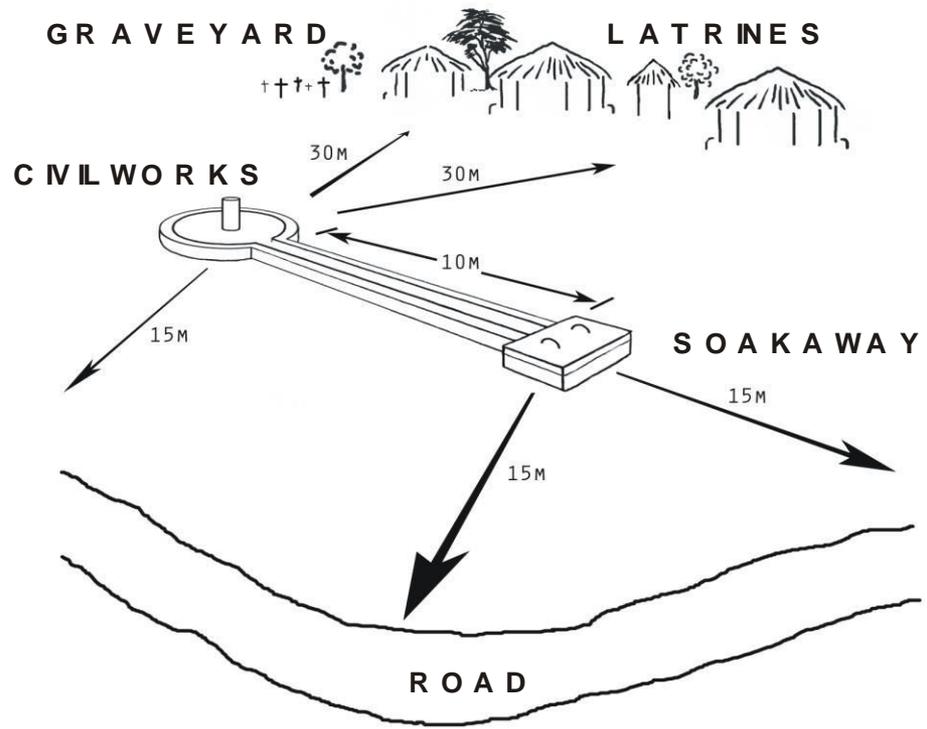


HYDROGEOLOGY AND DRILLING SUPERVISION TRAINING

Day 3

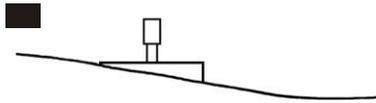
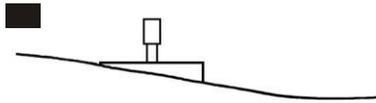
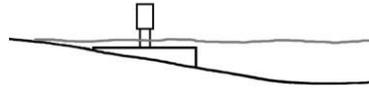
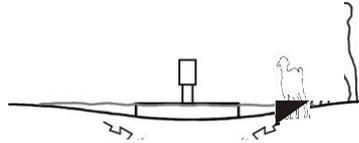
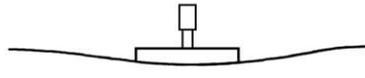


Distances

Flooding

DRY SEASON

WET SEASON



Siting Problems

- Not in the right place for community
- Too far away
- Explaining Groundwater potential – better to have a wet borehole in a slightly inconvenient place
- Community Agreement Form

Resistivity

Resistivity Theory

- Different rocks have different electrical properties
- Electrical properties also are effected by weathering and fractures
- Having an idea of the Geology before the survey is useful

