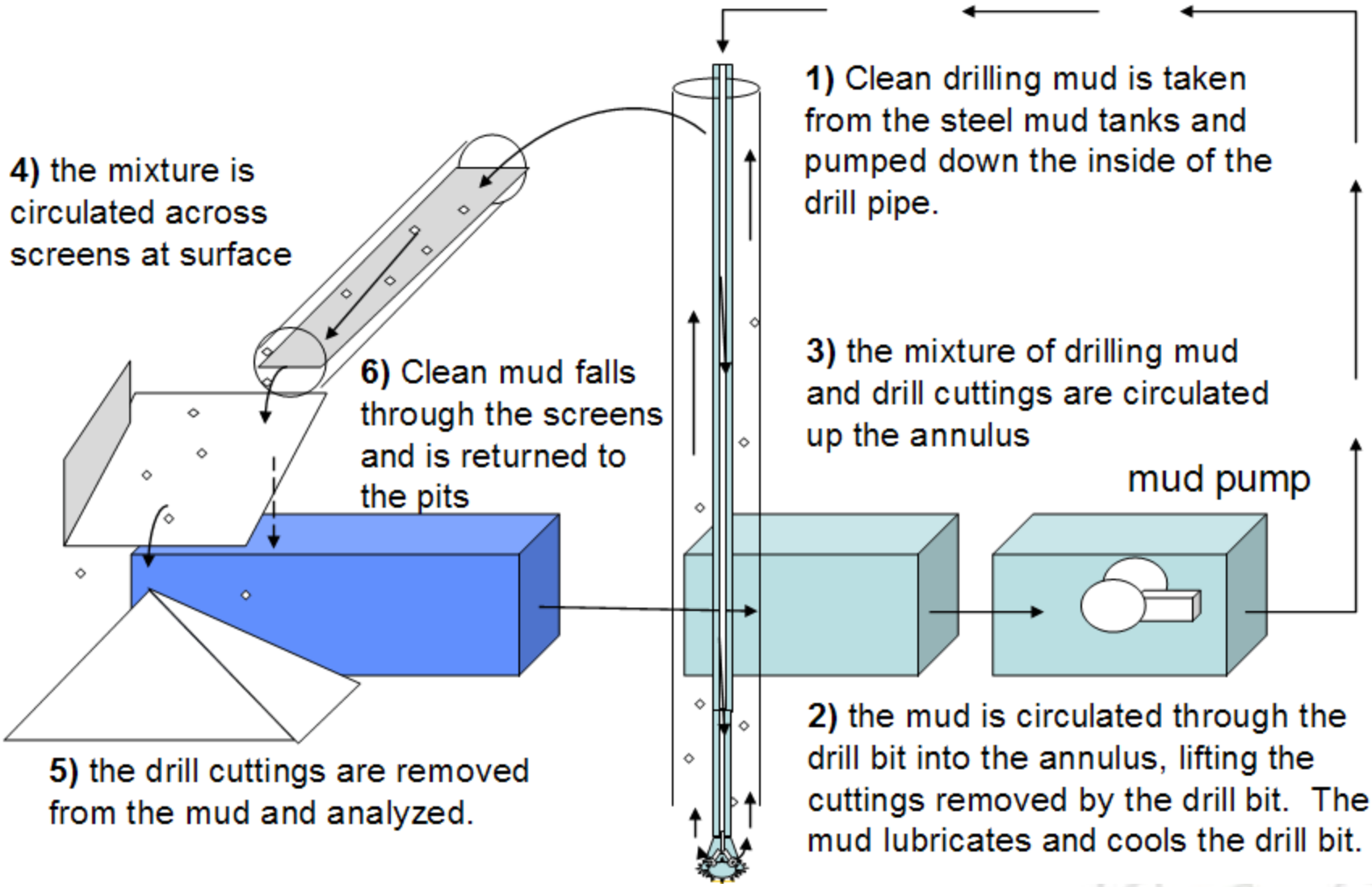


Drilling mud is pumped down the inside of the drill pipe, through jet nozzles in the bit, and into the "annulus". This is the space between the sides of the hole and the drill pipe.

The mud lifts the cuttings and circulates them back to surface where they are removed.

Source: http://www.ppdm.org/wiki/index.php/Well_Operations_Reference_guide

Rotary Mud Drilling Method



Source: http://www.ppdm.org/wiki/index.php/Well_Operations_Reference_guide

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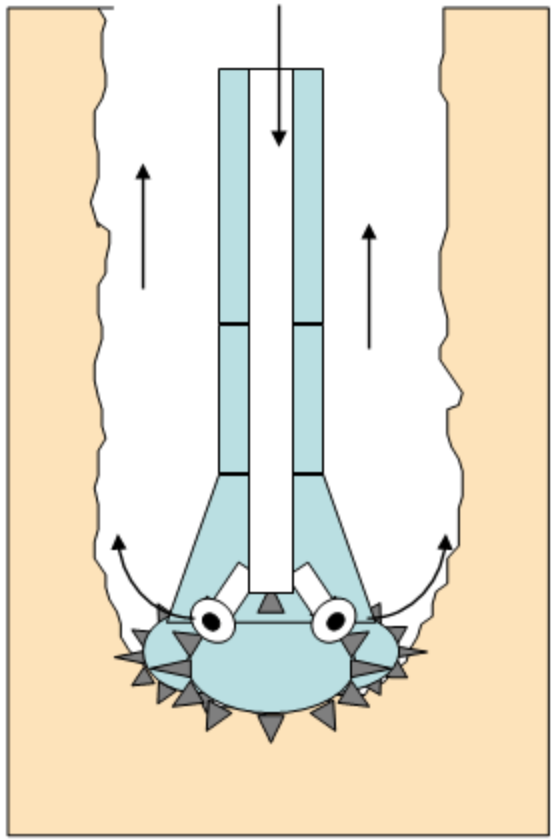
Rotary Mud Drilling Method

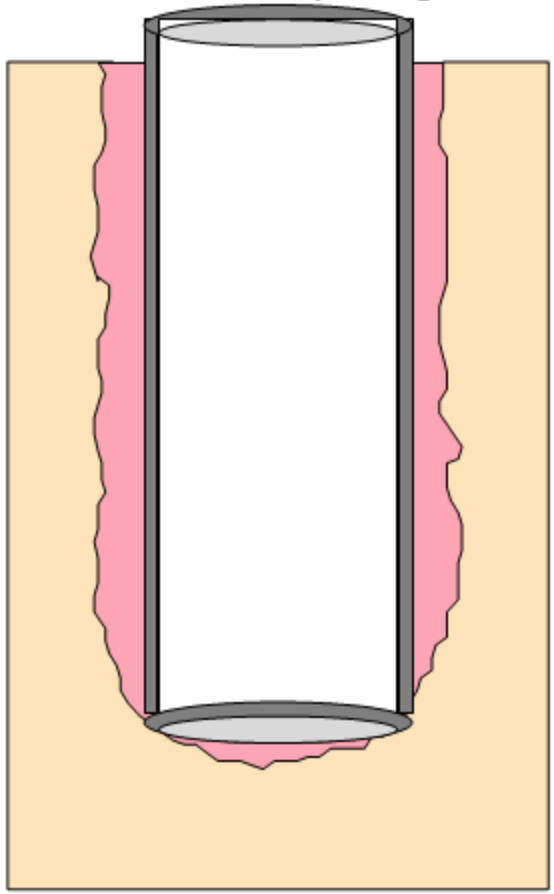
First, a large drill bit is used to drill a short interval of hole.



0

200

Then, steel casing is run and cemented on the outside to keep the hole from collapsing.



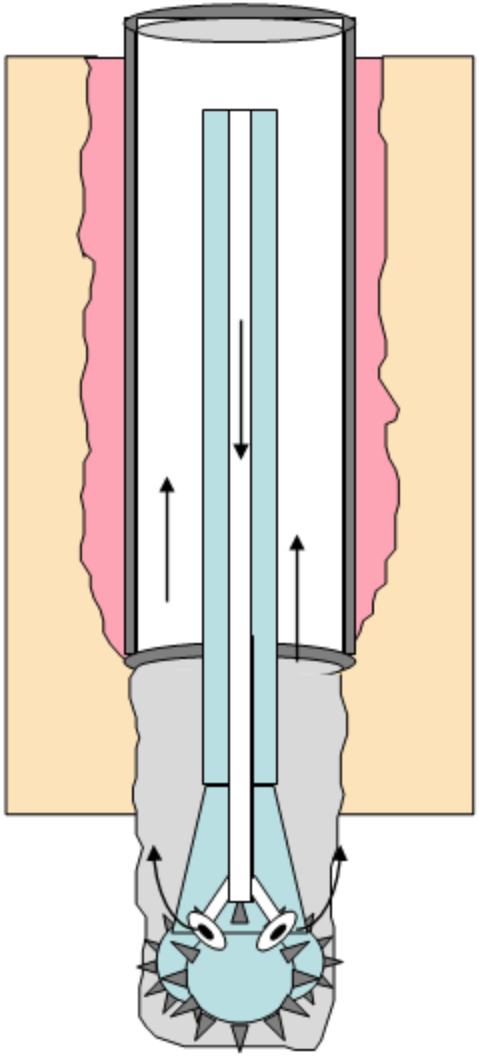
Source: http://www.ppdm.org/wiki/index.php/Well_Operations_Reference_guide

NORPLAN

Rotary Mud Drilling Method

Next,
a smaller bit is run inside the first casing.

This bit drills out the bottom of the casing, and drills new hole.

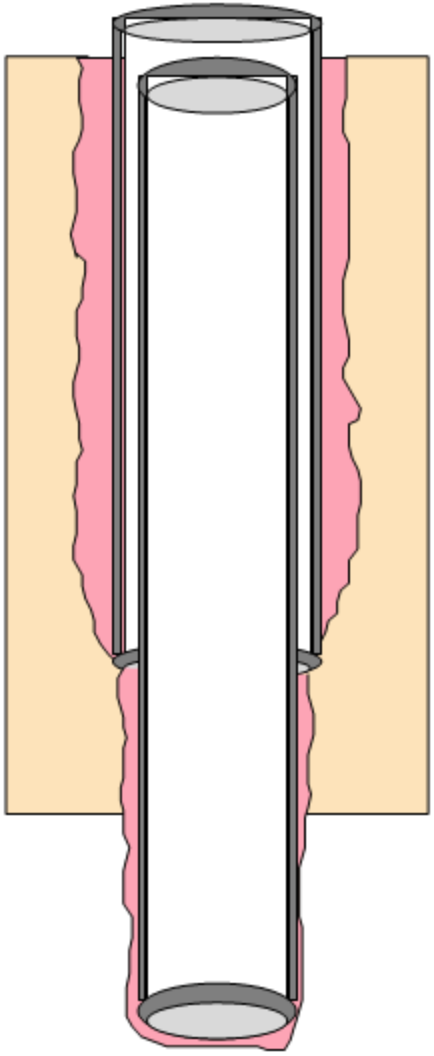


0

Then, this new hole is also cased off and cemented.

200

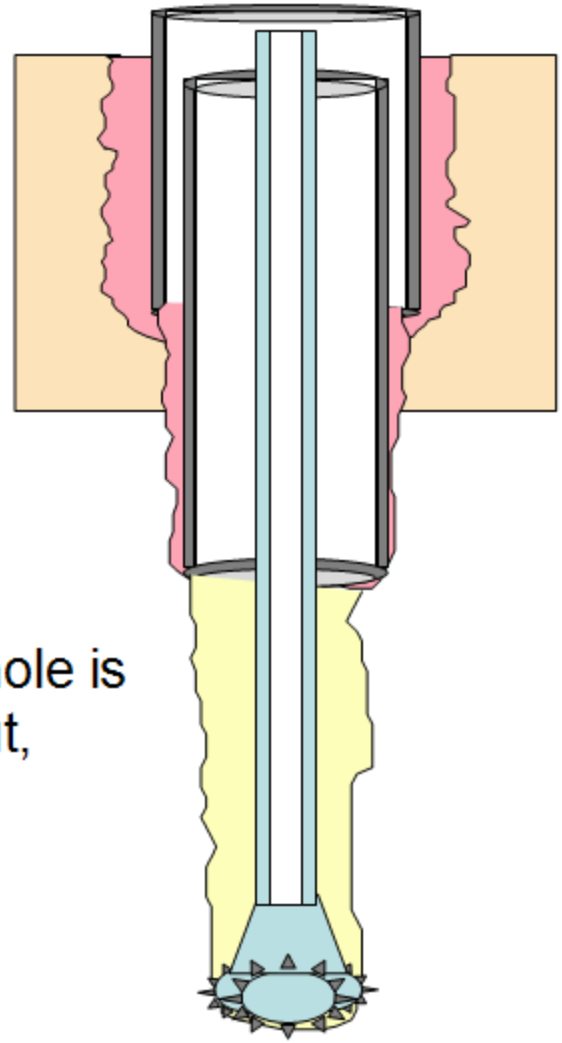
500



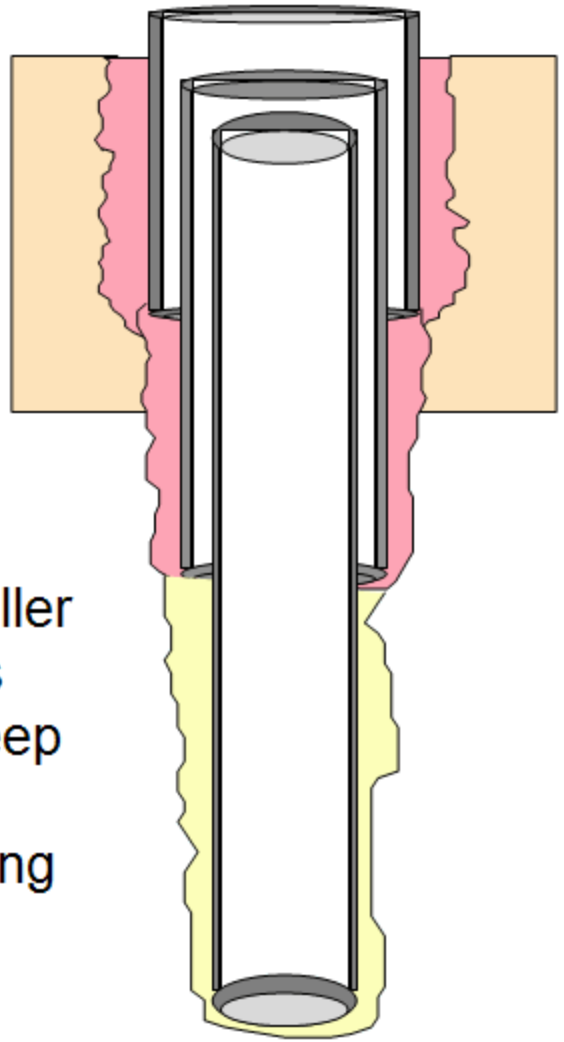
Source: http://www.ppdm.org/wiki/index.php/Well_Operations_Reference_guide

Rotary Mud Drilling Method

Again, a smaller hole is drilled out,



and smaller casing is run to keep the hole from falling in.



Source: http://www.ppdm.org/wiki/index.php/Well_Operations_Reference_guide

Direct Circulation Drilling Bits: Drag Bits

- Short cutting blades faced with durable metal.
- Cleaned & cooled by jetting drilling fluid down the faces.
- Used for fast penetration in unconsolidated and semi-consolidated formations e.g. sand & clay.
- Not suitable for coarse gravel or hard-rock formations.

Source: http://www.atlascopco.com/benl/products/navigationbyproduct/product.aspx?id=1517882
http://www.americawestdrillingsupply.com/products2/DragBits.asp

Direct Circulation Drilling Bits: Roller-Cone Bits

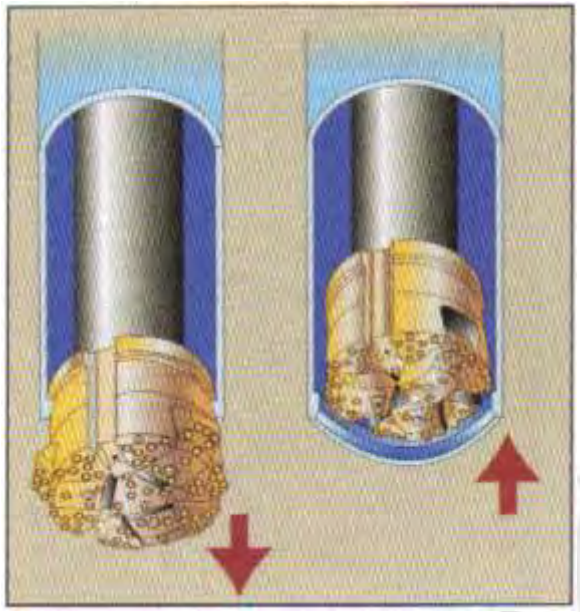
- Perform crushing & chipping action.
- Number of teeth on rollers depends on hardness of formation. More teeth for harder rocks.
- Hardened steel teeth for soft formations.
- Tungsten button bit for hardest formations.

Source: http://www.trenchlessonline.com/index/webapp-stories-action/id.662 & MEW

Borehole Reamers & Under-reamers

Source: http://www.seg-drilltech.com/b27.html

- Used to straighten, clean or enlarge boreholes.
- Under-reaming enlarges boreholes beneath casing using an expandable bit.



Source: Johnson; Groundwater & Wells, 3rd Edition

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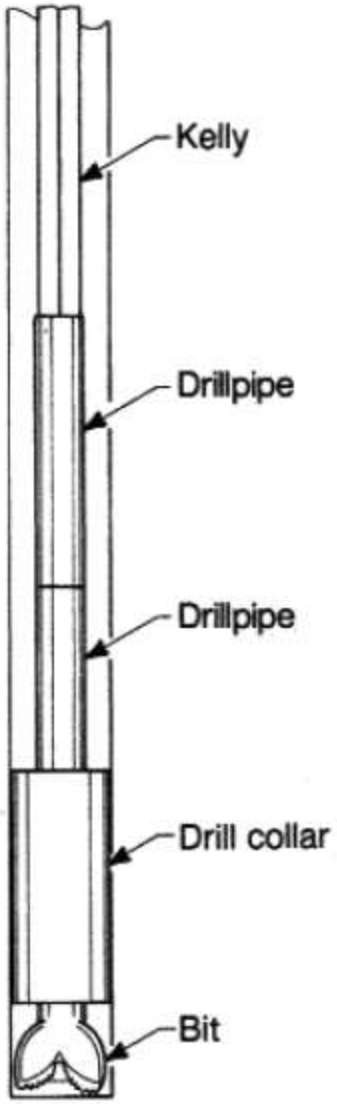
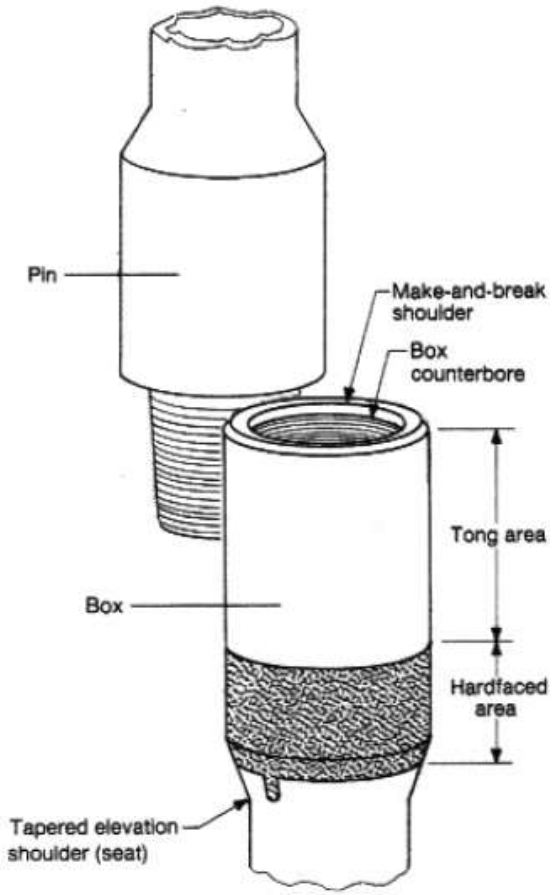
Drill Collars



- Heavy walled drill pipe which gives weight to base of drill string.
- Improves borehole straightness & penetration rate.

Source: Johnson; Groundwater & Wells, 3rd Edition

Drill Pipe



- Heavy walled seamless tubing 20’ to 30’ long (6.1 – 9.1m).
- Drilling fluid is pumped down the centre of the pipe.
- Joined by tool-joint pin and box-end fittings.

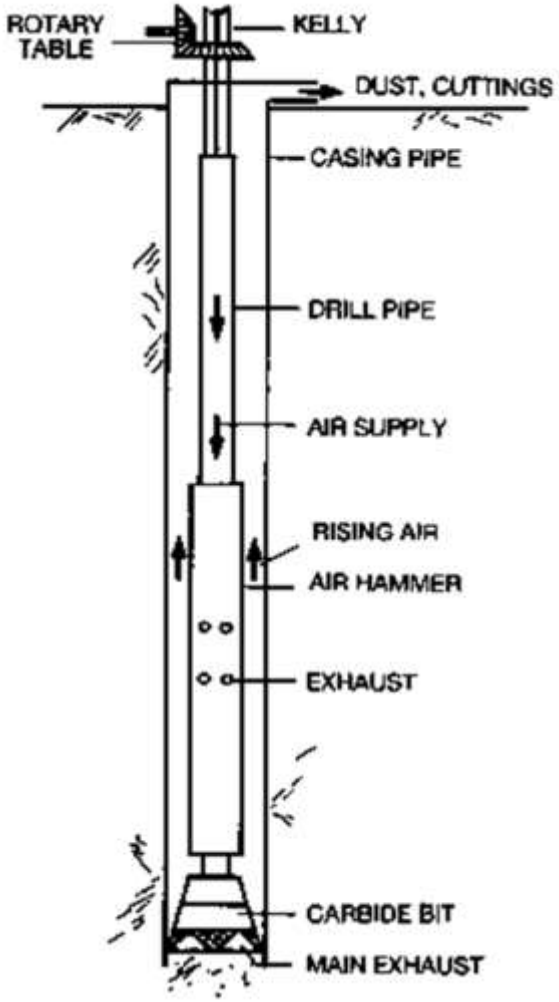
Source: Johnson; Groundwater & Wells, 3rd Edition

Source: http://www.seg-drilltech.com/b18.html

Rotary Drilling Video

5.2 Water Bore Hole Drilling Rig 29th April 2009.mp4

Direct Circulation Methods – Down-the-Hole Hammer Drilling



- Suitable for hard formations.
- Very fast drilling.
- Uses air as the drilling fluid.