Resistivity Setup

WRI E S C O N N E C T I N G
M E T A L L E C T R O D E S

O P E R A T O R

A 10

F R O M
O P E R A T O R



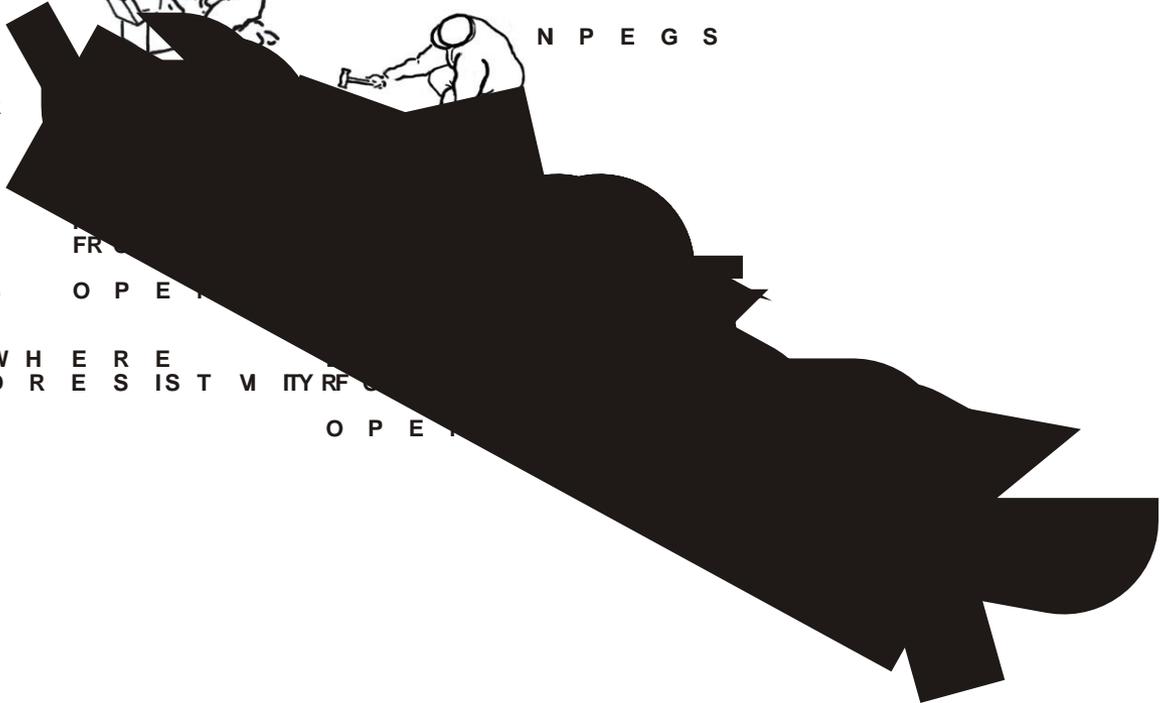
T E C H N I C I A N
H A M M E R I N G
N P E G S

M -1m
R F O M
O P E R A T O R



F R O M

P E G S H A M M E R E D O P E R A T O R
N A X T E D N T E R A V L S
R F O M T H E C E N T R E W H E R E
T H E O P E R A T O R A N D R E S I S T I V I T Y R E F
B O X I S P L A C E D O P E R A T O R



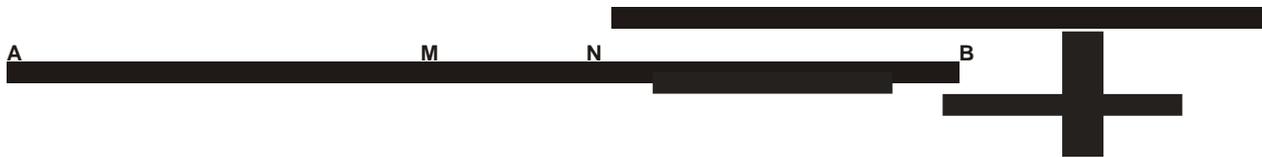
Resistivity Array

012 A - B S E P E R A O T N



th D E P th

01 A B S E P E R A T D N

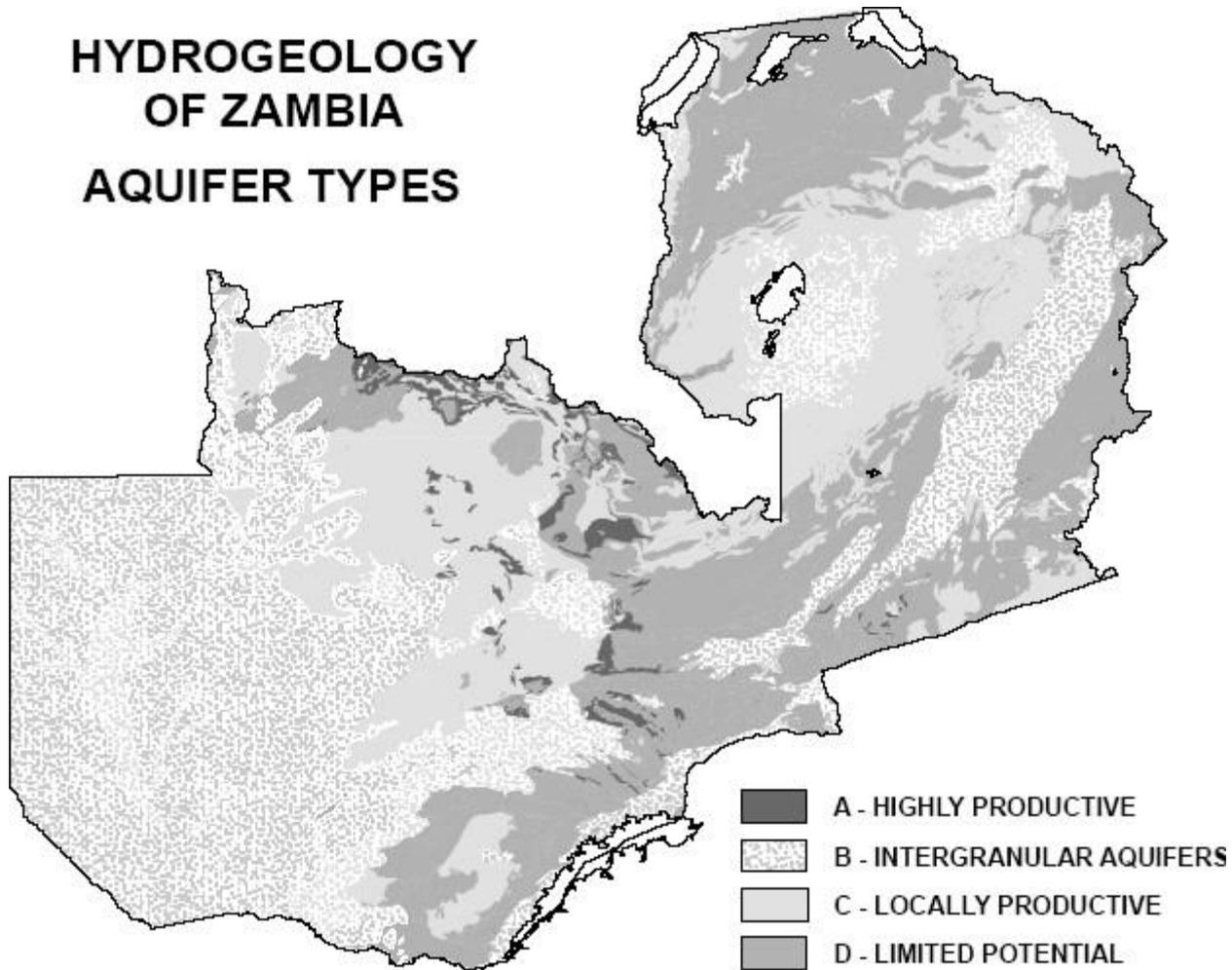


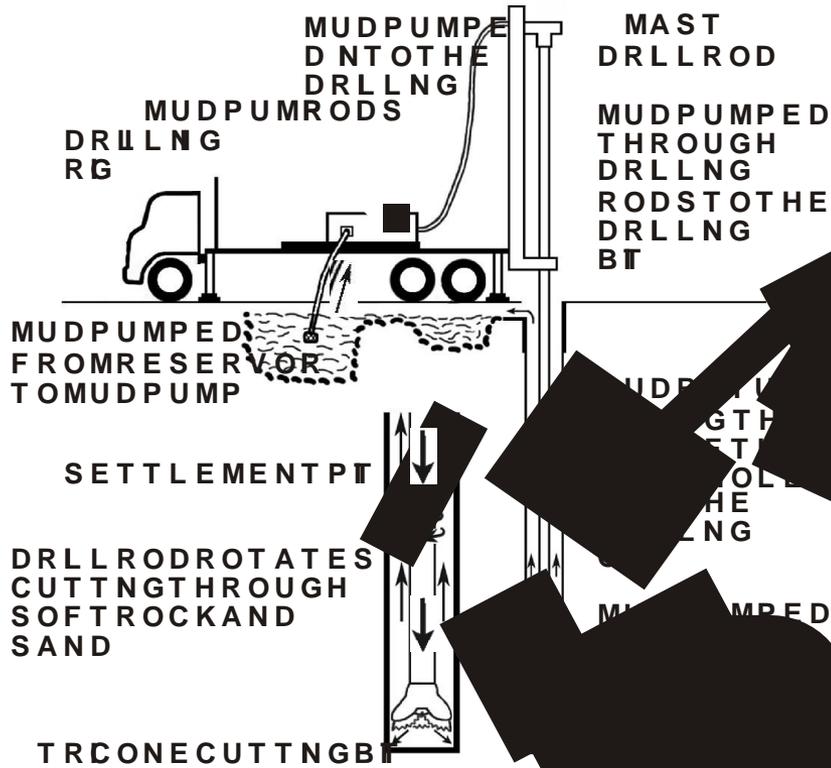
th D E P th



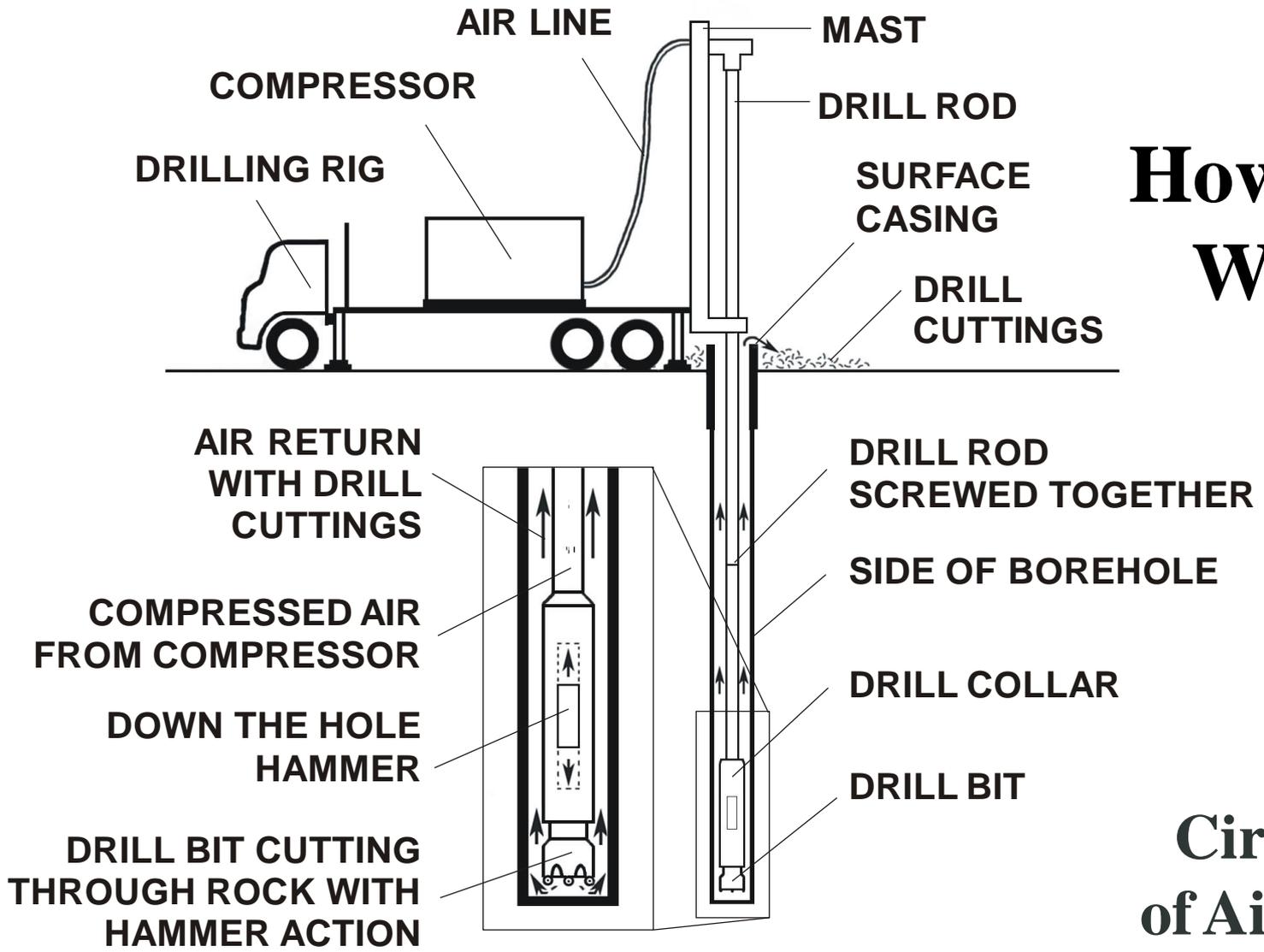
Geophysics and Aquifers

HYDROGEOLOGY OF ZAMBIA AQUIFER TYPES





Mud Rotary Drilling Rig



How DTH Works

Circulation of Air/Foam

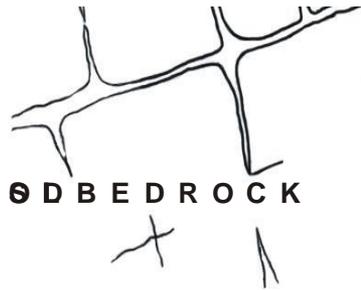
DTH Mud - Combination

D H D R N G R G

E M P O R A R C A N