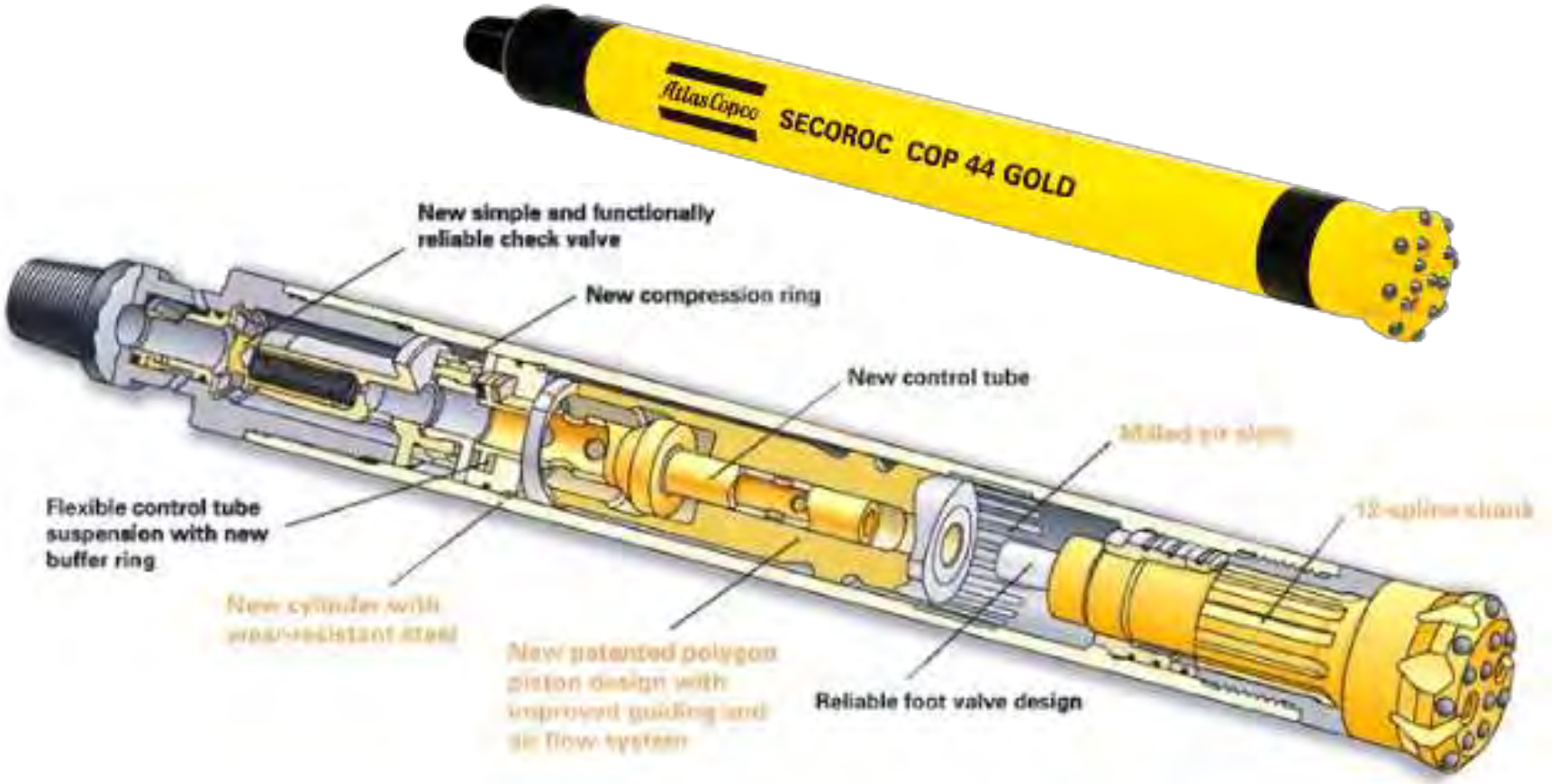
Source: http://helid.digicollection.org/en/d/Junr01/8.6.5.1.html

Down-the-Hole Hammer Rig

Source: http://www.americawestdrillingsupply.com/TheHoleStory2.asp

NORPLAN

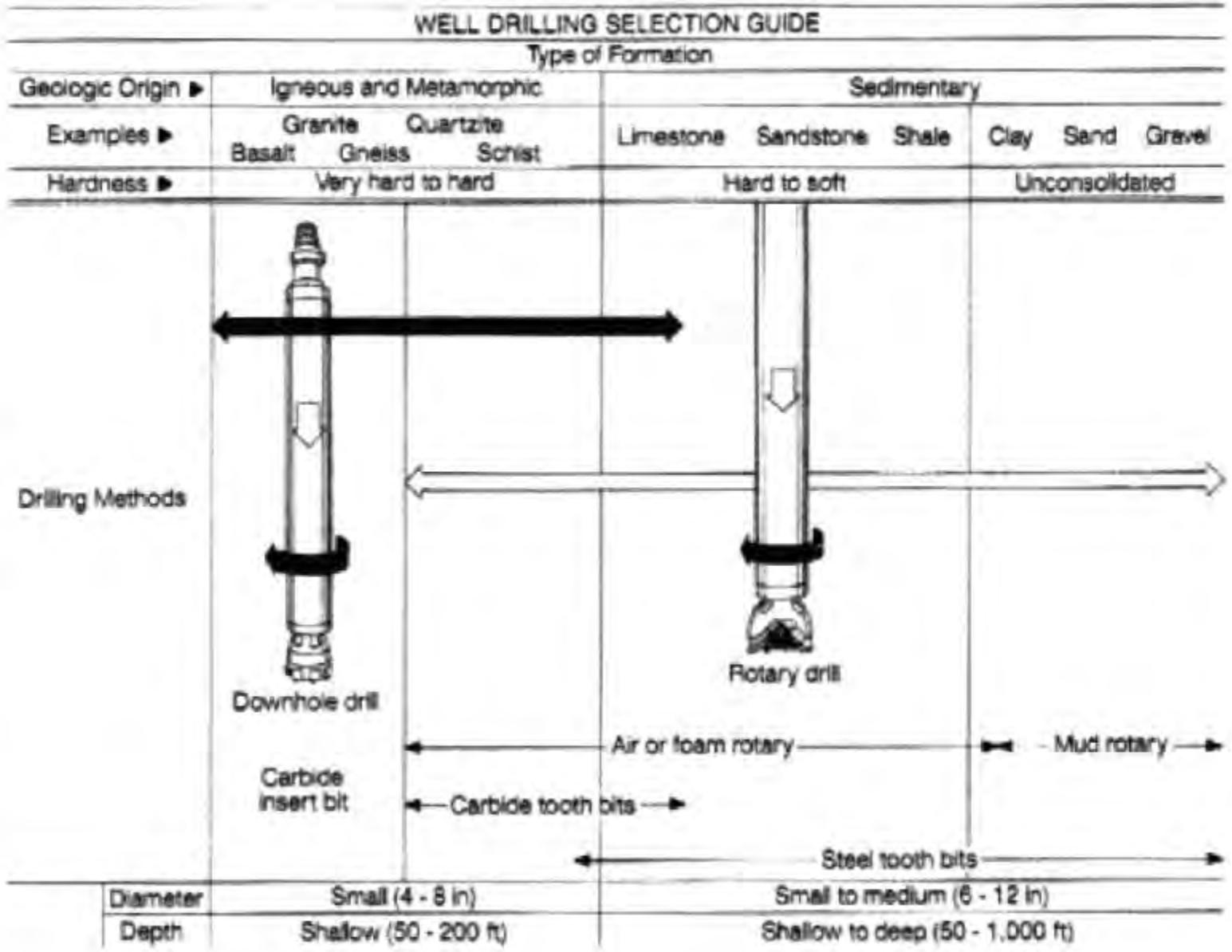
Down-the-Hole Hammer



Source: http://www.firstbreak.co.nz/Products/down-the-holeham.html

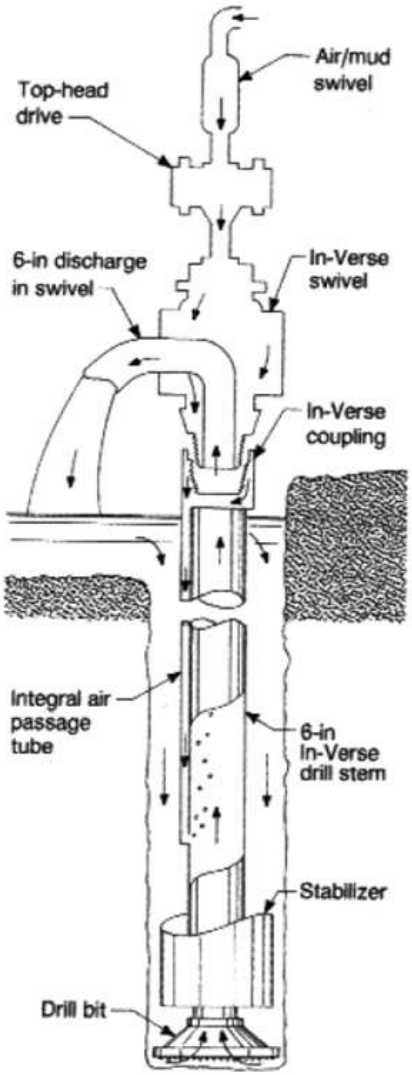
Down-the-hole Hammer Drilling Video

5.3 Down the hole drilling method.mp4



Source: Johnson; Groundwater & Wells, 3rd Edition

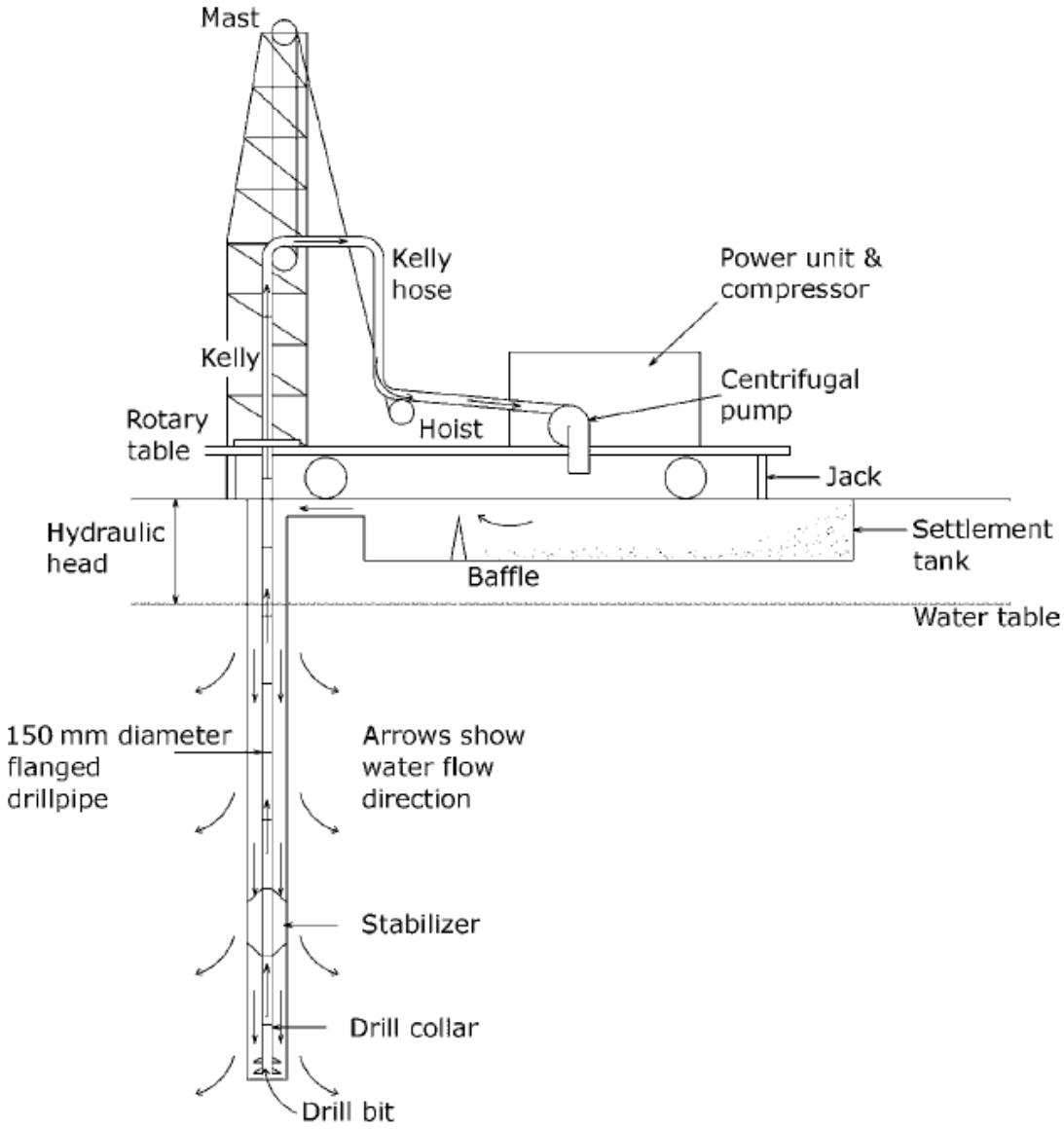
Reverse Circulation Rotary Methods



- Flow of drilling fluid is reversed, and drilling fluid & cuttings moves up inside the drillpipe & discharges at the surface.
- Pump suction is connected to the drillpipe through the swivel.
- Frequently use centrifugal pumps for uphole velocities of at least 45m/min.
- Fluid returns down the annulus to the bottom of the borehole & re-enters the drillpipe through ports in the bit.

Source: Johnson; Groundwater & Wells, 3rd Edition

Reverse Circulation Rig



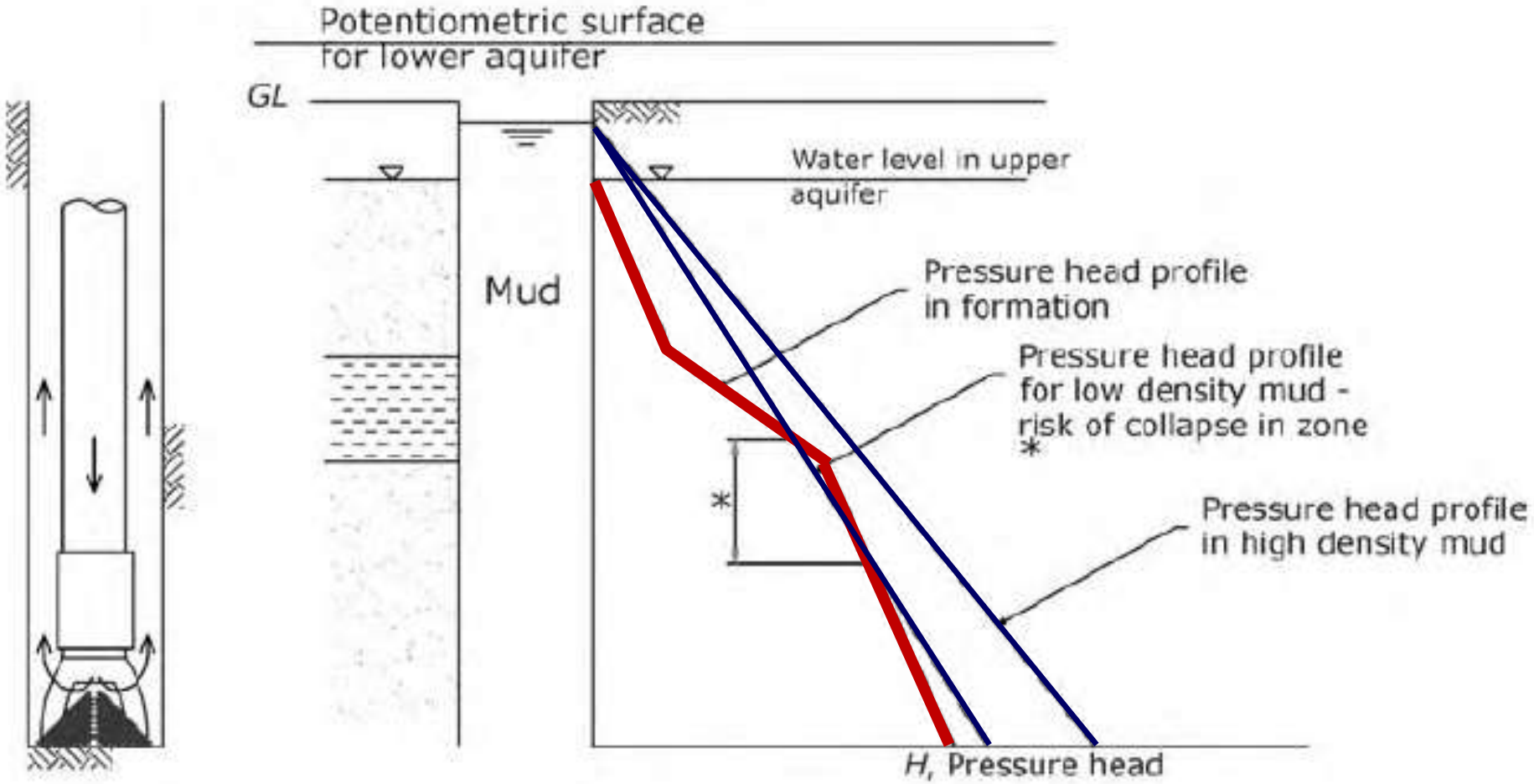
Source: B. Misstear, David Banks & L. Clark, 2006; Water Wells and Boreholes

Reverse Circulation Rotary Methods: Disadvantages

- A positive fluid pressure must be maintained in the borehole at all times.
- Static water level is should be >3m below surface.
- Large amounts of make-up water must be available at all times.

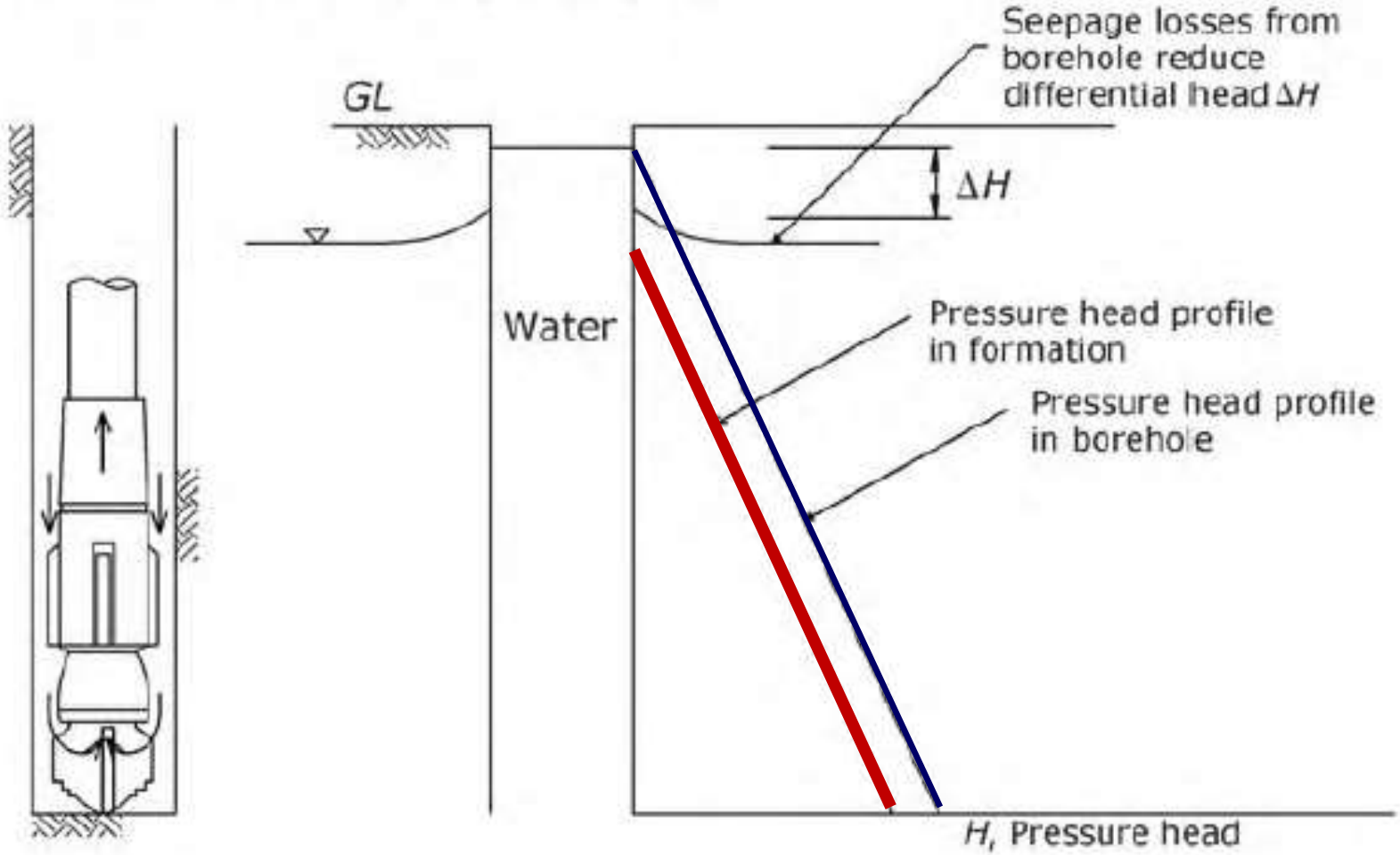
Source: Johnson; Groundwater & Wells, 3rd Edition

DIRECT CIRCULATION (DC)



Source: B. Misstear, David Banks & L. Clark, 2006; Water Wells and Boreholes

REVERSE CIRCULATION (RC)



Source: B. Misstear, David Banks & L. Clark, 2006; Water Wells and Boreholes

Reverse Circulation Drilling Video

5.4 Reverse circulation drilling method.mp4

Borehole Drilling Fluids

- ✓ Carry cuttings from bottom of borehole to the surface.
- ✓ Support & stabilize the borehole wall to prevent caving.
- ✓ Seal borehole wall to minimize fluid loss.
- ✓ Cool & clean the drill bit.
- ✓ Allow separation of cuttings from fluid at the surface.
- ✓ Lubricate bit, bearings, mud pump & drill pipe.

Source: Johnson; Groundwater & Wells, 3rd Edition

Drilling Products

Prevent contaminants during well construction:

- All water used should be potable or disinfected.
- Do not use organic material during drilling or to fix lost circulation.

Source: S. J. Schneider, 2012; Water Supply Well Guidelines for Use in Developing Countries, Second Edition.

Borehole Drilling Fluids used for Water Wells

Water Based	Air Based
Clean fresh water	Dry air
Water with clay additives	Mist: droplets of water entrained in the airstream
Water with polymeric additives	Foam: air bubbles surrounded by a film of water containing foam-stabilizing surfactant.
Water with clay and polymeric additives	Stiff foam: foam containing film strengthening materials such as polymers and bentonite

Source: Johnson; Groundwater & Wells, 3rd Edition

Marsh Funnel Viscosities

Measuring viscosity using a Marsh funnel

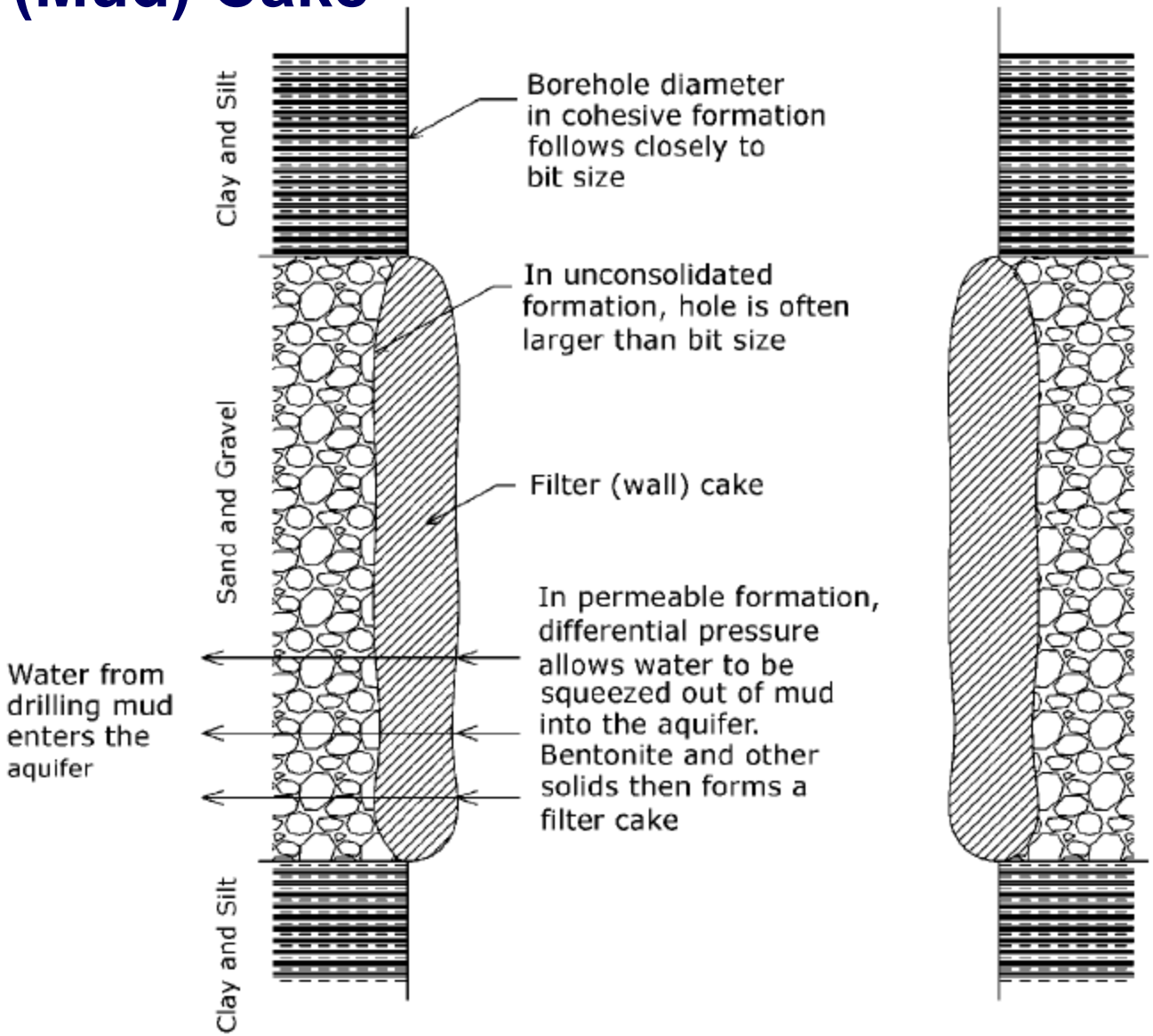
Table 7.1 Suggested Marsh funnel viscosities for unconsolidated materials

Material drilled	Marsh funnel viscosity (seconds)
Fine sand	30–45
Medium sand	40–55
Coarse sand	50–65
Gravel	60–75
Coarse gravel	75–85
Lost circulation	85–120

Because viscosity can often be confused with density, the specific gravity or density should be determined by means of a mud balance and not just estimated.

Source: Minimum construction requirements for water bores in Australia 3rd Edition, 2012.

Filter (Mud) Cake



Source: B. Misstear, David Banks & L. Clark, 2006; Water Wells and Boreholes

Borehole Drilling Fluids

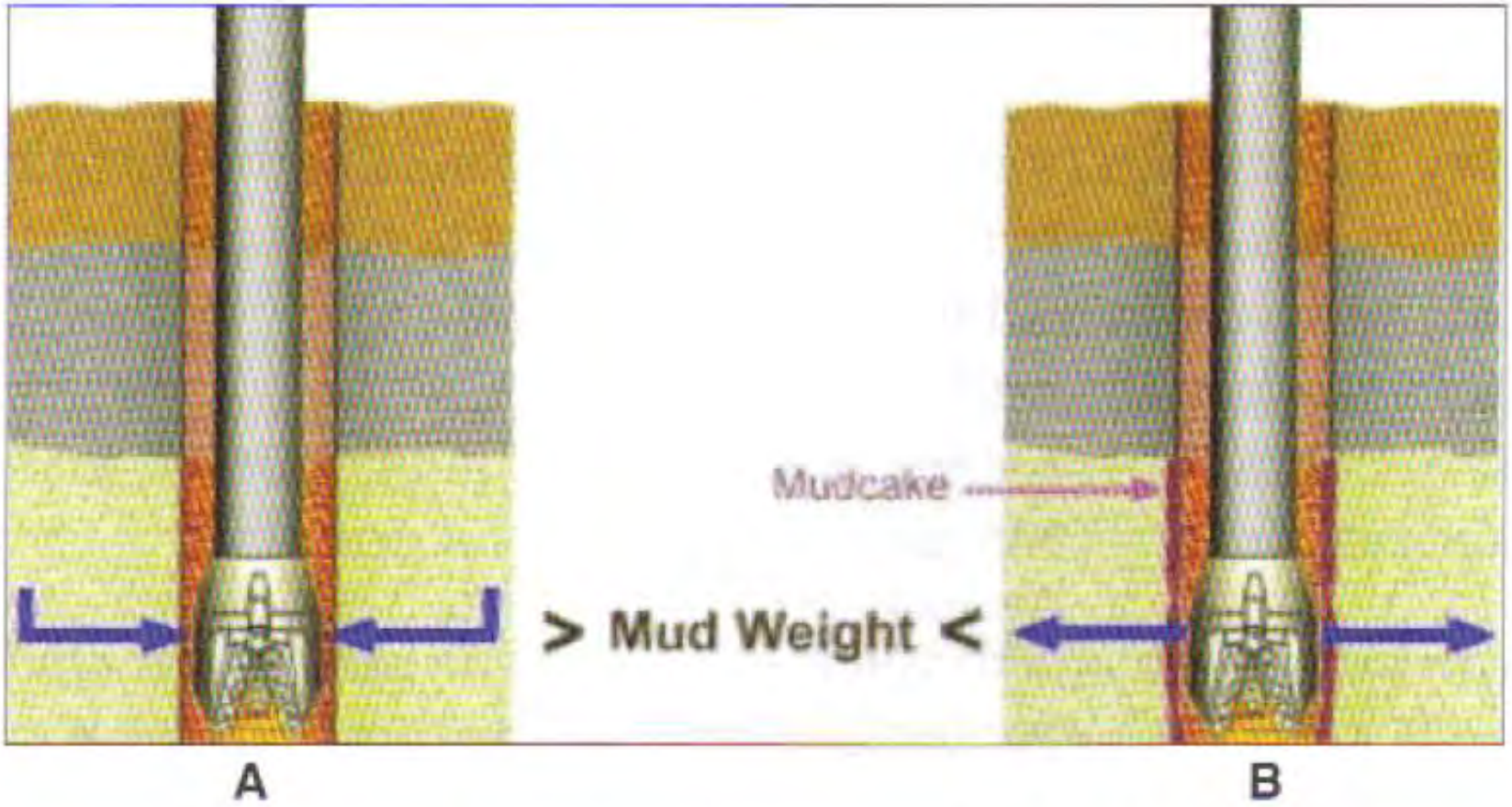


Figure 7.11. Differences in fluid migration with (A) and without (B) underbalanced drilling (www.rigzone.com).

Source: Johnson; Groundwater & Wells, 3rd Edition

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Drilling Fluids – Revert & Revert II

Johnson Revert and Revert II:

- Natural guar gum polymers
- Readily build high viscosity (8 to 10 times the viscosity building capacity of bentonite)
- Reduce clay swelling
- Settle drill cuttings faster in pits
- Readily biodegrade
- Save time and improve drilling efficiency and well performance.

Source: http://www.johnsonscreens.com

Drilling Fluids Video

Grouting School - Ideal viscosities and soda ash mix ratios.mp4

TOPICS TO BE COVERED

1. Introduction & Terminology
2. Well Location
3. Well Construction Methods
4. Well Drilling Methods
5. Well Completion & Development
6. Well Decommissioning
7. Cost Benefit Analysis
8. Drilling Management & Data Collection
9. Health & Safety

PART 5 – Well Completion & Development

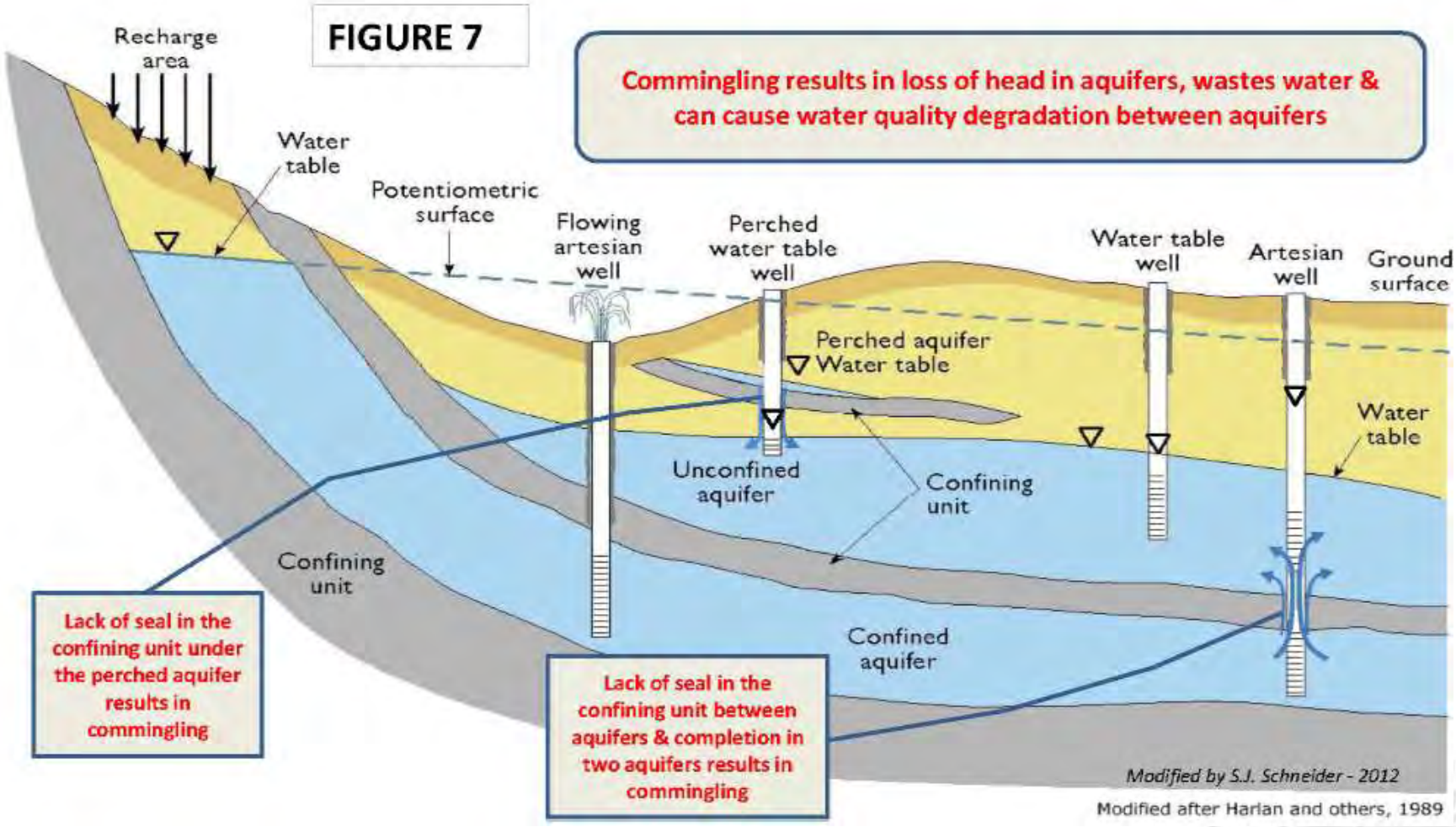
1. Well design.
2. Well casing & screen materials.
3. Well development & rehabilitation.
4. Well disinfection
5. Well completion.

Well Design

Key objectives:

1. Design a hydraulically efficient well that will have a long service life.
2. Protect the well from contaminants.
3. Protect under & overlying aquifers by preventing the well from becoming a vertical pathway between different aquifers.

Well Design



Source: S. J. Schneider, 2012; Water Supply Well Guidelines for Use in Developing Countries, Second Edition.

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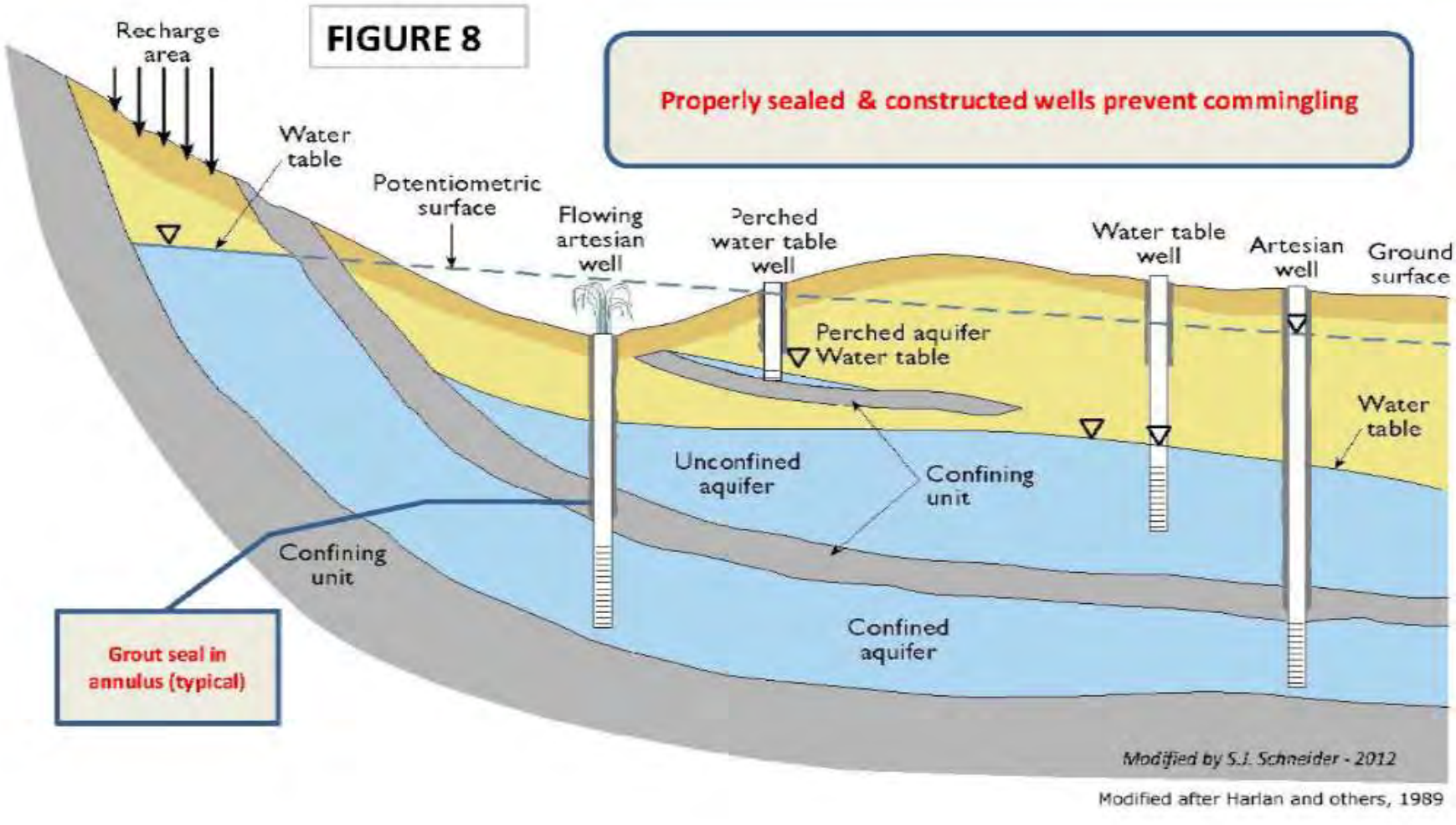
Well Design



Source: S. J. Schneider, 2012; Water Supply Well Guidelines for Use in Developing Countries, Second Edition.

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Parwan
Flowing Well

Source: MEW.

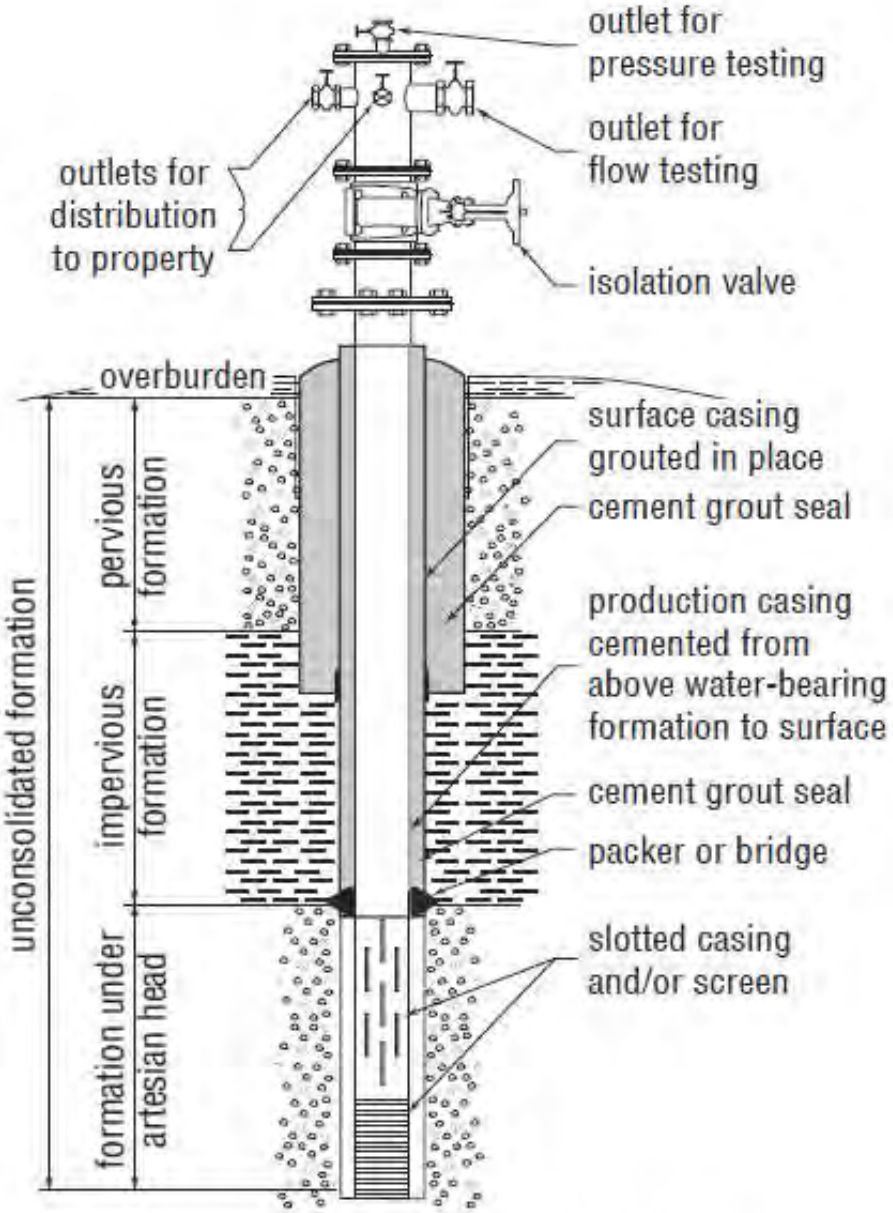

Figure 3.3 Flowing aquifer bore

Source: Minimum construction requirements for water bores in Australia 3rd Edition, 2012.

Well Design will be covered in next course

NORAD supported project in MRRD covering
Capacity Building and Institutional Cooperation in the
field of Hydrogeology for Faryab Province
Afghanistan

Hydrogeology Course 1.4
Well Design

By Andreas de Jong
September 2013

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1

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Annular Surface Seal

Prevents contaminants from entering the well:

- All wells must have an annular surface seal surrounding the surface casing to >=5m depth.
- Sealants should be neat cement grout and/or bentonite pellets.

Casing & Screen Materials

The main types of casing used in water wells are:

1. Steel
2. PVC-U (Un-plasticised polyvinyl chloride)
3. ABS (Acrylonitrile butadiene styrene)
4. FRP (Fibreglass-reinforced polyester) & FRE (Fibreglass-reinforced epoxy)
5. Stainless steel

Source: Minimum construction requirements for water bores in Australia 3rd Edition, 2012.

Casing Materials – Low Carbon steel

Schedule 40 Low carbon steel:

- ✓ OK for use in non-corrosive groundwater environments
- ✓ Strong
- ✓ Cheap

Source: http://www.johnsonscreens.com

Casing Materials - Polyvinyl Chloride (PVC)

PVC Advantages:

- Light weight allowing easy installation
- Cost-effective
- Resistance to chemical attack and to corrosion
- Long service life
- Smooth surfaces reduce encrustation
- OK for heavy metal sampling as it does not leach metal

PVC Disadvantages:

- Sensitive to UV light
- Low impact resistance, especially when cold.
- Low collapse strength

Source: http://www.johnsonscreens.com

Casing Materials - Polyvinyl Chloride (PVC)

PVC strength reduces rapidly with increasing temperature.

Heat of hydration from cement curing may cause failure.

Source: S. J. Schneider, 2012; Water Supply Well Guidelines for Use in Developing Countries, Second Edition.

Parwan Casing installation

Source:: MEW

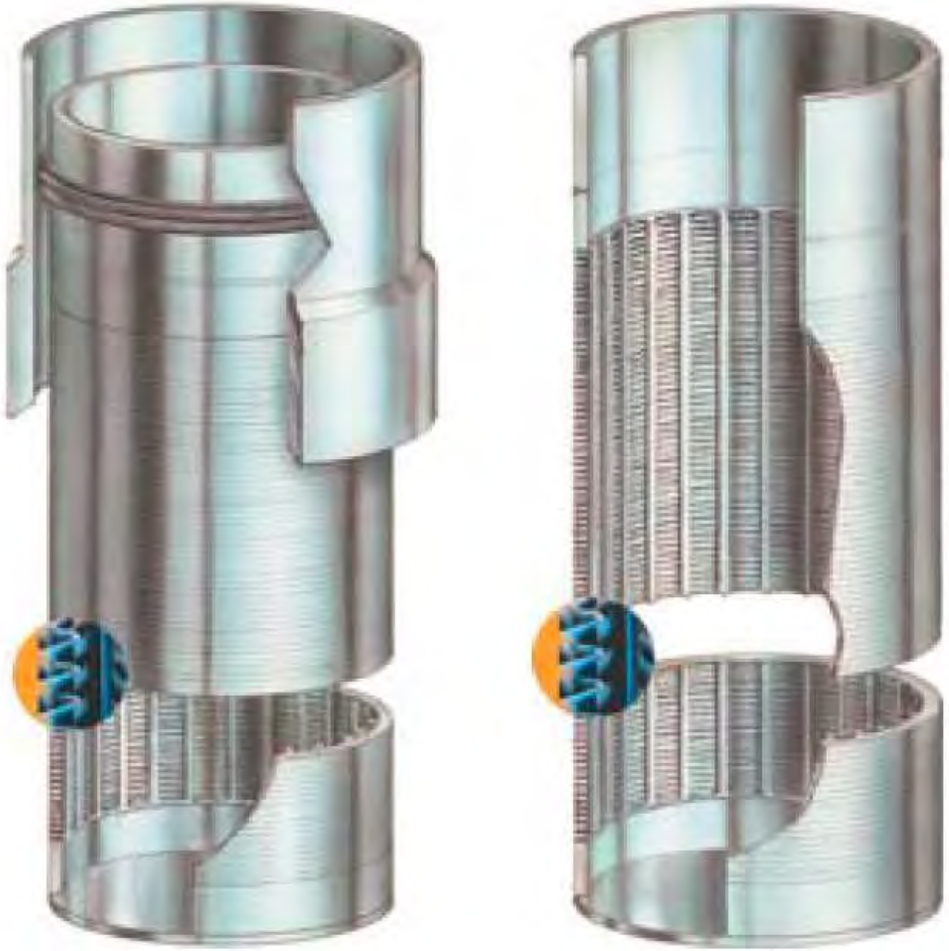
Casing Materials – Stainless Steel Wire-wrapped Screens

Johnson Screens:

- ✓ High % of open area
- ✓ High tensile strength
- ✓ Corrosion resistive (304 & 316 stainless steel)
- ✓ Expensive

Source: http://www.johnsonscreens.com

Casing Materials – Stainless Steel Wire-wrapped Screens



Telescope size screens (left) install through the casing and usually have a Figure K packer as the upper fitting. Pipe size screens (right) usually have weld rings at each end and attach directly to the casing.

Johnson screens®

Source: http://www.johnsonscreens.com

Casing Materials – MUNI-PAK™ PRE-PACKED WELL SCREENS

Johnson Pre-packed Screens:

- ✓ Smaller borehole needed
- ✓ Stronger construction
- ✓ Thinner filter pack
- ✓ Large open area
- ✓ Expensive

Johnson screens®

Source: http://www.johnsonscreens.com

Casing Materials – Pipe-based Screens

Pipe-based Screens:

- ✓ Greatest strength
- ✓ Rugged
- ✓ Thinner filter pack
- ✓ Large open area
- ✓ Expensive

Johnson screens®

Source: http://www.johnsonscreens.com

Casing Materials – Johnson screens®

STANDARD SCREEN

For shallow and medium-depth wells. High flow rates due to large open area.

REINFORCED SCREEN

For medium-depth and deep wells. Greater collapse strength is achieved with the use of heavy duty Vee-Wire®.

PIPE-BASED SCREEN

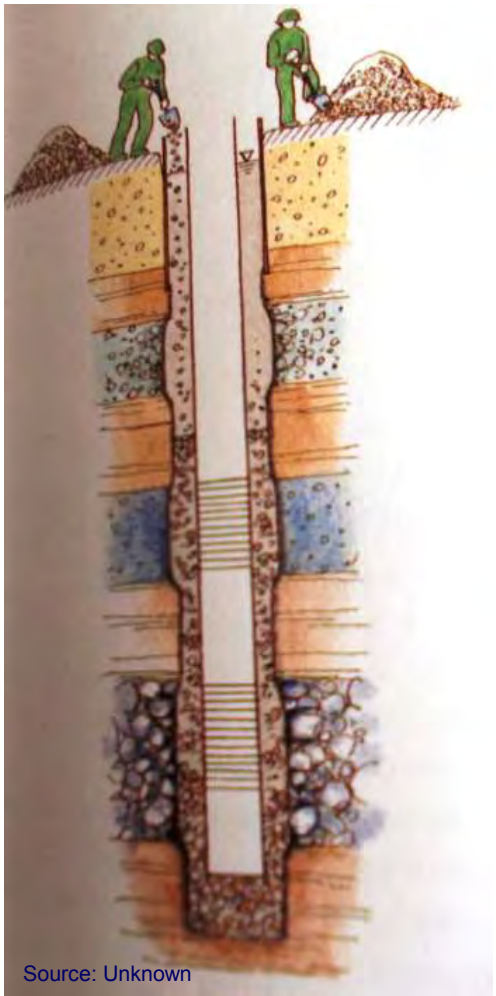
For deep wells. Very high strength as screen is supported by a perforated pipe.

Source: http://www.johnsonscreens.com

Kabul well Centralisers

Source: MEW

Installation of the gravel pack



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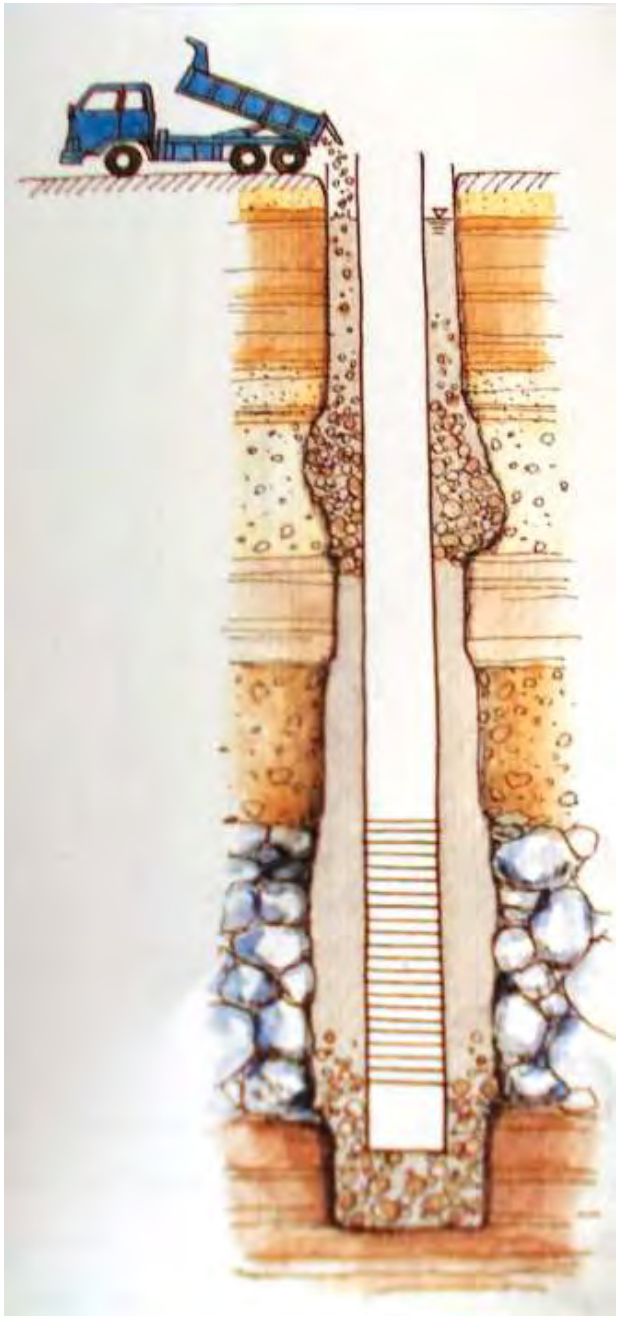
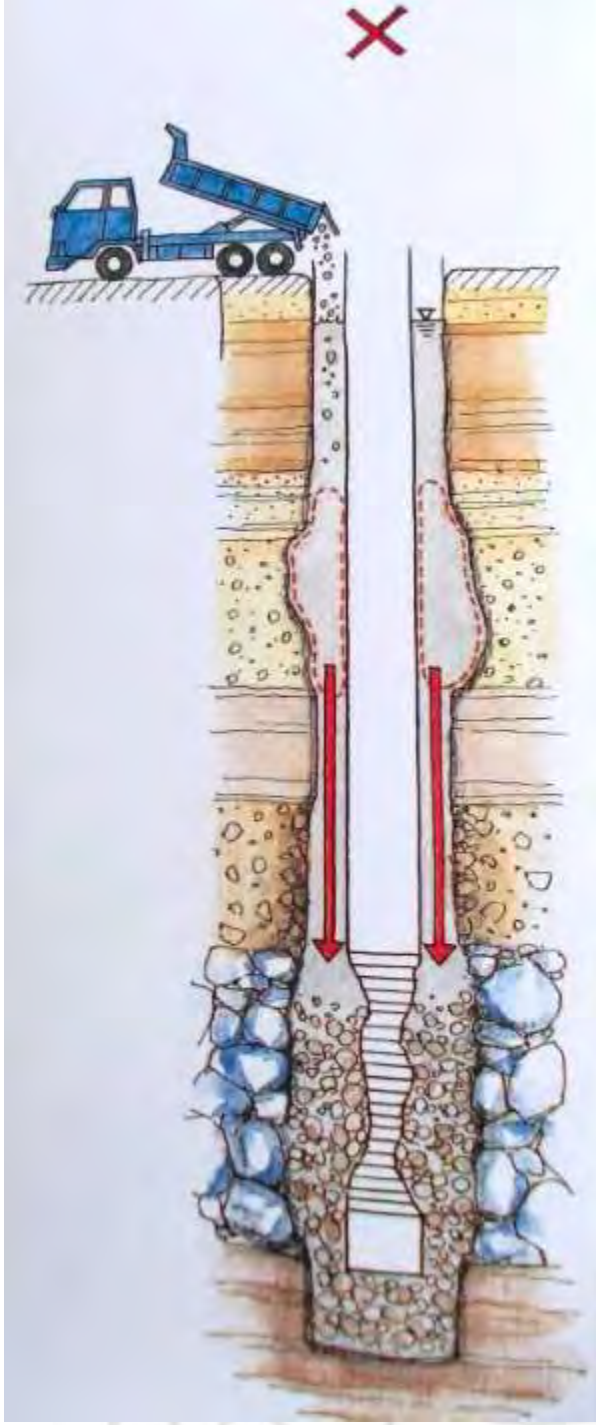


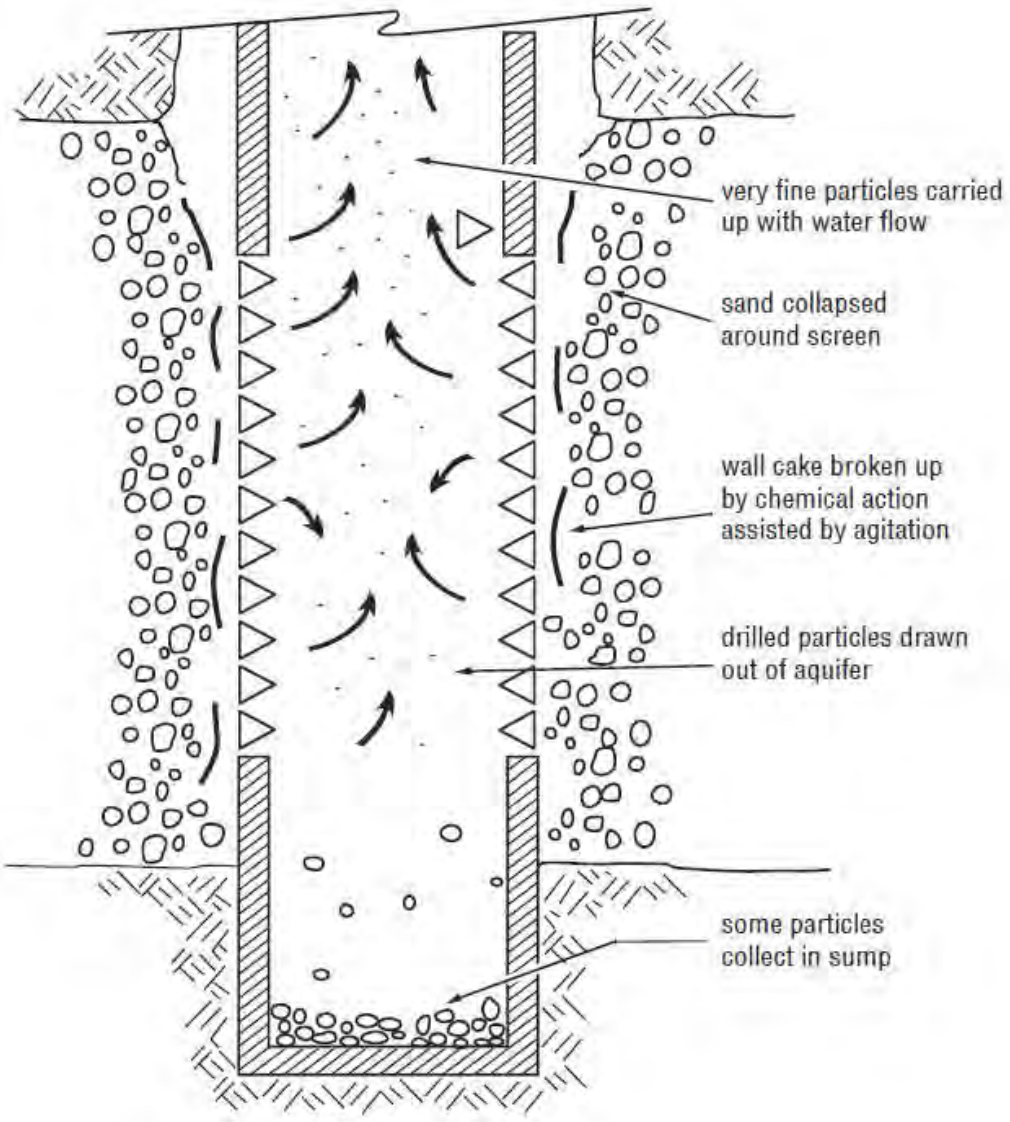


Well Development

The objectives of water well development are:

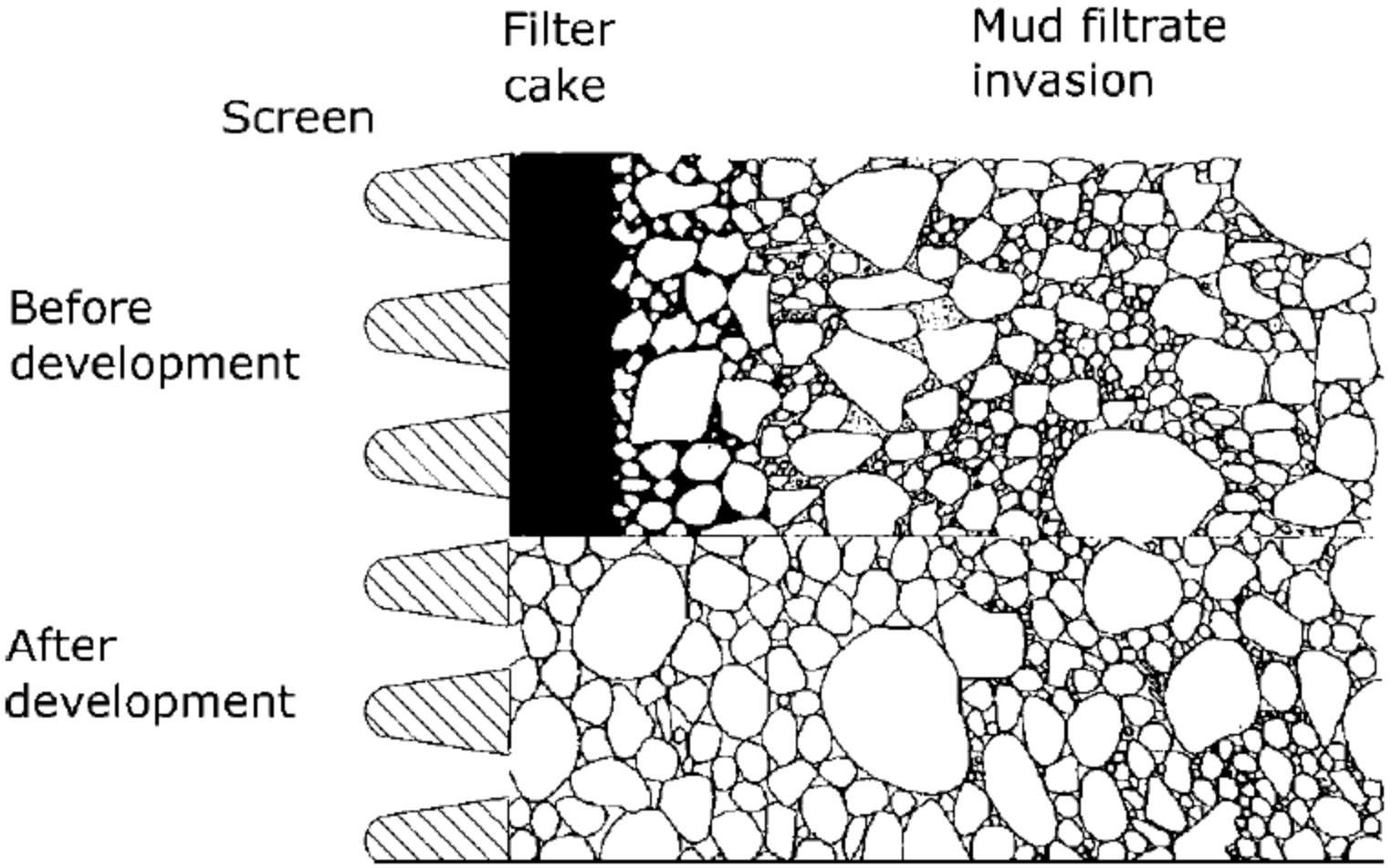
1. Improve the hydraulic efficiency of the well by removing fines from the formation near the well.
2. Reduce sand pumping to <25mg/L.
   Sand pumping can reduce the life of the pump, and cause sand blasting in the well casing.

Well Development



Source: Minimum construction requirements for water bores in Australia 3rd Edition, 2012.

Development of a Natural Gravel Pack



Source: B. Misstear, David Banks & L. Clark, 2006; Water Wells and Boreholes

Well Development Methods

Well development methods utilize mechanical, hydraulic or chemical techniques in order to maximize well production and efficiency. Technologies include:

a) Airlift pumping
b) Surging
c) Swabbing
d) Brushing
e) Jetting
f) Chemical treatment
g) Hydraulic fracturing

Airlift pumping

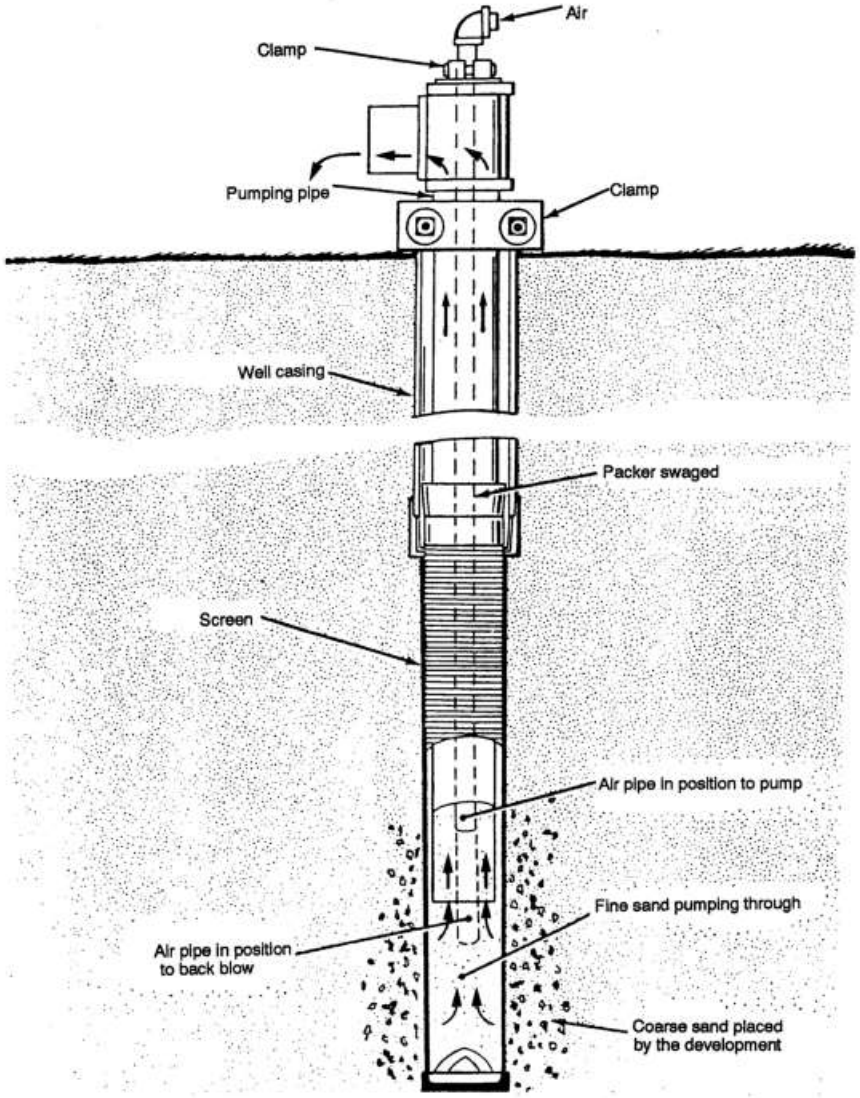


Figure 7-3. Placing the drop pipe and air line in the well

- Compressed air is pumped down the well through the airline.
- The airline is moved up and down relative to the drop pipe to either agitate the aquifer or pump out the water.

Source: https://rdl.train.army.mil/catalog/view/100.ATSC/E410BF83-C22A-4330-9350-DD056750B4F6-1274313873272/5-484/Ch7.htm

Kabul well airlift development

Source: MEW

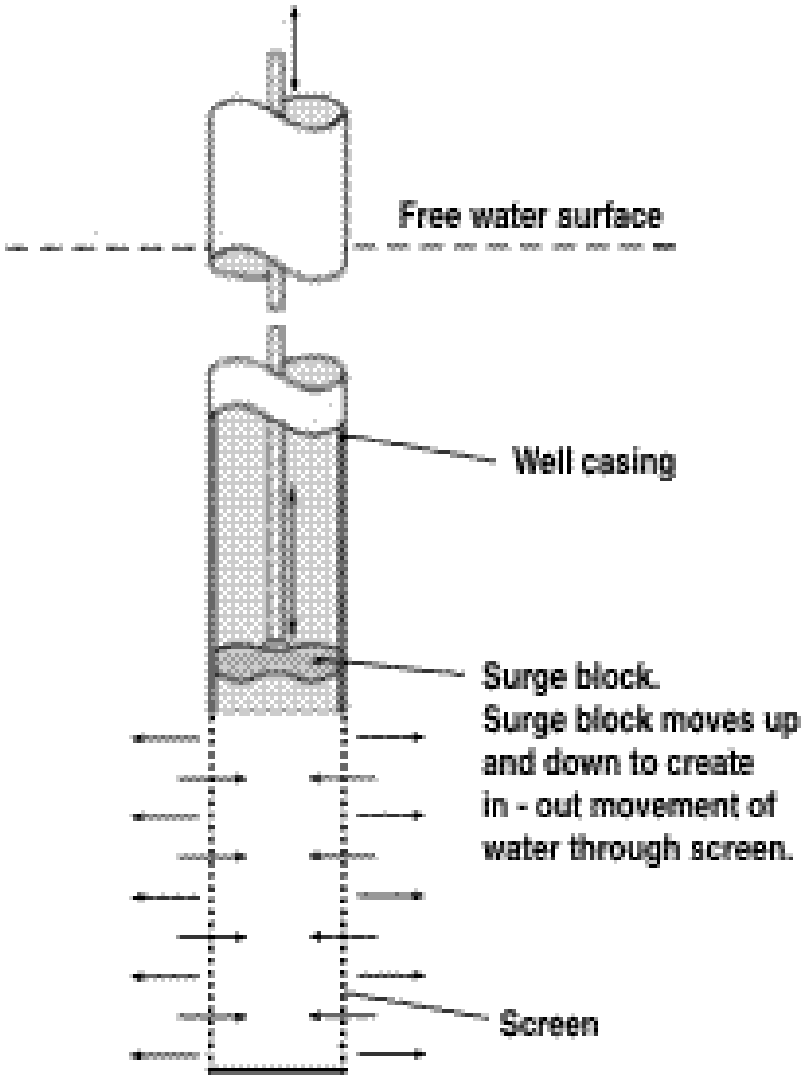
Kabul well airlift development

Source: MEW.

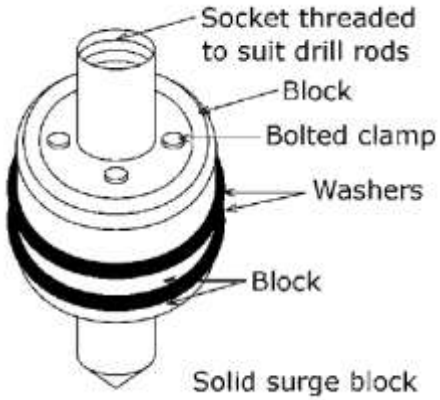
Kabul well airlift development

Source: MEW.

Surging

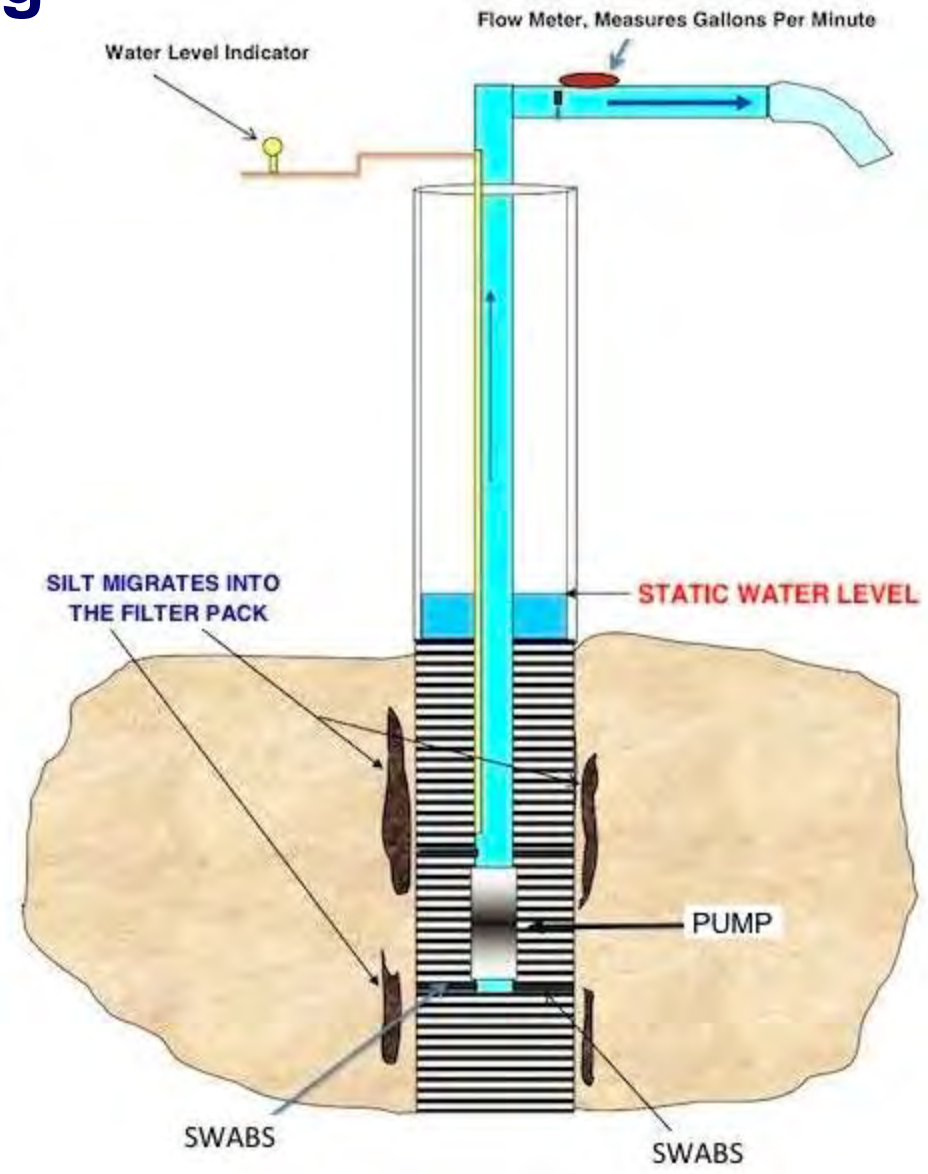


- The surge block is moved up & down inside the well.
- On the down stroke, water is forced outward into the formation.
- On the up stroke water, silt and fine sand are pulled into the well



Source: http://www.ext.nodak.edu/extnews/snouts/spout233.htm

Swabbing



Source: http://www.groundwaterpumpandwell.com/services/advance-hydro-well-development-tool/

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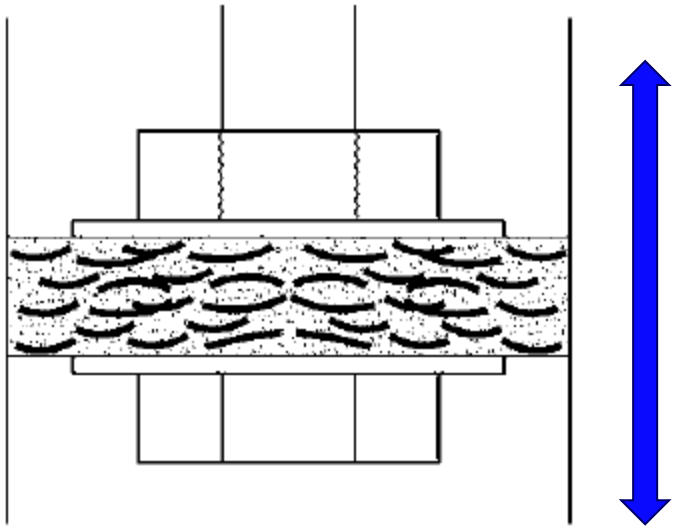
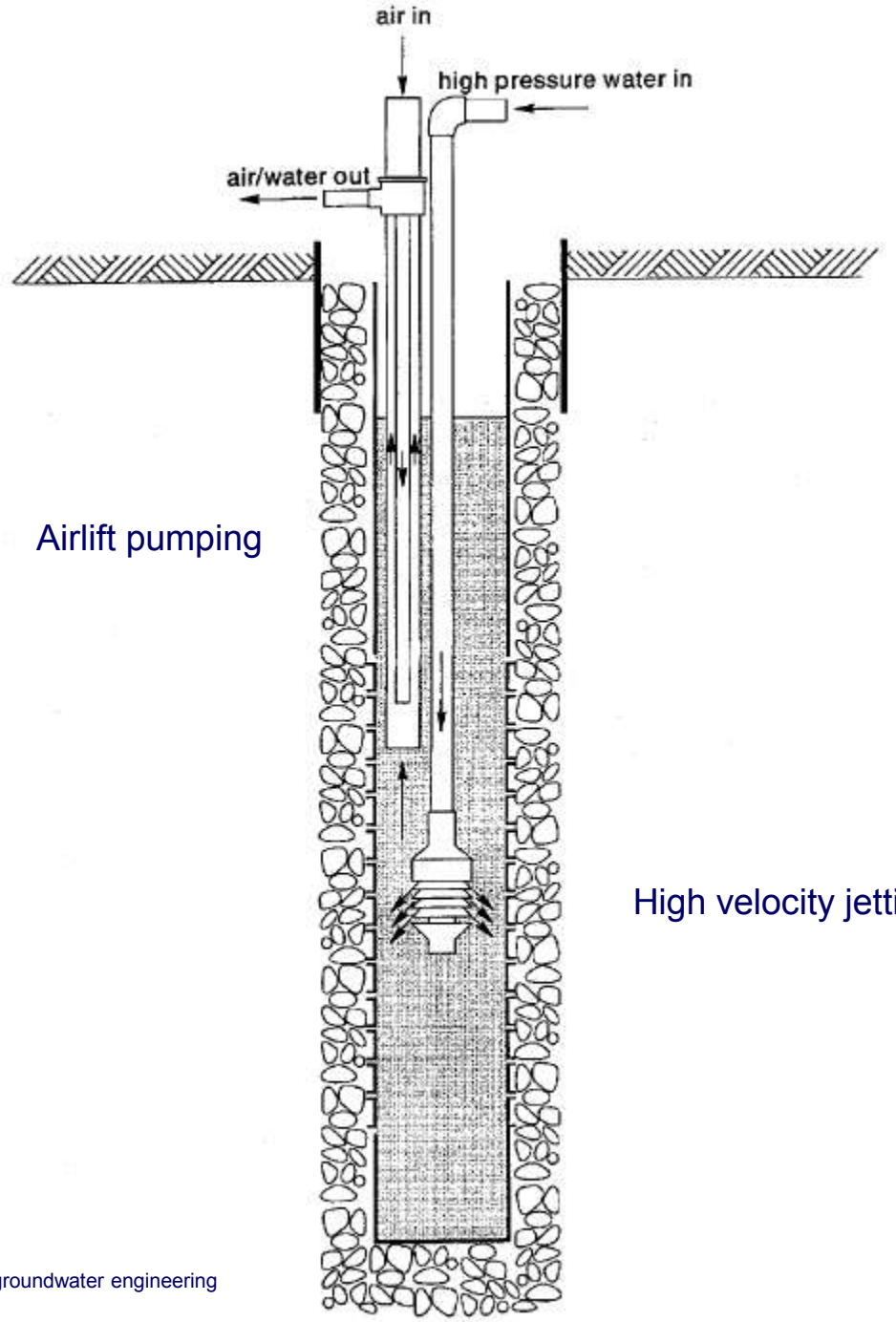
Brushing



Source: https://www.atlanticsupply.com/product_item.asp?id=2398&category_id=179

Jetting



Airlift pumping

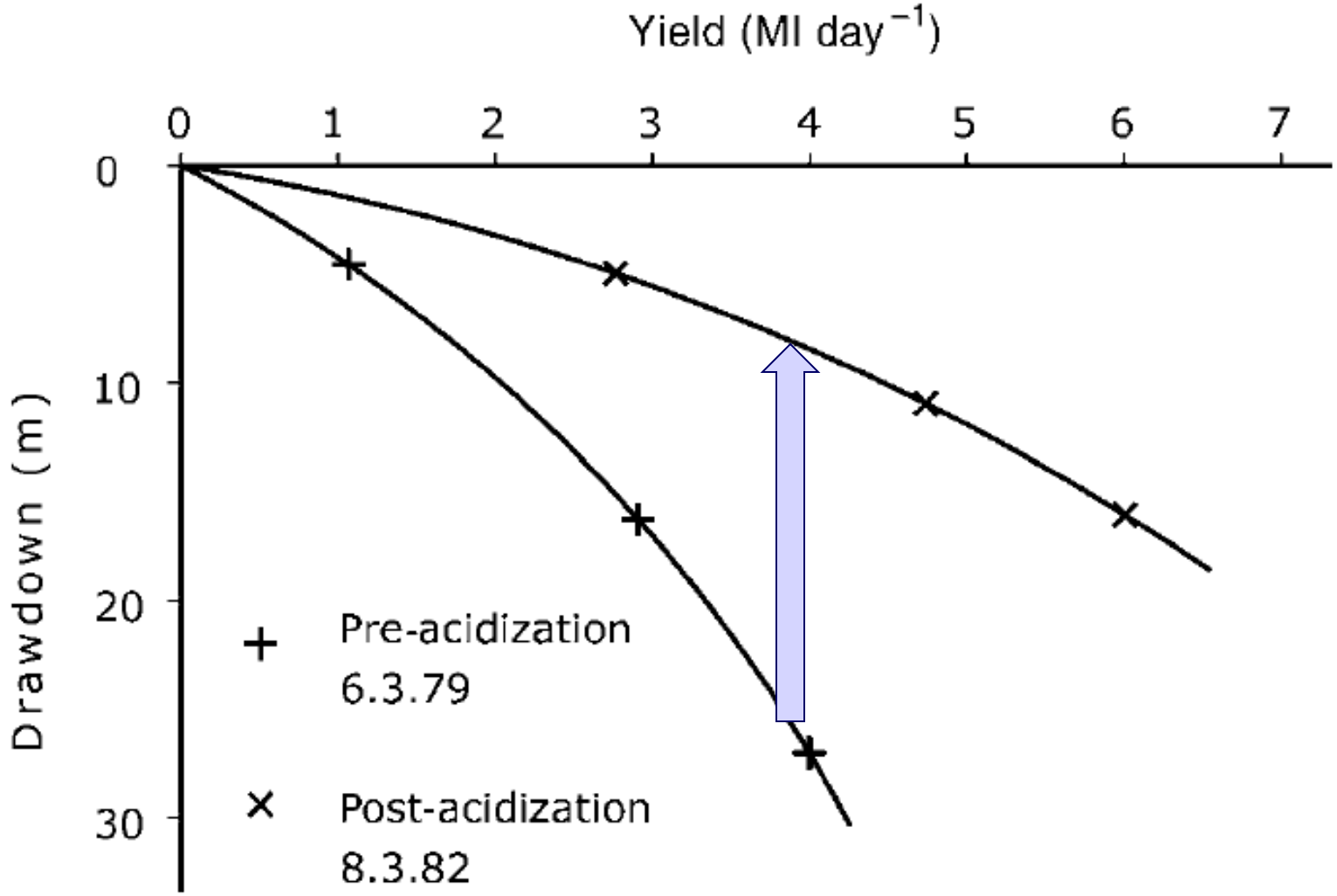
High velocity jetting

Source: JW Delleur,1999; The handbook of groundwater engineering

Chemical Application

Source: http://www.johnsonscreens.com

Acidization of a Chalk Well



Source: B. Misstear, David Banks & L. Clark, 2006; Water Wells and Boreholes

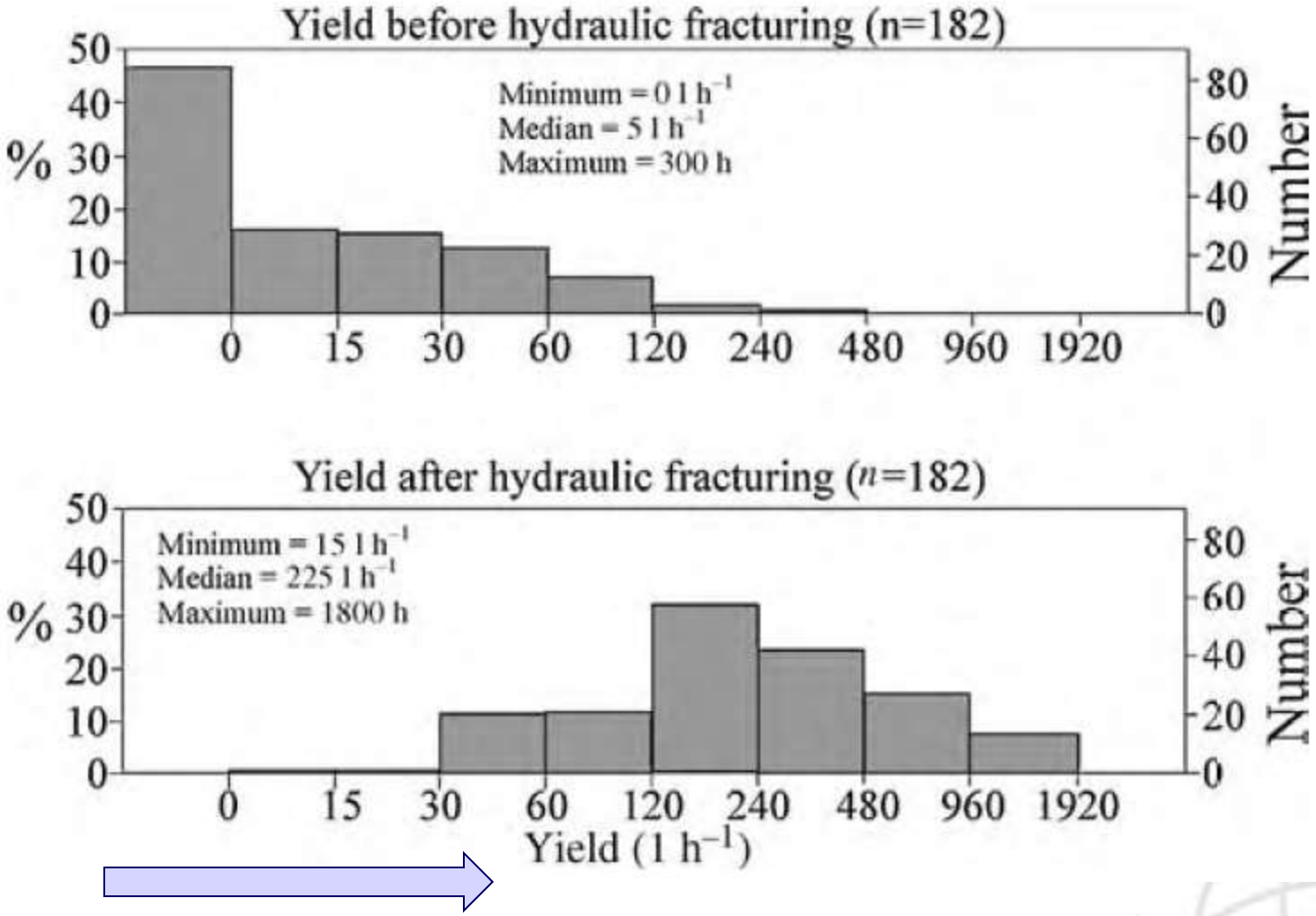
Chemical Application

Product	Remove Carbonate Scale	Remove Sulfate Scale	Remove Iron/ Manganese Scale	Remove Biofilm	Remove Hydrocarbon	Drill Mud Break Down	Remove Clays and Bentonite	Buffer Chlorine	Neutralize Chlorine
Nu-Well 100 Pelletized Acid	Good	Fair	Fair	Poor	Poor	No	No	Fair	No
	VG with *Nu-Well* 310	VG with *Nu-Well* 310	VG with *Nu-Well* 310	G with *Nu-Well* 310	F - G with *Nu-Well* 310				
Nu-Well 110 Granular Acid	Good	Fair	Fair	Poor	Poor	No	No	Fair	No
	VG with *Nu-Well* 310	VG with *Nu-Well* 310	VG with *Nu-Well* 310	G with *Nu-Well* 310	F - G with *Nu-Well* 310				
Nu-Well 120 Liquid Acid	Good	Good	Good	Poor	Poor	No	No	Good	No
	VG with *Nu-Well* 310	VG with *Nu-Well* 310	VG with *Nu-Well* 310	VG with *Nu-Well* 310	G with *Nu-Well* 310				
Nu-Well 220 Clay Dispersant	No	No	No	No	No	Fair	Good	No	No
						VG with X			
Nu-Well 310 Bioacid Dispersant	Poor	Poor	Poor	Good	Poor	No	Fair	Good	No
	VG with *Nu-Well* 120	VG with *Nu-Well* 120	VG with *Nu-Well* 120	VG with *Nu-Well* 120	F with *Nu-Well* 120		G with *Nu-Well* 400		
Nu-Well 320 Biocaustic Dispersant	No	No	No	Fair	Poor	No	No	No	No
Nu-Well 400 Non-ionic Surfactant	Add Surfactant to *Nu-Well* 100, *Nu-Well* 120, *Nu-Well* 310 or *Nu-Well* 320 to improve penetration of cleaning chemistry and hydrocarbon solubility.					No	No	No	No
Nu-Well 410 Chlorine Enhancer	No	No	Good	Fair	Fair - Good	No	No	VG	No
			Especially Iron Hydroxides						
Nu-Well 500 ChlorOut	No	No	No	No	No	No	No	No	VG

VG = Very Good, G = Good, F = Fair, X = Commercial sodium or calcium hypochlorite up to 1,200 ppm to facilitate polyacrylamide breakdown

Source: http://www.johnsonscreens.com

Hydraulic fracturing of 182 boreholes, Sweden



Source: B. Misstear, David Banks & L. Clark, 2006; Water Wells and Boreholes

Impulse Generation Technology

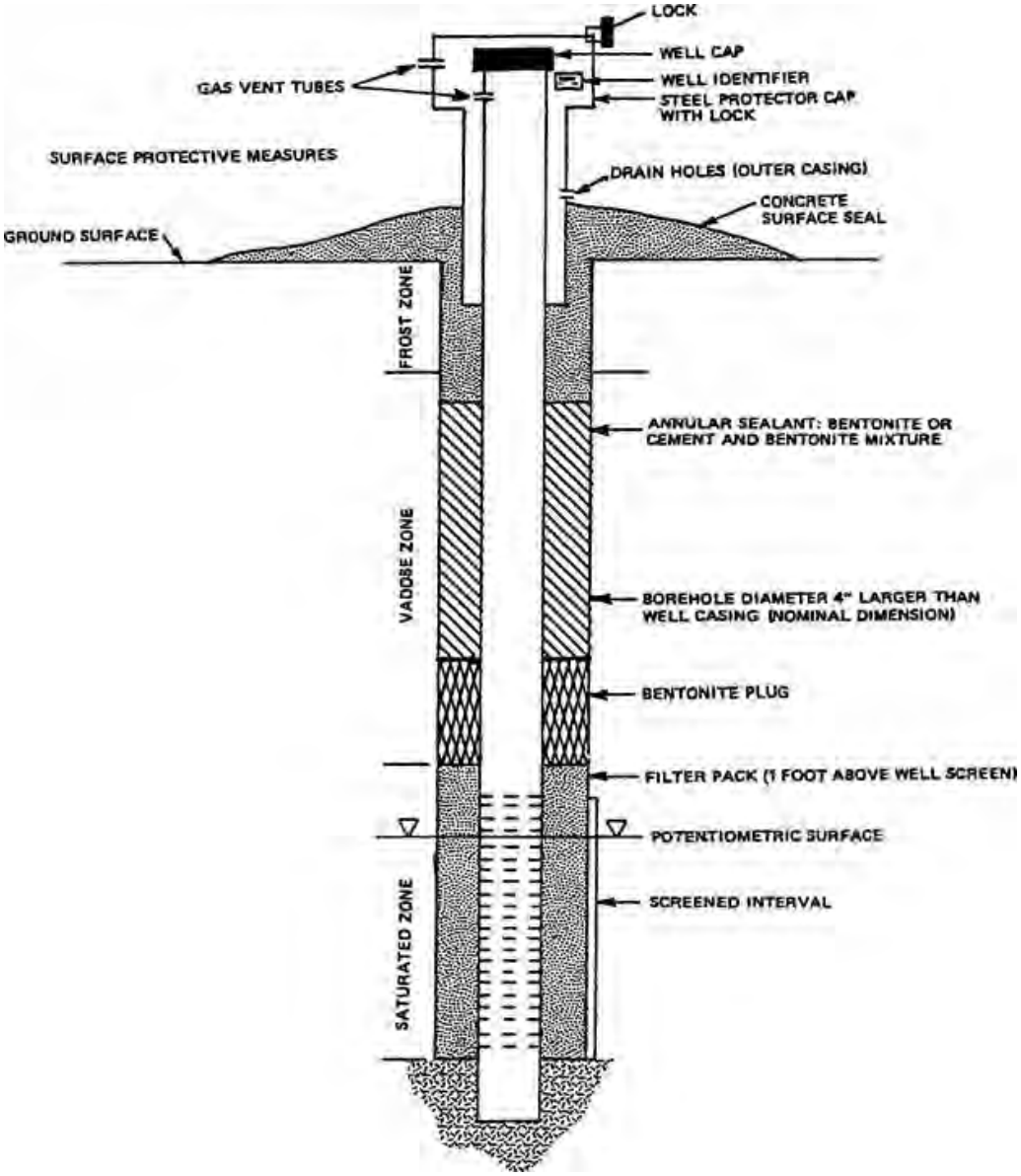
- Repeated instantaneous releases of high-pressure gas impulses inside the well
- Creates concussive shock waves
- Creates expanding, contracting and oscillating bubbles
- Intensely surges water in and out of the gravel pack, screen and/or aquifer
- Breaks up scale and encrustation
- Removes bacteria slime/biofouling

Airshock demo video:

http://www.youtube.com/watch?v=vnC7Mp7yTcM

Source: http://www.seidc.com/pages/well_rehabilitation.html

Well Completion Example



Source: http://apps.leg.wa.gov/wac/default.aspx?cite=173-160&full=true

Parwan Wellhead

Source: MEW.

Parwan Wellhead

Source: MEW.

Pumping Test Parwan

Source: MEW

Kabul well pumping test

Source: MEW

Pumping Tests will be covered in next course

NORAD supported project in MRRD covering
Capacity Building and Institutional Cooperation in the
field of Hydrogeology for Faryab Province
Afghanistan

Hydrogeology Course 1.5
Introduction to Well Hydraulics

By Andreas de Jong
September 2013

Well Disinfection

TABLE 4
CHLORINE DISINFECTANT REQUIRED
for 50 mg/l [ppm] CONCENTRATION in
30 METER [98 FEET] of WATER in a WELL

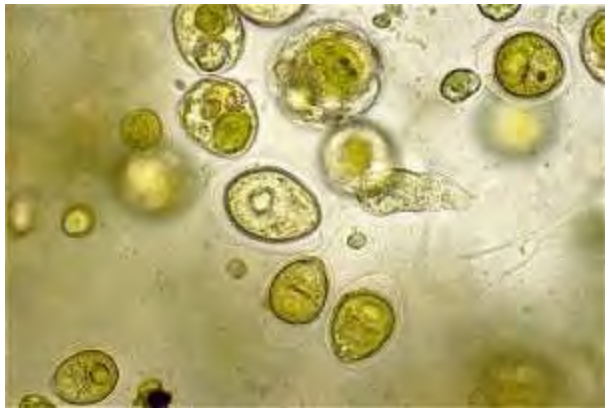
Hole Diameter		Hole Volume		65% Dry Weight*		5% Liquid**	
centi meters	inches	liters	gallons	grams	ounces	liters	ounces
5.1	2	62	16	5	0.2	0.1	2
10.2	4	247	65	19	0.7	0.2	8
12.7	5	386	102	30	1.0	0.4	13
15.2	6	556	147	43	1.5	0.6	19
20.3	8	988	261	76	2.7	1.0	33
25.4	10	1544	408	119	4.2	1.5	52
30.5	12	2224	587	171	6.0	2.2	75
35.6	14	3027	800	232	8.2	3.0	102
40.6	16	3953	1044	304	10.7	4.0	134
45.7	18	5003	1322	384	13.6	5.0	169
50.8	20	6177	1632	474	16.7	6.2	209
61.0	24	8894	2350	683	24.1	8.9	301
76.2	30	13898	3672	1067	37.6	13.9	470
91.4	36	20012	5287	1537	54.2	20.0	677

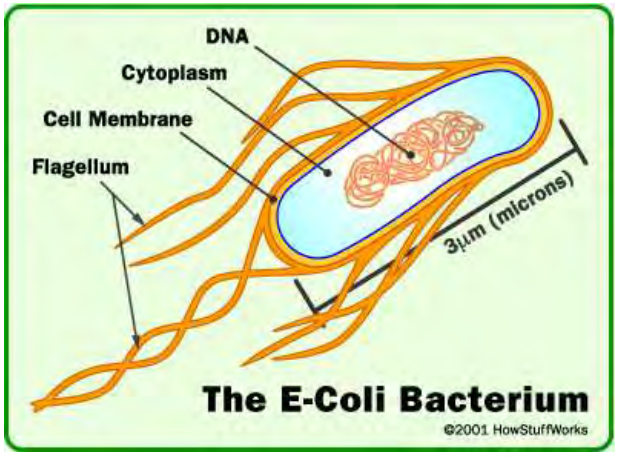
*65% dry weight is often found as granular calcium chloride.

**5% liquid is often found as liquid bleach.

The quantity of other compounds required to obtain the same concentration is proportional to the above percent concentrations.

The quantity of the above compounds required to obtain a concentration other than 50 mg/l [ppm] is proportional to the above quantities.





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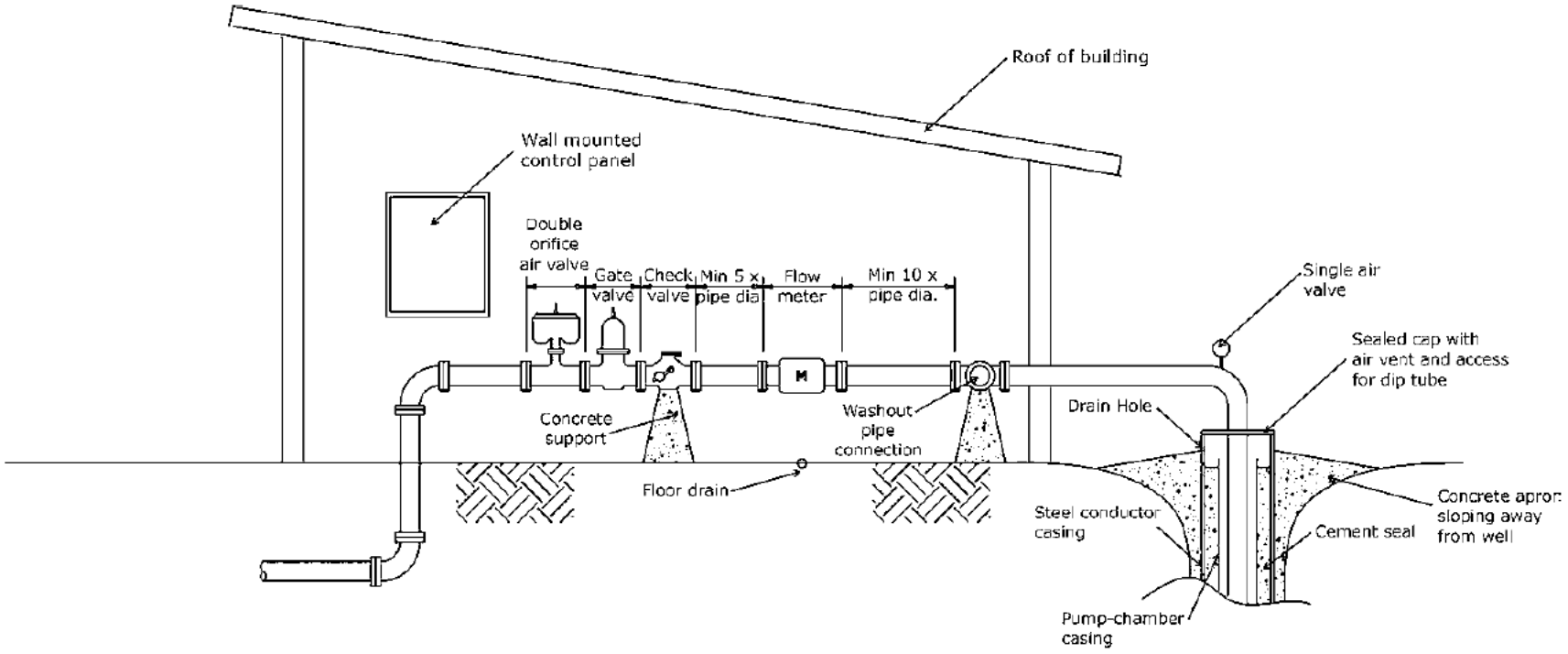
Above ground wellhead completion example



Source: B. Misstear, David Banks & L. Clark, 2006; Water Wells and Boreholes

Wellhead completion example in a wadi, Oman

Source: B. Misstear, David Banks & L. Clark, 2006; Water Wells and Boreholes

TOPICS TO BE COVERED

1. Introduction & Terminology
2. Well Location
3. Well Construction Methods
4. Well Drilling Methods
5. Well Completion & Development
6. Well Decommissioning
7. Cost Benefit Analysis
8. Drilling Management & Data Collection
9. Health & Safety

PART 6 – Well Decommissioning

1. When wells are no longer needed they need to be sealed properly to:
   a) avoid contamination of the aquifers
   b) avoid leakage of groundwater between aquifers of different heads.

Well Decommissioning – Non-flowing Wells

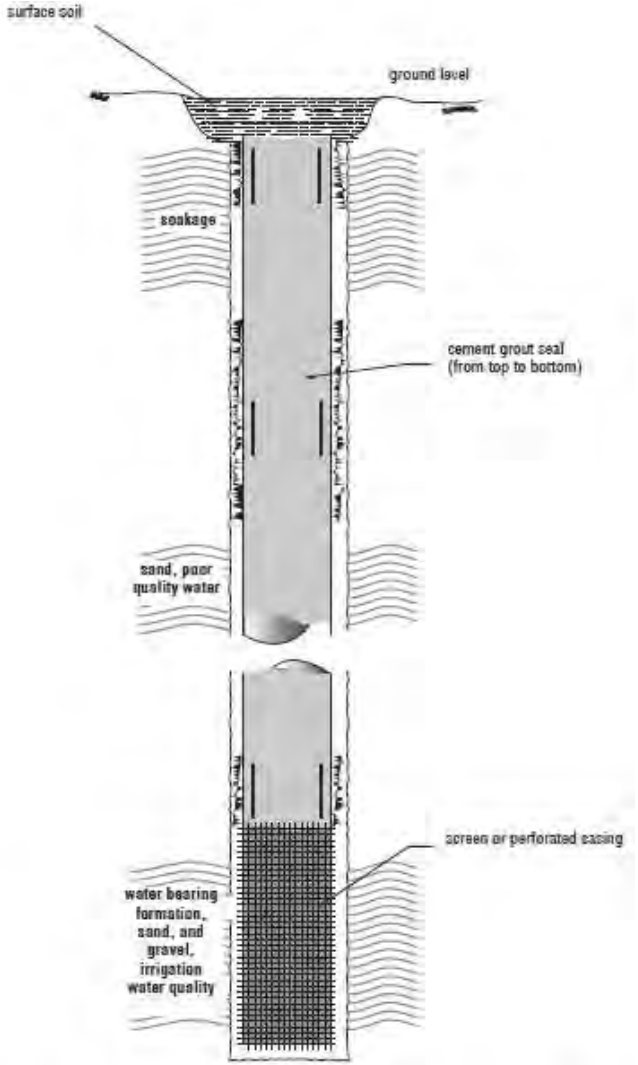


Figure 18.1 Decommissioning a non-flowing bore by fully grouting (preferred method for all bores)

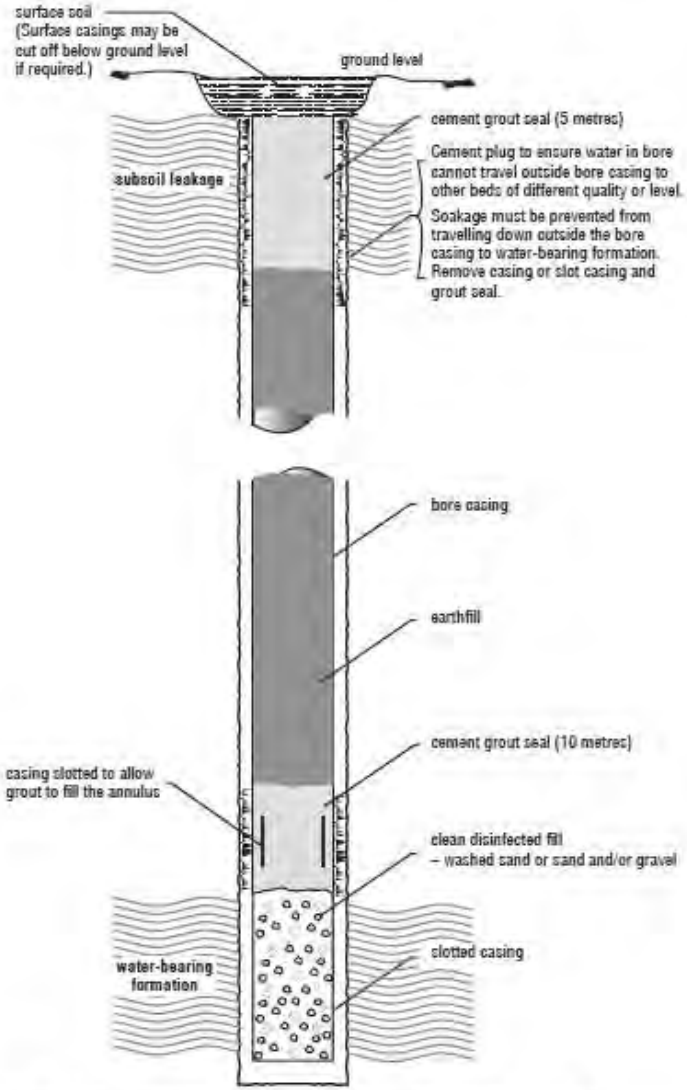


Figure 18.2 Decommissioning a single aquifer non-flowing bore

Source: Minimum construction requirements for water bores in Australia 3rd Edition, 2012.

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Well Decommissioning – Non-flowing Wells

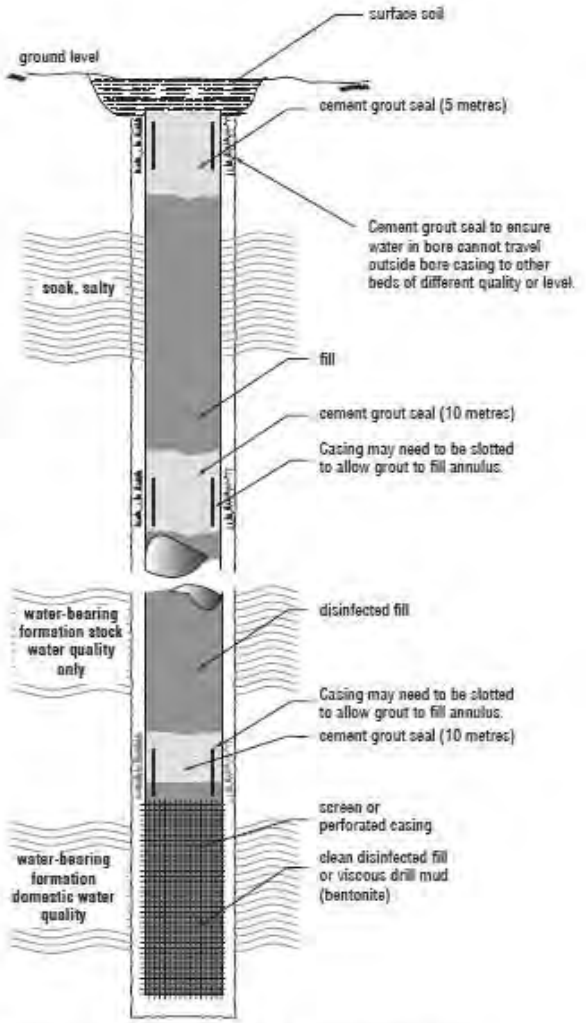

Figure 18.3 Decommissioning a multiple aquifer non-flowing bore using cement grout bridges

Source: Minimum construction requirements for water bores in Australia 3rd Edition, 2012.

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Well Decommissioning – Flowing Wells

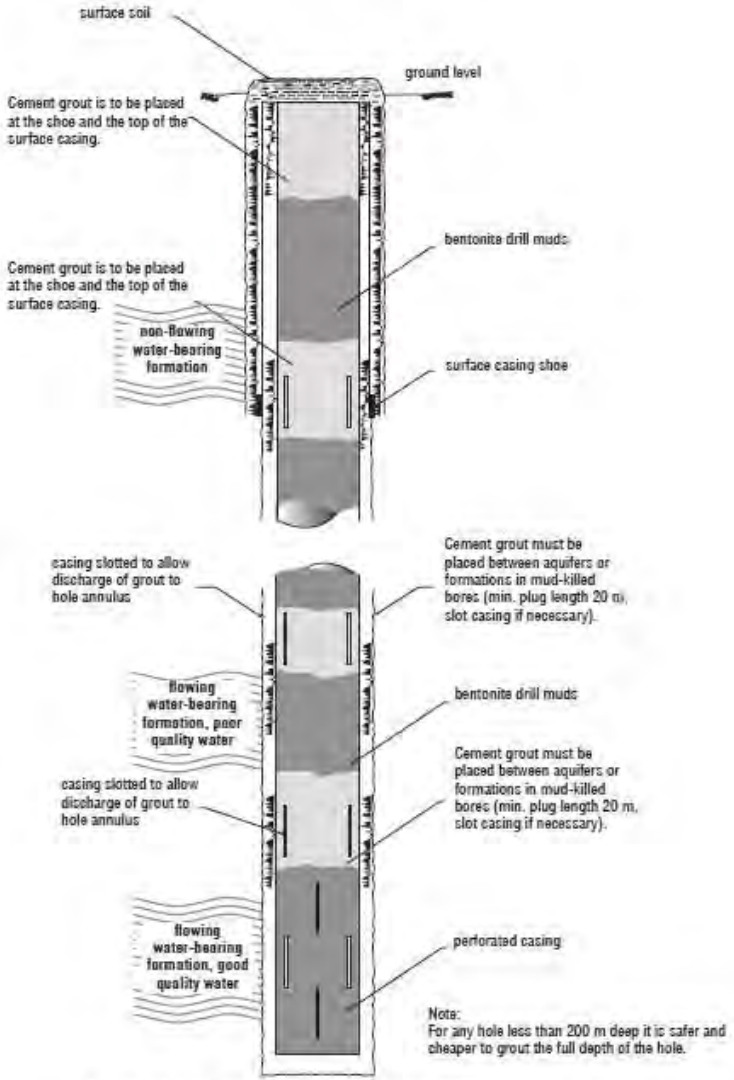

Figure 18.4 Decommissioning a flowing bore using cement grout bridges

Source: Minimum construction requirements for water bores in Australia 3rd Edition, 2012.

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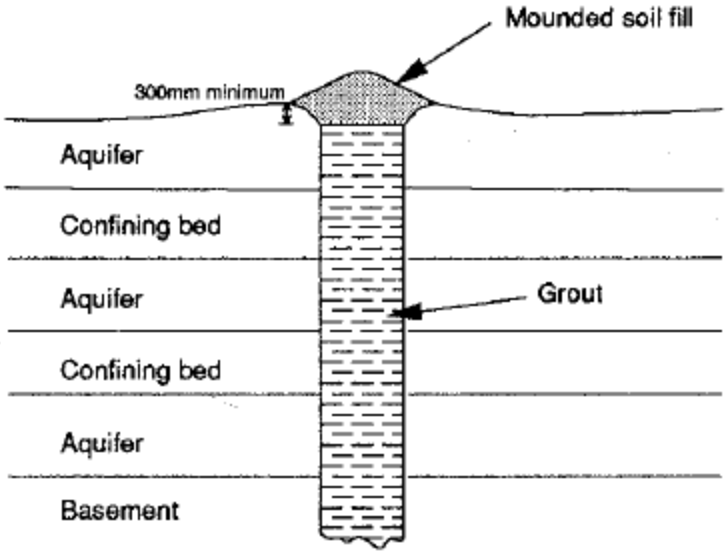
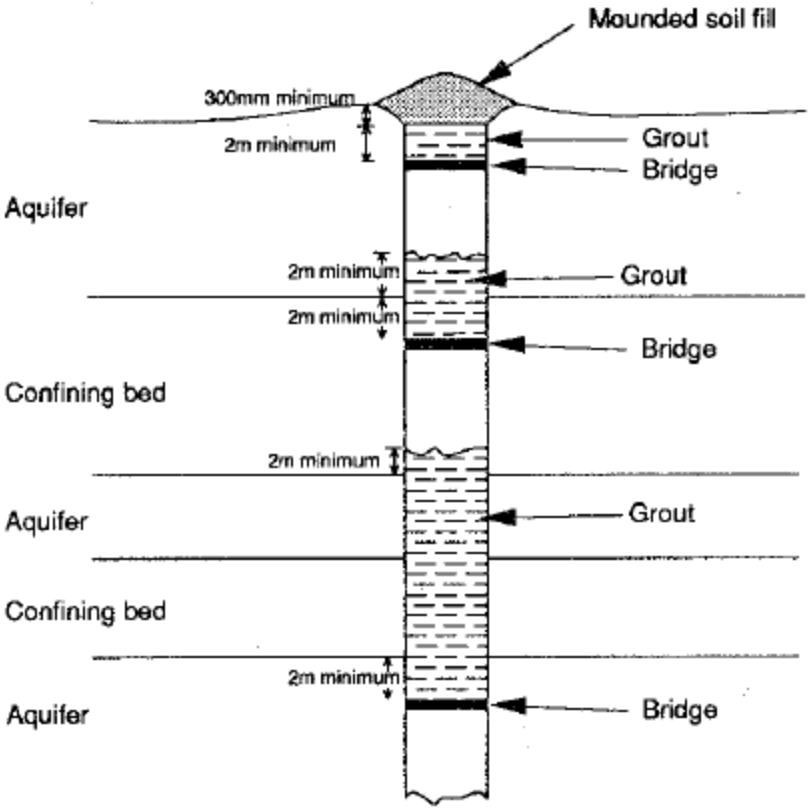
Decommissioning Exploration Boreholes



(a) Complete infilling of drillhole with cement grout



(b) Cement grout plugs set in drillhole

Source: http://new.dpi.vic.gov.au/__data/assets/pdf_file/0017/21284/2_GFEM.pdf

TOPICS TO BE COVERED

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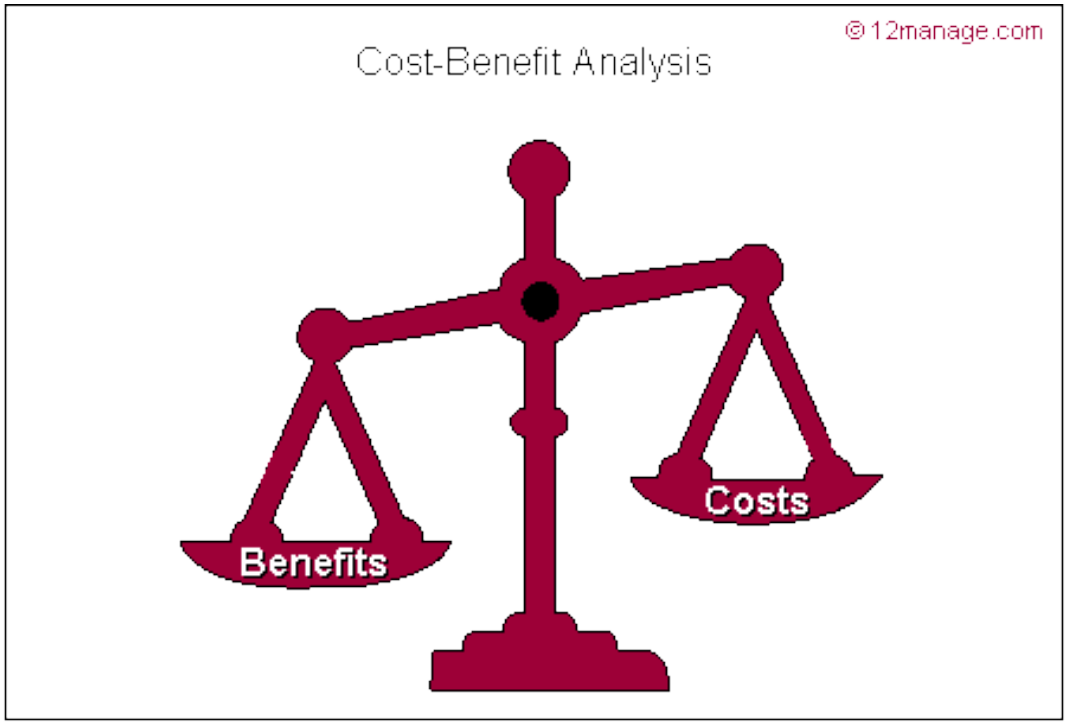
9. Health & Safety

PART 7 – Cost Benefit Analysis

Cost Benefit Analysis (CBA) is an analysis of the cost effectiveness of different alternatives in order to see whether the benefits outweigh the costs.



Source: http://www.12manage.com/methods_cost-benefit_analysis.html

Cost Benefit Analysis – Kenya Case Study

J. Whinnery (2012) in *A Well Construction Cost-Benefit Analysis: For Water Supply Well Guidelines for use in Developing Countries* compares the costs and benefits of a properly completed well versus inferior completed wells.

Factors of influence include:

- the lifespan of the well;
- the number of beneficiaries;
- project expenses;
- environmental and health consequences, and
- other economic factors.

Source: Jaynie Whinnery, 2012; A Well Construction Cost-Benefit Analysis (CBA): For Water Supply Well Guidelines for use in Developing Countries

Cost Benefit Analysis – Kenya Case Study

Estimated lifespan of wells:

- Properly constructed well with O&M = 20 years
- Inferiorly constructed well with O&M = 5 years
- Properly constructed well without O&M = 4 years
- Inferiorly constructed well without O&M = 1 year

Source: Jaynie Whinnery, 2012; A Well Construction Cost-Benefit Analysis (CBA): For Water Supply Well Guidelines for use in Developing Countries

Cost Benefit Analysis – Kenya Case Study

CBA Project Alternative	Total Benefits PDV	Total Cost PDV	Total NPV	Benefit/Cost Ratio
Proper Construction; With O&M	$670,651	$17,455	$653,196	38.42
Inferior Construction; With O&M	$206,445	$12,583	$193,862	16.41
Proper Construction; No O&M	$167,560	$14,876	$152,684	11.26
Inferior Construction; No O&M	$43,765	$11,914	$31,851	3.67
Inferior Construction; No O&M; Local GW Quality Compromised, No Treatment	$0	$11,914	-$11,914	0
Inferior Construction; With O&M; Local GW Quality Compromised, No Treatment	$0	$12,583	-$12,583	0
Inferior Construction; No O&M; Local GW Quality Compromised, Treatment Provided	$43,765	$171,601	-$127,836	0.26
Inferior Construction; With O&M; Local GW Quality Compromised, Treatment Provided	$206,445	$765,845	-$559,399	0.27

Source: Jaynie Whinnery, 2012; A Well Construction Cost-Benefit Analysis (CBA): For Water Supply Well Guidelines for use in Developing Countries

Cost Benefit Analysis – Kenya Case Study

1. Wells need to be constructed properly & money generated/set aside for operation & maintenance in order to achieve full economic benefit of the investment.
2. Inferior construction of wells will reduce their lifespans & could also cause serious negative impacts such as groundwater contamination & aquifer damage.

Water well construction is not for amateurs!

Source: Jaynie Whinnery, 2012; A Well Construction Cost-Benefit Analysis (CBA): For Water Supply Well Guidelines for use in Developing Countries

TOPICS TO BE COVERED

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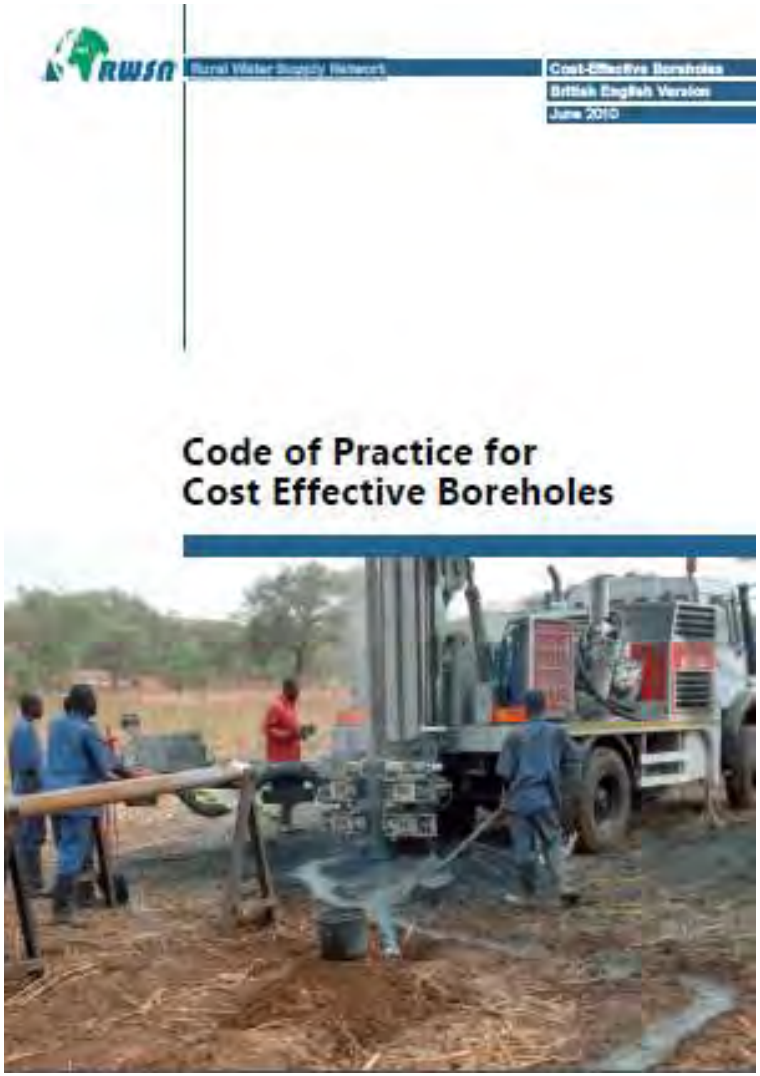
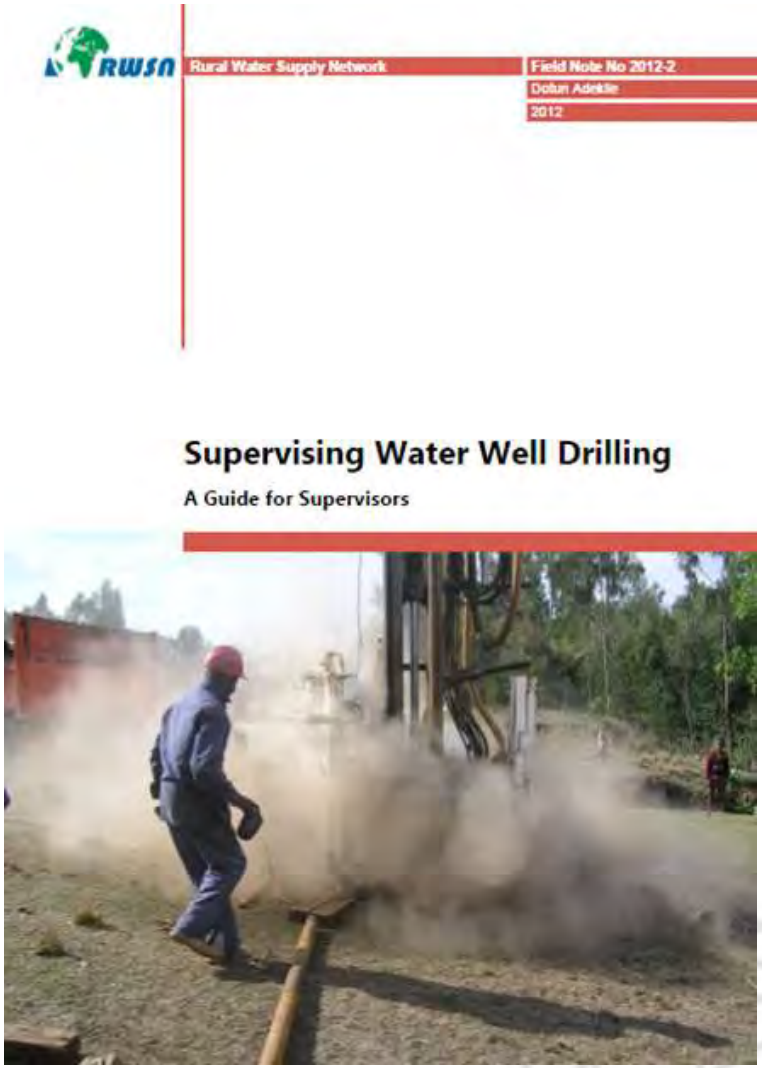
8. Drilling Management & Data Collection
9. Health & Safety

PART 8 – Drilling Management

1. Principles of cost-effective wells
2. Management of drilling contractor.
3. Inspection of drill site.
4. Data to be collected during drilling.
5. When things go wrong.

Drilling Management – Key References





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Nine Principles for Cost-Effective Wells

- ✓ **Principle 1: Professional Drilling Enterprises and Consultants** - Construction of drilled water wells and supervision is undertaken by professional and competent organisations which adhere to national standards and are regulated by the public sector.
- ✓ **Principle 2: Siting** - Appropriate siting practices are utilised and competently and scientifically carried out.

Source: RWSN 2010, Code of Practice for Cost Effective Boreholes

Nine Principles for Cost-Effective Boreholes

- ✓ **Principle 3: Construction Method** - The construction method chosen for the borehole is the most economical, considering the design and available techniques in-country. Drilling technology needs to match the borehole design.
- ✓ **Principle 4: Procurement** - Procurement procedures ensure that contracts are awarded to experienced and qualified consultants and drilling contractors.

Source: RWSN 2010, Code of Practice for Cost Effective Boreholes

Nine Principles for Cost-Effective Boreholes

- ✓ **Principle 5: Design and Construction** - The borehole design is cost-effective, designed to last for a lifespan of 20 to 50 years, and based on the minimum specification to provide a borehole which is fit for its intended purpose.
- ✓ **Principle 6: Contract Management, Supervision and Payment** - Adequate arrangements are in place to ensure proper contract management, supervision and timely payment of the drilling contractor.

Source: RWSN 2010, Code of Practice for Cost Effective Boreholes

Nine Principles for Cost-Effective Boreholes

- ✓ **Principle 7: Data and Information** - High quality hydrogeological and borehole construction data for each well is collected in a standard format and submitted to the relevant Government authority.
- ✓ **Principle 8: Database and Record Keeping** - Storage of hydrogeological data is undertaken by a central Government institution with records updated and information made freely available and used in preparing subsequent drilling specifications.

Source: RWSN 2010, Code of Practice for Cost Effective Boreholes

Nine Principles for Cost-Effective Boreholes

- ✓ **Principle 9: Monitoring** - Regular visits to water users with completed boreholes are made to monitor functionality in the medium as well as long term with the findings published.

Source: RWSN 2010, Code of Practice for Cost Effective Boreholes

Management of drilling contractor

1. What are the characteristics of a good drilling contractor?
2. How do we select the best one?
3. How do we get value for money?
4. How do we control the drilling contractor during the well drilling operations?
5. How do we pay the contractor?

Levels of Supervision

1. Full-time supervision
2. Part-time milestone supervision
   - mobilisation
   - check siting/site selection
   - termination of drilling
   - lining of the borehole
   - borehole development
   - pumping test
   - demobilisation
   - platform construction and pump installation
3. End of contract supervision

Source: RWSN 2012, **Supervising Water Well Drilling, A guide for supervisors**

Supervision Tools

4T10 SITE INSTRUCTION PRO-FORMA

From: Principal Agent
Name: .....
Company: .....
Date: .....

To: Contractor
Name: .....
Company: .....
Fax No: .....

RE: PROJECT NO: ..... **PROJECT NAME:** .....

Following our recent visit to the abovementioned project on ..... [Date], we hereby wish to bring to your attention the following concerns:

1. Problems Identified	Problems Resolved *	
	Date	Initial

2. Actions Required	By Whom	By When

3. **Conditions for Authorisation of next Contractors Payment Claim:**

.....
.....
.....
.....

Signed: ..... Received by: .....
Project Manager / Designer Contractors Representative

Distribution: Original - Contractor , Copy - Project Manager , Copy – IA Project Manager

4T10 Site Instruction v4-0

Source: RWSN 2012, **Supervising Water Well Drilling, A guide for supervisors**

Inspection of Drilling Site

1. Is the rig & other equipment in good condition?
2. Is the equipment available on site sufficient to do the job?
3. Are there enough spare parts available?
4. Are the drill crew wearing the correct safety equipment?
5. Is the site clean and organised?
6. What precautions are in place to deal with potential accidents?

Documentation: Well Records

Minimum information to be collected:

- Well location (GPS & description)
- Well identification number
- Well owner/user
- Well contractor's name/organisation
- Drill depth & well completion depth
- Cuttings log
- Water strike log & yield with depth
- Well design (full details of casing, screen, gravel pack, grout seals, conductor casing etc)
- Date & depth to static water level
- Date and data of well yield test.

Source: S. J. Schneider, 2012; Water Supply Well Guidelines for Use in Developing Countries, Second Edition.

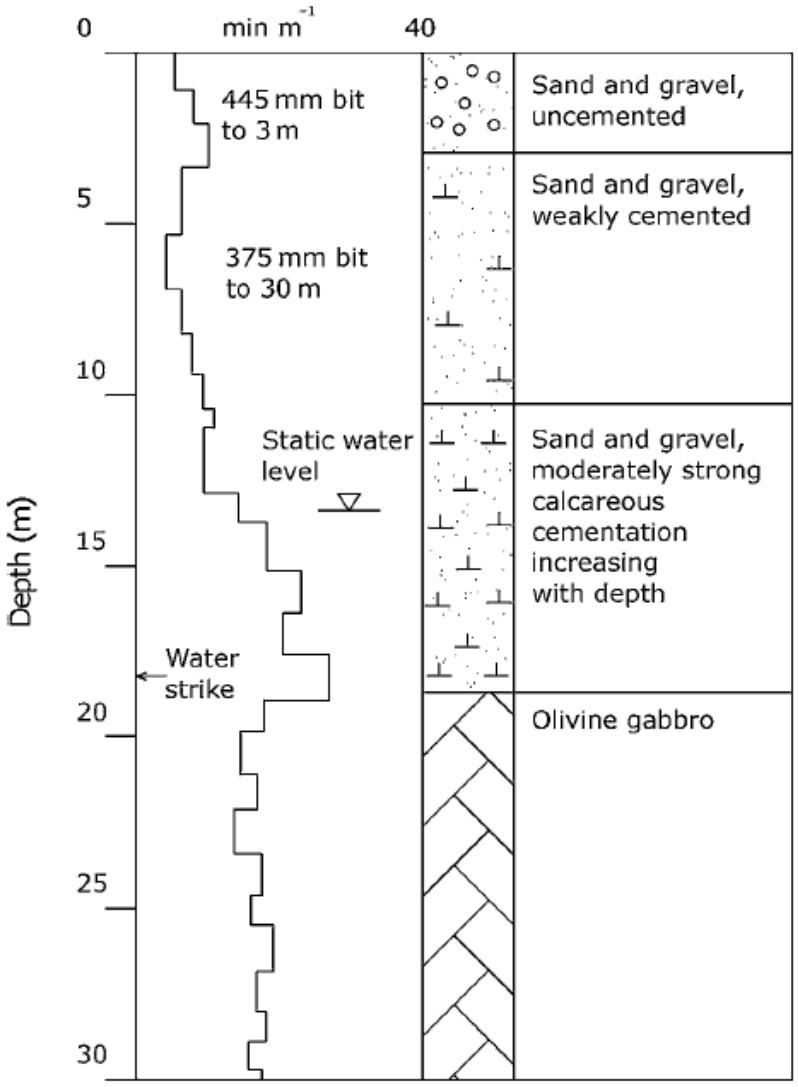
Documentation: Wall Supply Well Records

Minimum information to be collected:

- Pump record: type of pump, rising main, depth of pump installation, voltage & phase if electric powered, manufacturer, model, serial number etc.
- Water quality records: date & results of chemical tests, name of individual collecting sample, date sample was taken, name of lab & individual analysing the sample, test methods utilized.

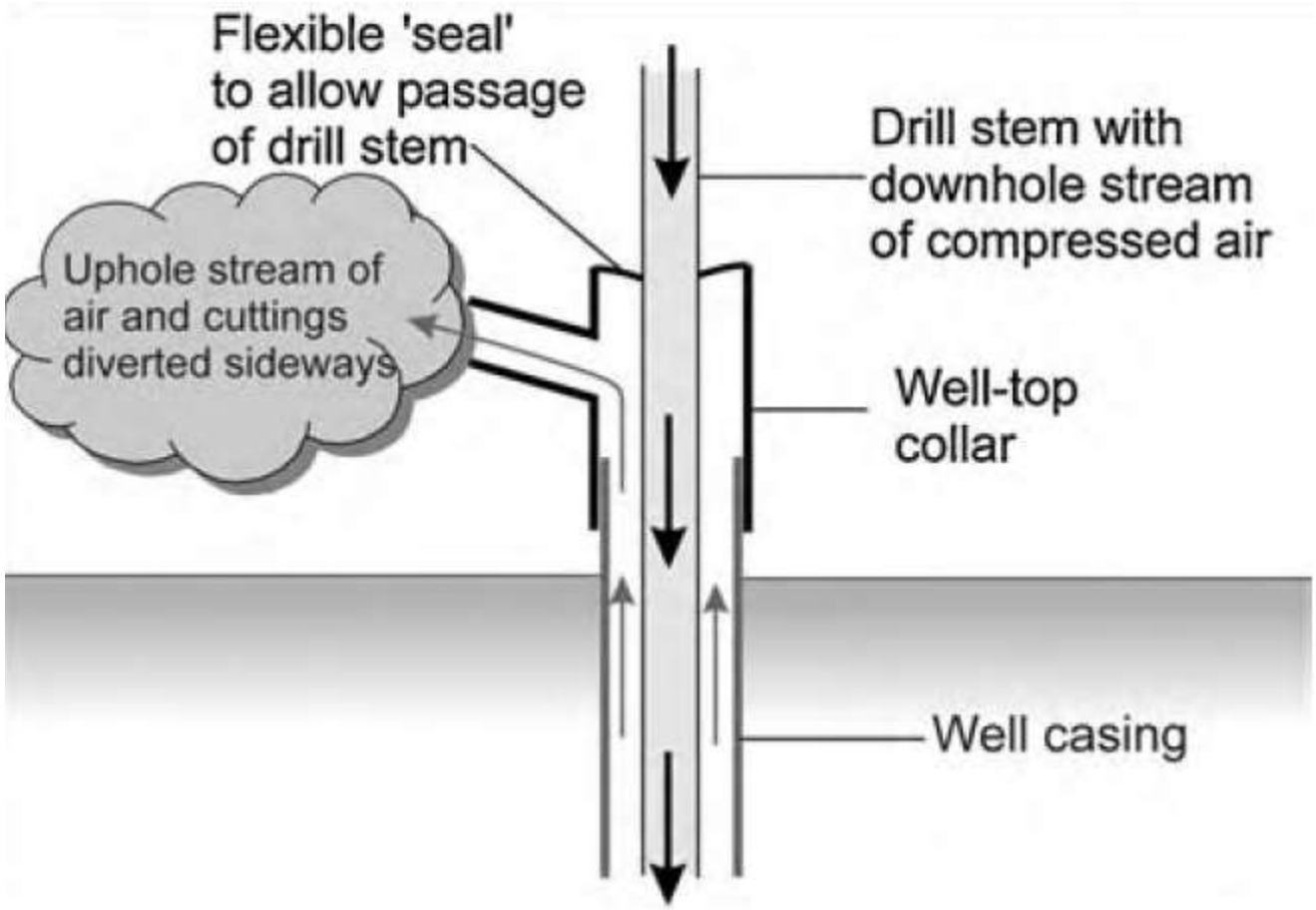
Source: S. J. Schneider, 2012; Water Supply Well Guidelines for Use in Developing Countries, Second Edition.

Borehole Penetration Log Example



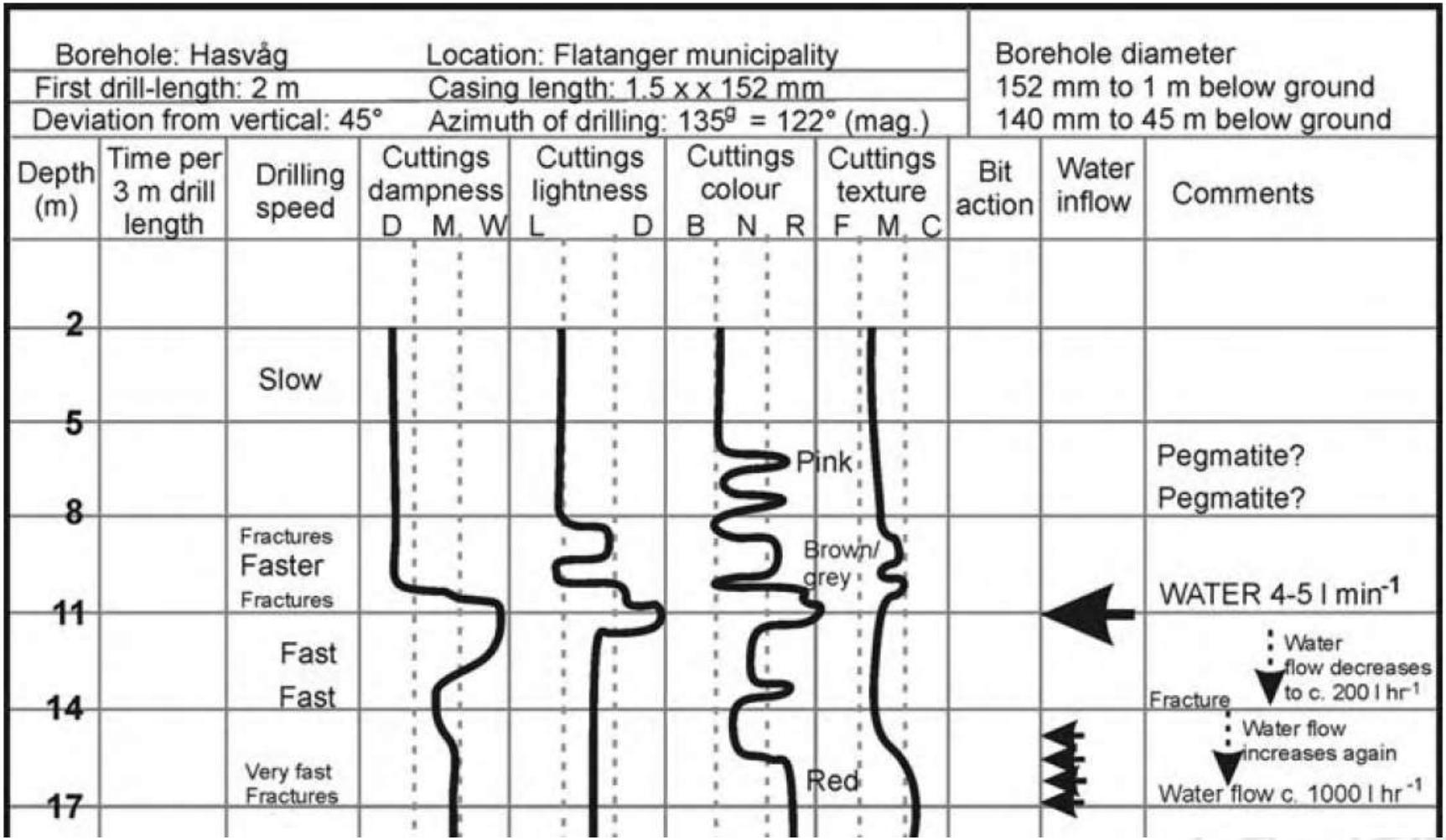
Source: B. Misstear, David Banks & L. Clark, 2006; Water Wells and Boreholes

DTH Drilling – Sample collection



Source: B. Misstear, David Banks & L. Clark, 2006; Water Wells and Boreholes

Cuttings Log – Norway Example

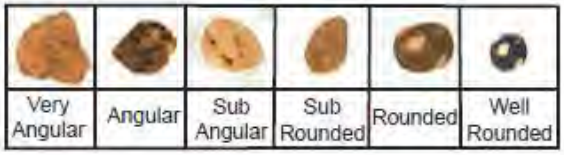


Source: B. Misstear, David Banks & L. Clark, 2006; Water Wells and Boreholes

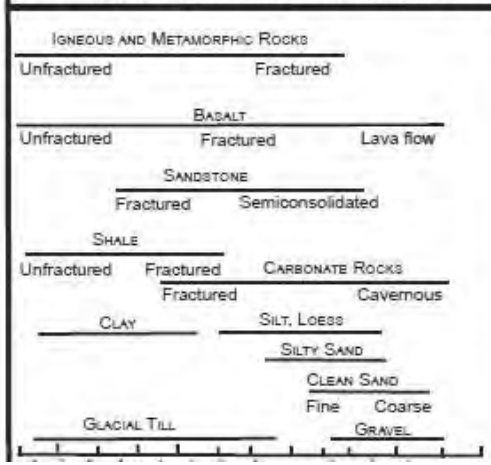
Describing Drill Cuttings

Sand / Slot Size Gauge

Gauge	Name	Natural Development Slot		Filter Pack	Filter Pack Slot	
		inches	mm	sieve	inches	mm
	Gravel	0.125	3.2	3/8" - 3/4"	0.250	6.4
	Sand - Coarse	0.100	2.5	4 - 3/8"	0.160	4.1
		0.080	2.0	3 - 6	0.120	3.0
	Sand - Medium	0.060	1.5	4 - 8	0.090	2.3
		0.040	1.0	6 - 12	0.070	1.8
	d - Fine	0.020	0.5	10 - 20	0.040	1.0



Range of Hydraulic Conductivities



Source: Minimum construction requirements for water bores in Australia 3rd Edition, 2012.

NORPLAN

Parwan Cuttings samples

Source: MEW

Sieve Analysis in MEW Laboratory

Source: MEW

Sieve Analysis Report

SIEVE ANALYSIS REPORT

CLIENT: Bill Brown

BORE NO.: 123456 SAMPLE NO.: 1

ADITC REFERENCE NO.: 413

REMARKS:

EXAMPLE

Modal Size = Greatest Mass Retained

= 0.21 mm on Sieve No. 70

Then 0.21 X 5 = 1.05 mm Pack Material

Screen Aperture selected is 20% smaller

than pack material i.e. 1.05 x 0.8 = 0.84 mm

SIEVE ANALYSIS Sample Mass: 448.6 g

Method of Bore Construction:

☐ Natural Pack

☑ Gravel Pack

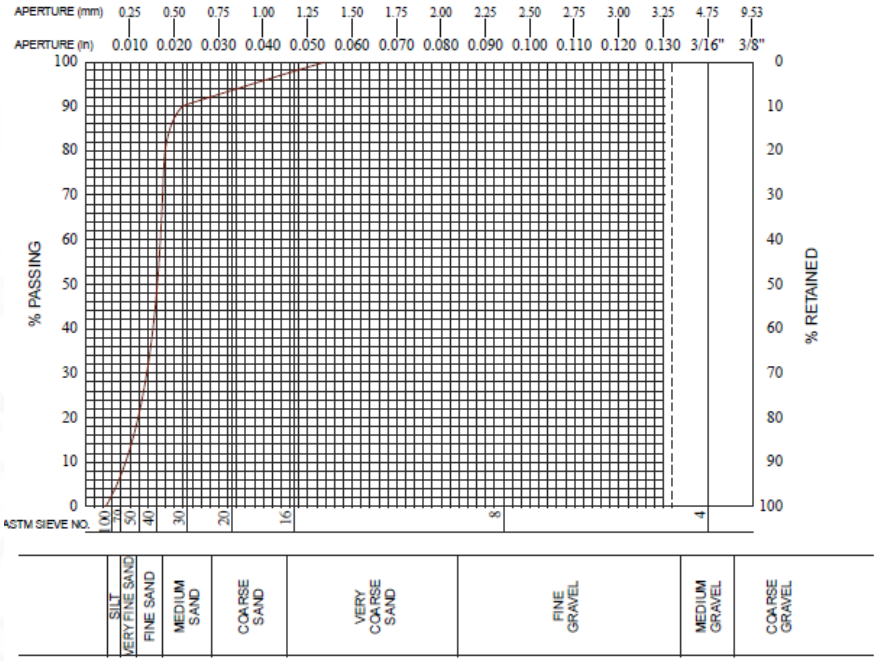
Recommended Screen Slot Size: 0.8 mm

% Passing:

Gravel Pack Grain Size: 1 mm

ASTM SIEVE NO.	APERTURE mm	APERTURE in.	INDIVIDUAL WT. RETAINED	CUMULATIVE WT. RETAINED	CUMULATIVE % RETAINED
3/8"	9.53	0.375	0	0	0
4	4.75	0.187	0	0	0
8	2.38	0.094	0	0	0
16	1.19	0.047	8.76	8.76	2
20	0.84	0.033	28.28	37.04	8
30	0.60	0.023	35.04	72.08	16
40	0.42	0.016	26.28	98.36	22
50	0.30	0.012	48.18	146.54	33
70	0.21	0.008	245.28	391.82	87
100	0.15	0.006	48.18	440.00	98
TRAY			8.60	448.60	100

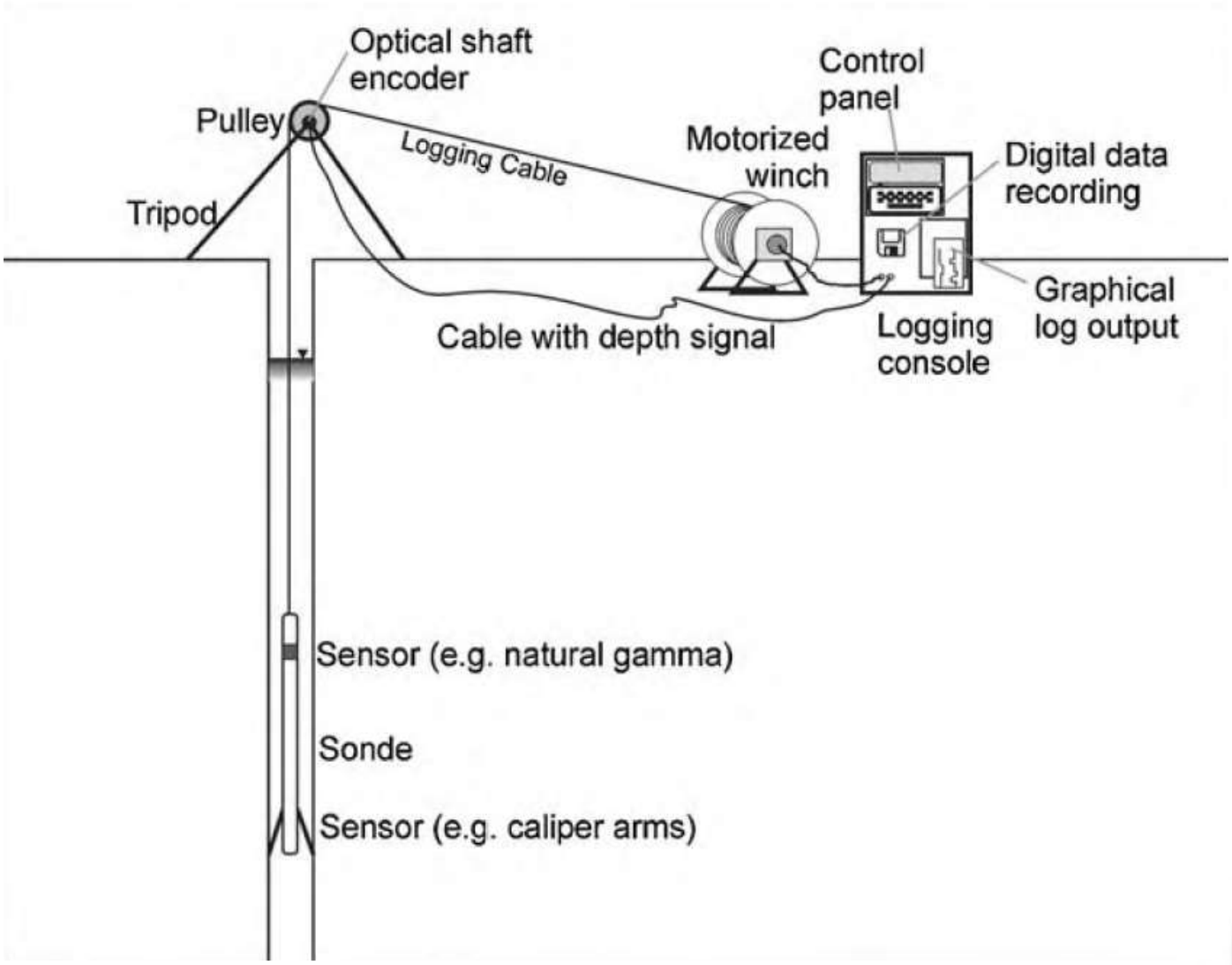
GRAPH OF ANALYSIS



Name: Signature: Date:

Source: Minimum construction requirements for water bores in Australia 3rd Edition, 2012.

Geophysical Borehole Logging



Source: B. Misstear, David Banks & L. Clark, 2006; Water Wells and Boreholes


05 07 2013


GEOVISTA
0006.95M
6.0MPM
GeoVista.co.uk
WINCH SIGNAL
WINCH DEPTH
GeoVista.co.uk
POWER
05 07 20

Core drilling

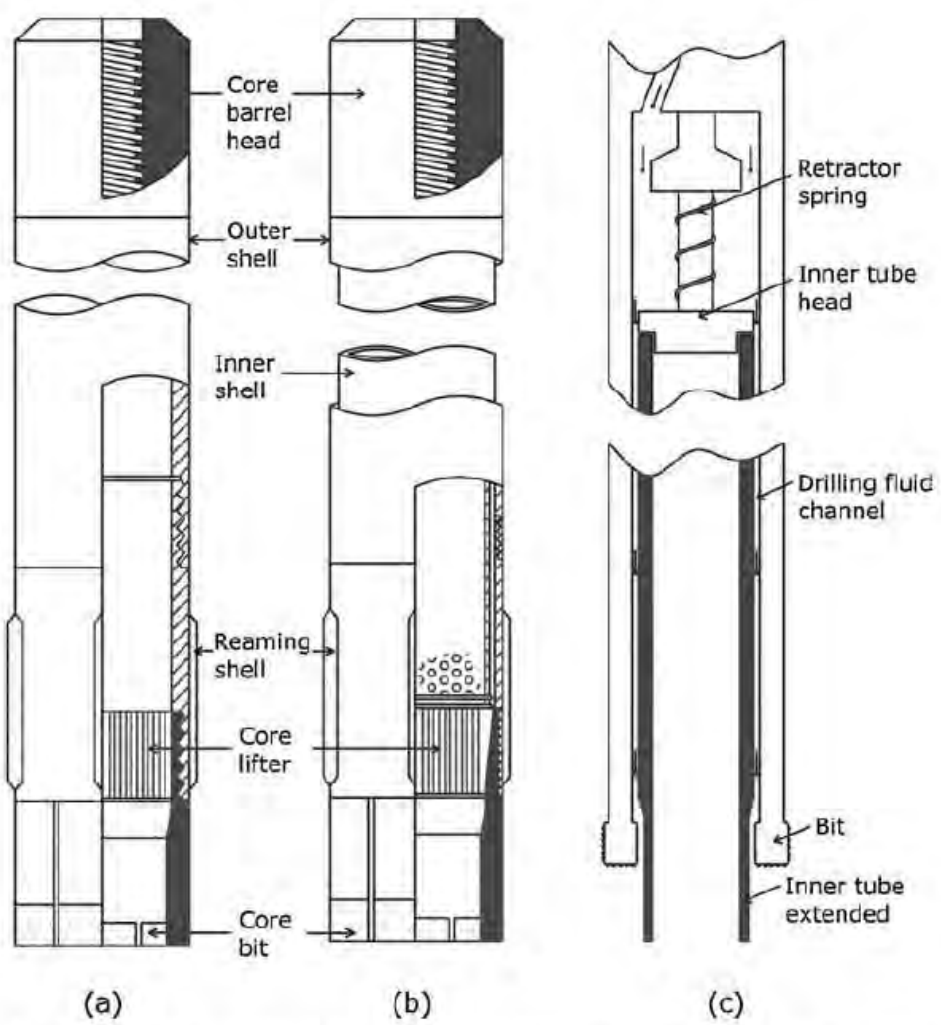


Figure 6.10 Core barrels. (a) single-tube, (b) double-tube (internal discharge design) and (c) triple-tube (Mazier type)

Source: B. Misstear, David Banks & L. Clark, 2006; Water Wells and Boreholes

Example Well Record - UK

SLEEPYVILLE PARVA No. 5 WELL

TF 54 / 13E

Owner Sleepyville Water Company | Licence No. T13/54/12

Occupier Sleepyville Water Company | IGS Ref. No.

Nat. Grid Ref. TF 5312 4969

Status Public water supply

Ground Level	32.195 m OD	105.63 ft. OD
Level of Well Top	32.515 m OD	106.69 ft. OD
Rest Water Level	15.24 m bwt	50.00 ft. bwt
(Date 29/7/85)	17.28 m OD	56.69 ft. OD

Aquifer UPPER CHALK

Construction Borehole

Depth bwt	Dia.	Linings (below well top) From	To	Dia.	Type
158 m	610mm	0 m	45 m	610 mm	Plain steel
		45 m	65 m	610 mm	Slotted steel

Summary of Geological Section	Thickness	Depth
Alluvial sands & gravels	4 m	4 m
Lower London Tertiary Strata	34 m	38 m
Chalk with flints	97 m	135 m
Very hard Chalk	3 m	138 m
Chalk with flints	20 m	158 m
Data from drillers' log		

Abstraction Rates

340 m^3 hr^{-1} on test

gpd

Type of Pump 250 mm elec. sub.

Chem./Bact. Anal. (YES) NO

Well Driller Acme Drilling May 1985

If insufficient space has been allowed, continue in 'Notes' overleaf.

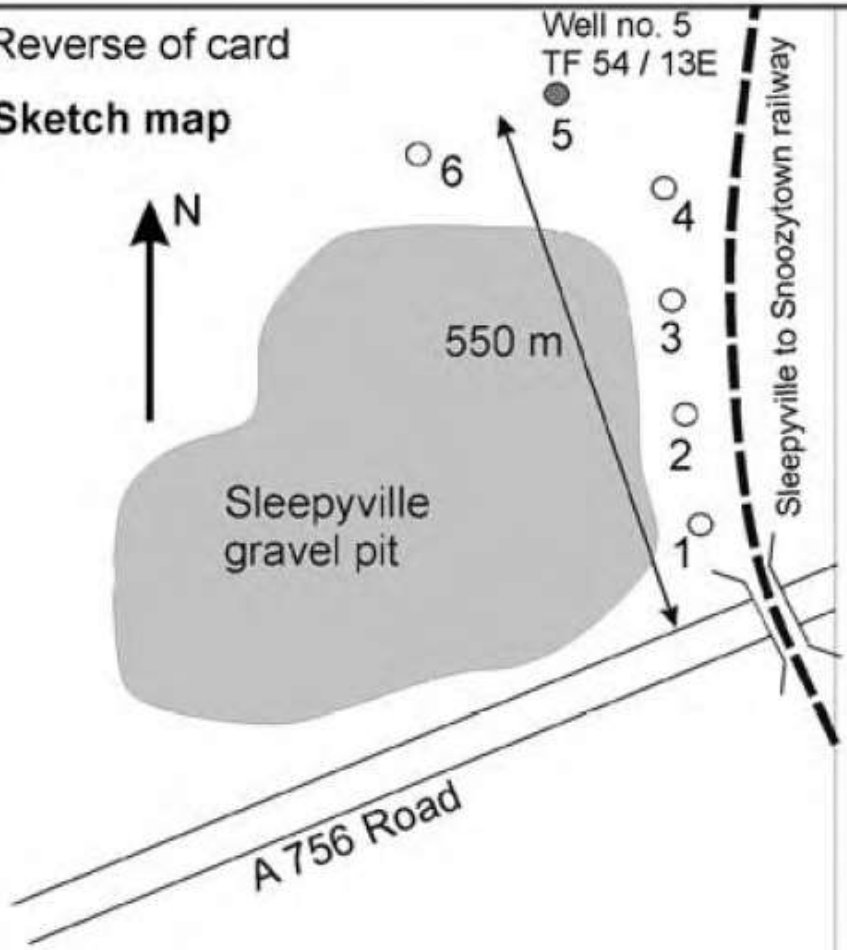
Geophysical logs: Temp./ EC / pH, caliper, guard resistivity, natural gamma

Source: B. Misstear, David Banks & L. Clark, 2006; Water Wells and Boreholes

Example Well Record - UK

Reverse of card

Sketch map



Notes

2 hour step test June 1985

Rate ($m^3 hr^{-1}$)	Drawdown (m)
90	0.82
175	1.73
260	2.82
340	4.11

Source: B. Misstear, David Banks & L. Clark, 2006; Water Wells and Boreholes

WATER SUPPLY WELL REPORT

Well ID # / Name_____ Location of ID on well_____

(1) **OWNER**: Land___ User___ Both___

Name_____

Address_____

(2) **TYPE OF WORK**

☐ New Well ☐ Deepening ☐ Alteration (repair/recondition) ☐ Decommissioning

(3) **DRILL METHOD:**

☐ Rotary Air ☐ Rotary Mud ☐ Cable

☐ Other_____

(4) **PROPOSED USE:**

☐ Domestic ☐ Community ☐ Industrial ☐ Irrigation

☐ Thermal ☐ Injection ☐ Livestock ☐ Other_____

(5) **BORE HOLE CONSTRUCTION:**

All Depths Are in ____Meters ____Feet Below Grounc Surface

Depth of Completec Well _____

HOLE				SEALS		
Diameter	From	To	Material	From	To	Sacks or pounds

(9) **LOCATION OF WELL** GPS:

Latitude_____ Longitude_____

Other (legal or locally used documentable location description):

_____

_____

(10) **STATIC WATER LEVEL:**

_____ below land surface. Date _____

Artesian pressure _____ kPa___ PSI___ Date _____

(11) **WATER BEARING ZONES:**

Depth at which water was first found _____

From	To	Estimated Flow Rate	SWL

(12) **WELL LOG:**

Source: S. J. Schneider, 2012; Water Supply Well Guidelines for Use in Developing Countries, Second Edition.

How was seal placed:

Backfill placed from _____ to _____ Material _____

Filter pack placed from _____ to _____ Size of pack _____

(6) CASING/LINER:

	Diameter	From	To	Gauge	Steel	Plastic	Welded	Threaded
Casing:					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
					☐	☐	☐	☐
Liner:					☐	☐	☐	☐
					☐	☐	☐	☐

Drive Shoe used ☐ Inside ☐ Outside ☐ None

Final location of shoe(s) _____

(7) PERFORATIONS/SCREENS:

☐ Perforations Method _____

☐ Screens Type _____ Material _____

From	To	Slot size	Number	Diameter	Tele/pipe size	Casing	Liner
						☐	☐
						☐	☐
						☐	☐
						☐	☐

(8) WELL TESTS: Minimum testing time is 1 hour

☐ Pump ☐ Bailer ☐ Air ☐ Flowing Artesian

Yield gal/min	Drawdown	Drill stem at	Time
			1 hr.

Temperature of water _____ Degrees C___ F___

Was a water analysis done? ☐ Yes By whom _____

Did any strata contain water not suitable for intended use? ☐ Too little

☐ Salty ☐ Muddy ☐ Odor ☐ Colored ☐ Other _____

Depth of strata: _____

(12) WELL LOG:

Ground Elevation _____

Material	From	To	SWL

Date started _____ Completed _____

Person or Organization responsible for well's construction:

Name: _____

Address _____

Phone # _____ E-mail _____

Source: S. J. Schneider, 2012; Water Supply Well Guidelines for Use in Developing Countries, Second Edition.

Source: S. J. Schneider, 2012; Water Supply Well Guidelines for Use in Developing Countries, Second Edition.

Data Management: Pump Installation Records

Source: http://net.grundfos.com/doc/webnet/waterutility/products-ws-submersible.html

PUMP INSTALLATION RECORD

Well ID # / nomenclature _____

Owner _____

Type of Owner: Land____ User____ Both____

Date of Installation _____

Type of Pump _____

Manufacturer _____

Model Number _____Serial #_____

If Electric Powered: Volts_____Phase____ Amps_____

Type of Drop Pipe / Column _____

Drop Pipe / Column: Inside Diameter_____Length_____

NORPLAN

Source: S. J. Schneider, 2012; Water Supply Well Guidelines for Use in Developing Countries, Second Edition.

Size, type & material of rod / shaft _____

Water Level Access? Probe Tube_____ Plug/Cap_____ None_____

Water Level Access: Inside Diameter _____ Material_____

Well Pump Chamber (e.g. Casing): Inside Diameter_____Material_____

Static Water Level _____

Well Depth _____

Installer _____

All Depths Reported Are In: Meters_____ Feet_____ Datum*_____

All Diameters Reported Are In: Millimeters_____ Inches_____

Other Information: _____

_____

* Datum is reference from which all depths are reported (e.g. ground surface, top of pad, etc.)

S.J. Schneider - 2012

Source: S. J. Schneider, 2012; Water Supply Well Guidelines for Use in Developing Countries, Second Edition.

When things go wrong: Fishing

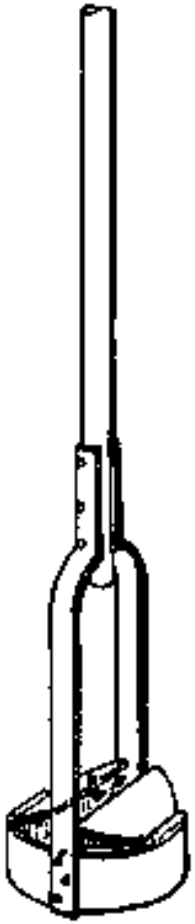
- Equipment that has fallen into the well is referred to as **fish** or **junk**, and regular drill bits cannot drill through it.
- Should a fish fall into a well, fishing is required to remove it.

Source: http://www.agedevelopments.com.au/content/water_bore_services/fishing_equipment_and_services/18

When things go wrong: Fishing

Source: http://www.agedevelopments.com.au/content/water_bore_services/fishing_equipment_and_services/18

Fishing Tools



For retrieving lengths of pipe

For picking up small objects

For retrieval of broken rope or cable

Hook for attaching supplemental line to stuck tool

When things go wrong: Fishing

"We spent 12 hours a day for 3 weeks trying to get something to hook our equipment in a blind hole….. before we could call for the truck..."

Watch David Catherina's YouTube Video:
http://www.youtube.com/watch?v=PZc9UbfvELg

Fishing Video

6.1 WHEN THINGS DON_T GO WELL WITH WELL DRILLING.mp4

TOPICS TO BE COVERED

1. Introduction & Terminology
2. Well Location
3. Well Construction Methods
4. Well Drilling Methods
5. Well Completion & Development
6. Well Decommissioning
7. Cost Benefit Analysis
8. Drilling Management & Data Collection
9. Health & Safety

PART 9 – Health & Safety

1. Common Drilling Accidents
2. Risk & Risk Management
3. Personal Protection Equipment (PPE)

Common Drilling Accidents (1)

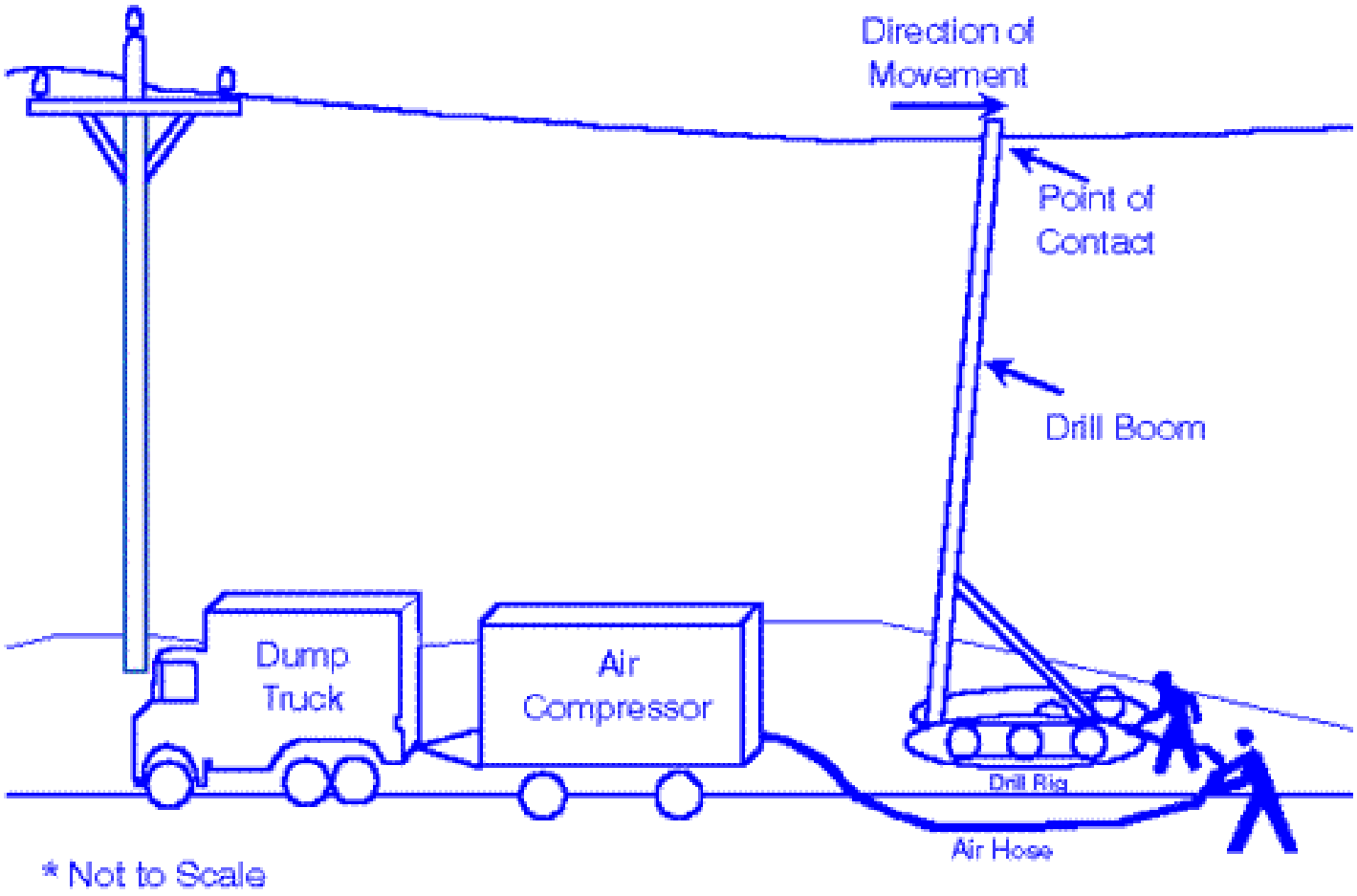
On Thursday September 1, 2011, a 29-year-old contract driller with 1 year, 3 months of experience was killed at a surface coal mine.

The victim was attempting to separate a pipe connection when he was struck by a tong wrench. The rig was being used to drill a water well.

The crew was working to free the drill stem that was stuck in the drill hole when the accident occurred.

Source: http://www.msha.gov/fatals/2011/FAB11c15.asp

Common Drilling Accidents (2)



Two drilling crew members were electrocuted when the boom of their drill rig contacted a high voltage overhead power line.

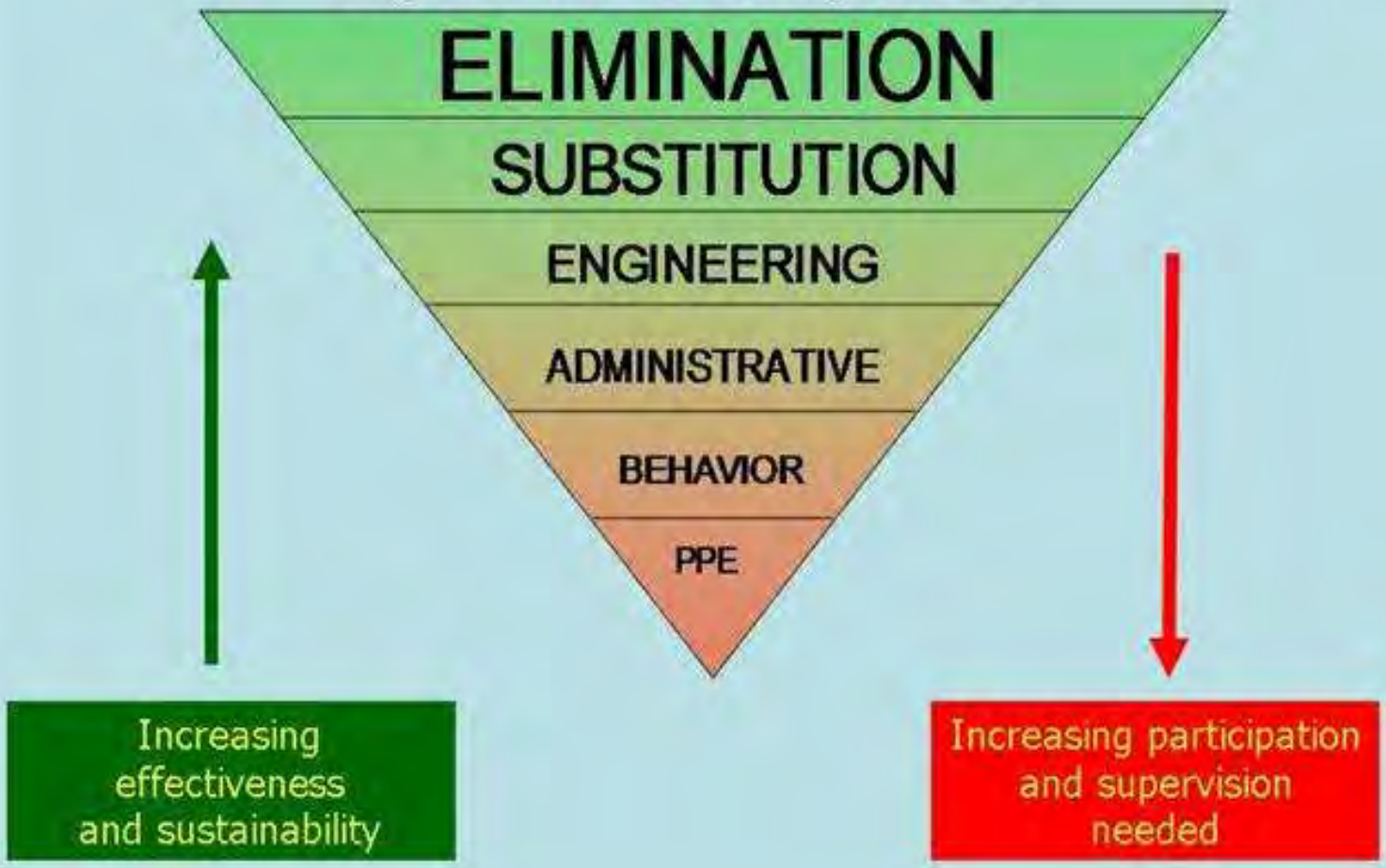
Source: http://www.nj.gov/health/surv/face/ffdrill.shtml

Risks to Personal Health & Safety

1. Loss of sight or hearing
2. Burns and abrasions
3. Crushed limbs
4. Dismemberment
5. Chronic diseases
6. Lifelong disabilities
7. Permanent brain damage
8. Death

Hierarchy of Control

Apply the highest level of control commensurate with the risk level– lower value controls may be used in the interim until long-term controls are implemented.

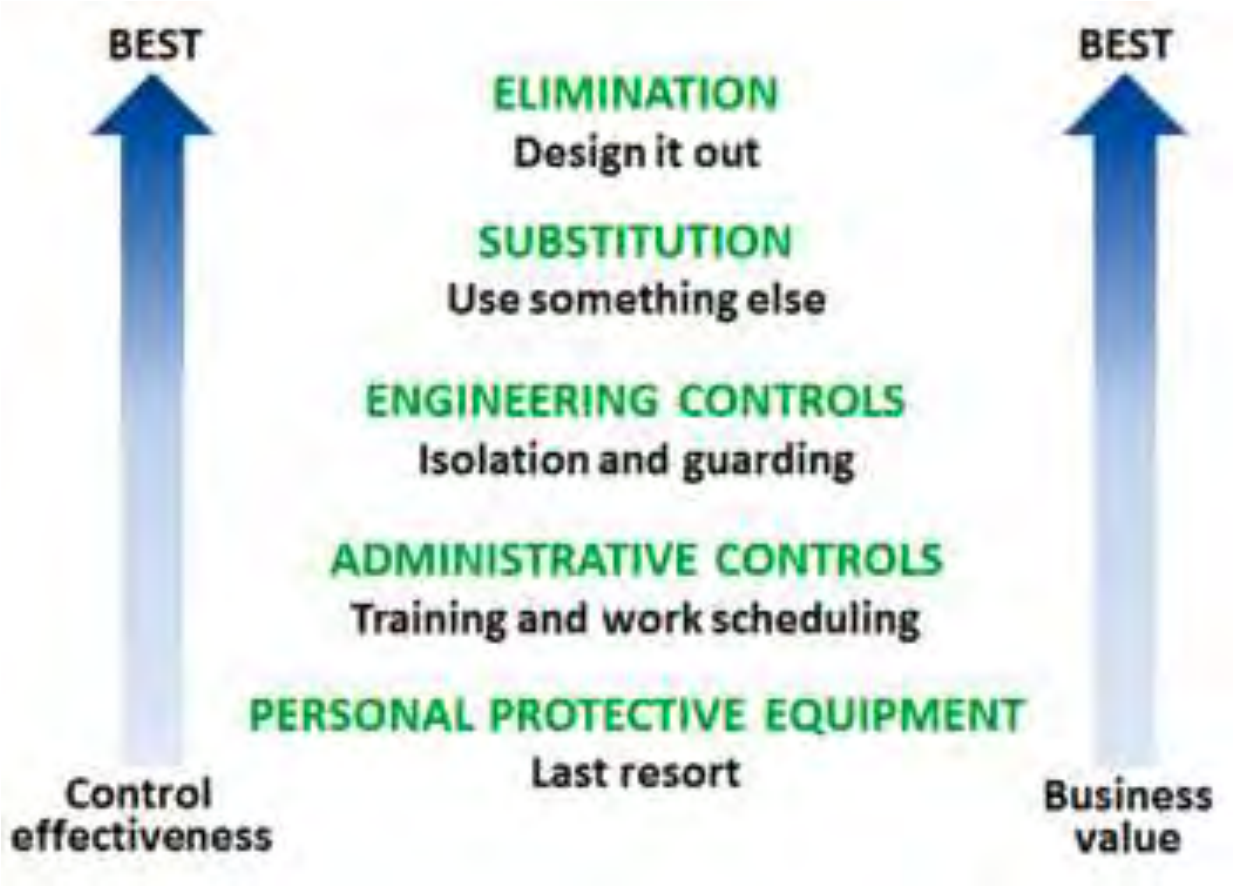


Source: http://www.qualitysystems.com/support/pages/hierarchy-of-controls

Personal Protection Equipment (PPE)

1. Hard Hat
2. Gloves
3. Dust Mask
4. Eye Protection
5. Boots with steel toe caps.
6. Hearing protection.

Source: S. J. Schneider, 2012; Water Supply Well Guidelines for Use in Developing Countries, Second Edition.



PPE is the LAST line of defence!

Source: http://en.wikipedia.org/wiki/File:Hierarchy_of_Controls.PNG

Health & Safety Videos

8.1 Dales Water Services Ltd Rotary Drilling Rig.wmv.mp4

8.2 Water well tips.mp4

Practical Workshop (1)

You have been assigned the task of preparing for a large drilling program for groundwater exploration in Nimroz Province. Inside your group develop checklists for the following:

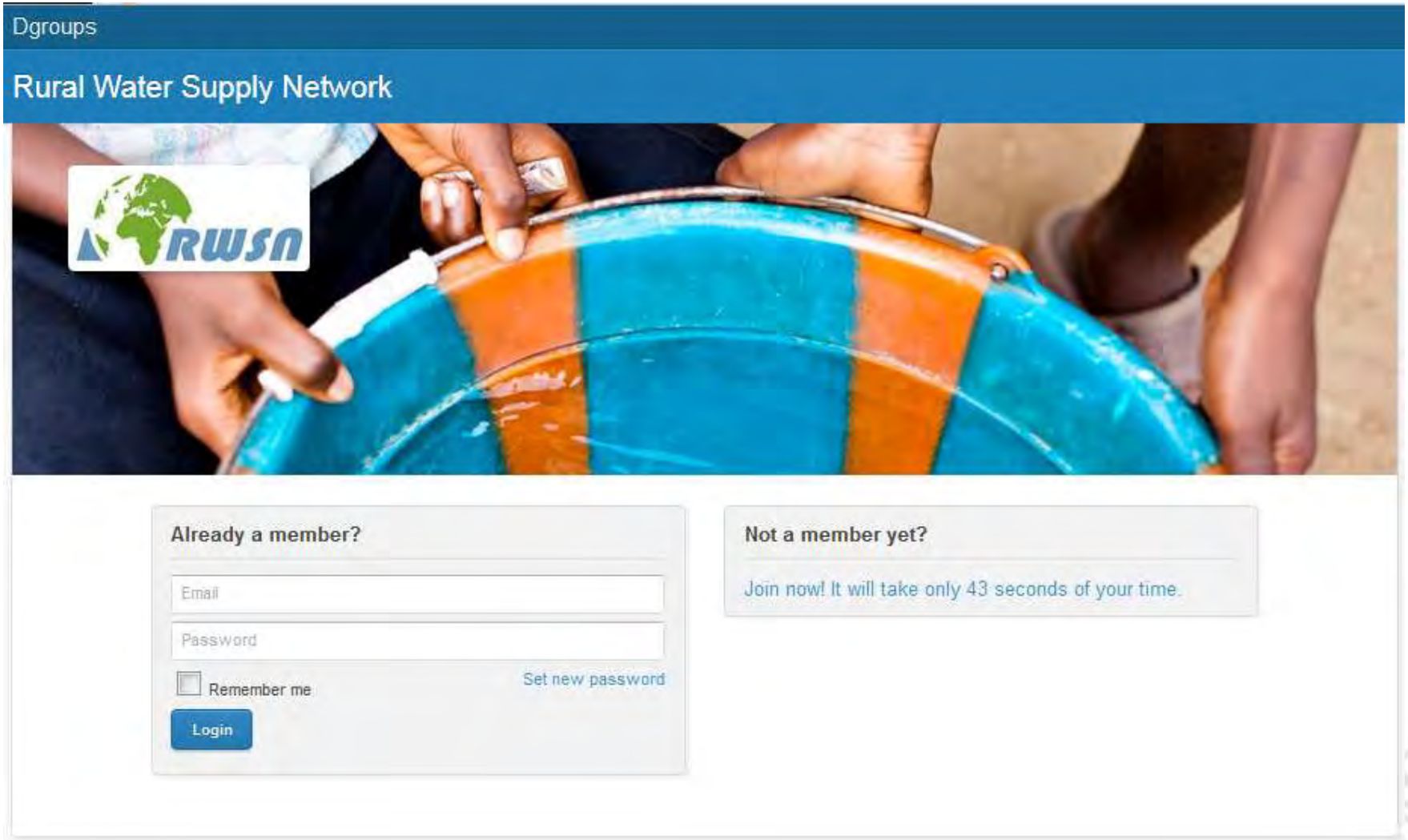
1. Equipment required to be on site before drilling can commence.
2. Information to be recorded during drilling.
3. Information to be recorded during well development.
4. Information to be recorded during well design & well completion.

Practical Workshop (2)

Design standard formats for the following:

1. Daily drilling report
2. Geologists Log
   - drill penetration rates
   - water strikes
   - cuttings log
3. Well completion report
4. Pump installation report

Join RWSN at https://dgroups.org/rwsn



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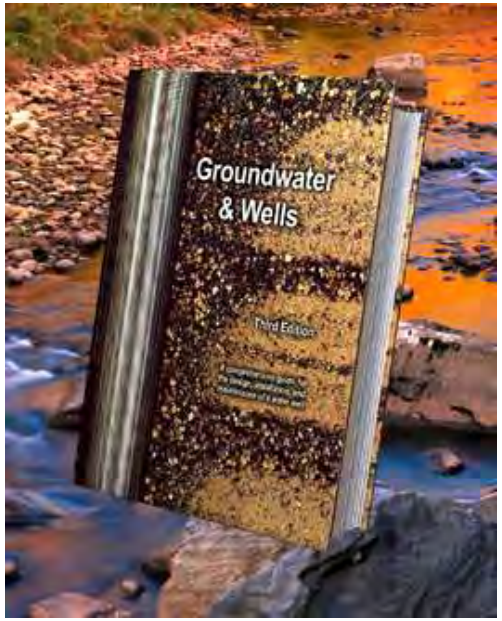

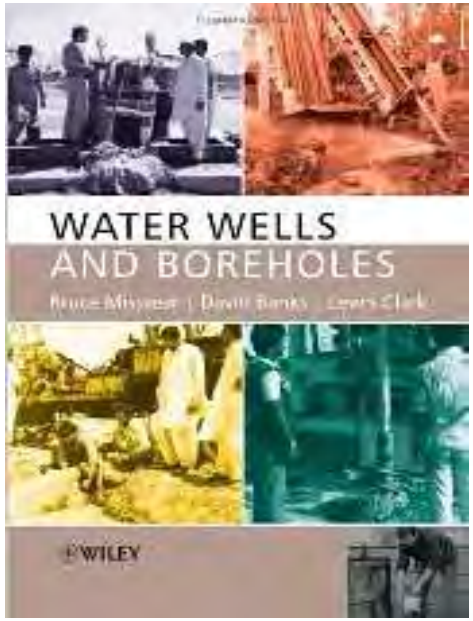

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9. Rural Water Supply Network, 2012; Field Note No 2012-2; Supervising Water Well Drilling, A Guide for Supervisors. Available online at: http://www.rural-water-supply.net/en/resources/details/392