G A R G E N O U G
H O R N C H D H B T

U P E R R O F
B O R B O B R
W H M U D R O A R Y

K A H A R S A N D S



Ø D B E D R O C K

Ø H D A M E R
Ø C H Ø
m



Access of Drilling Rigs

- Drilling rigs can weigh up to 30 tons
- Deep sand is not the issue - warned in contract
- Bridges and Dambos are the issue
- If this issue dealt with early - mitigate

Before Drilling

- The contractor must not start till shown the site by consultant
- Should be clearly marked
- Should be an A (Priority) and a B (Backup) site

Supervision of Drilling

- GPS location of the drill site
- Mark rods
- Penetration Rates
- V Notch Weir
- Formation sampling and Interpretation
- Marsh Funnel
- DATA - used to design borehole

Borehole Design Elements

Physical Elements

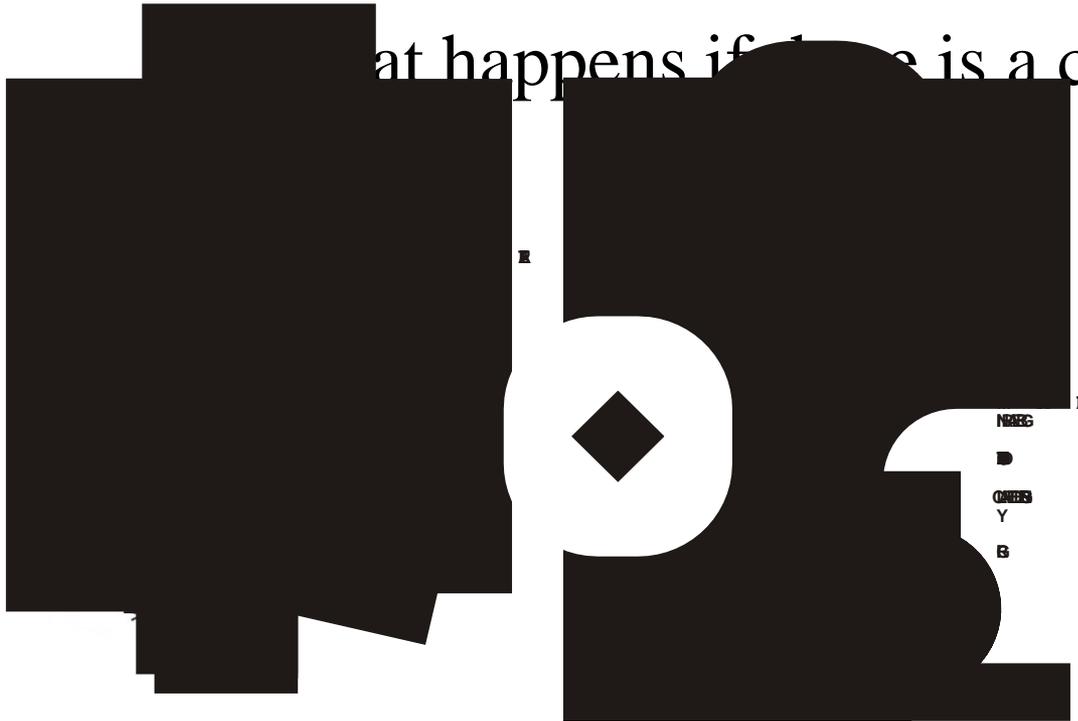
- Screen
- Casing - Sump
- Gravel Pack
- End Cap

Borehole Design Factors

- Borehole Efficiency
- Inflow of fine material minimised
- Quality Materials
- Sealed off from contamination
- Allow for 1m Collapse

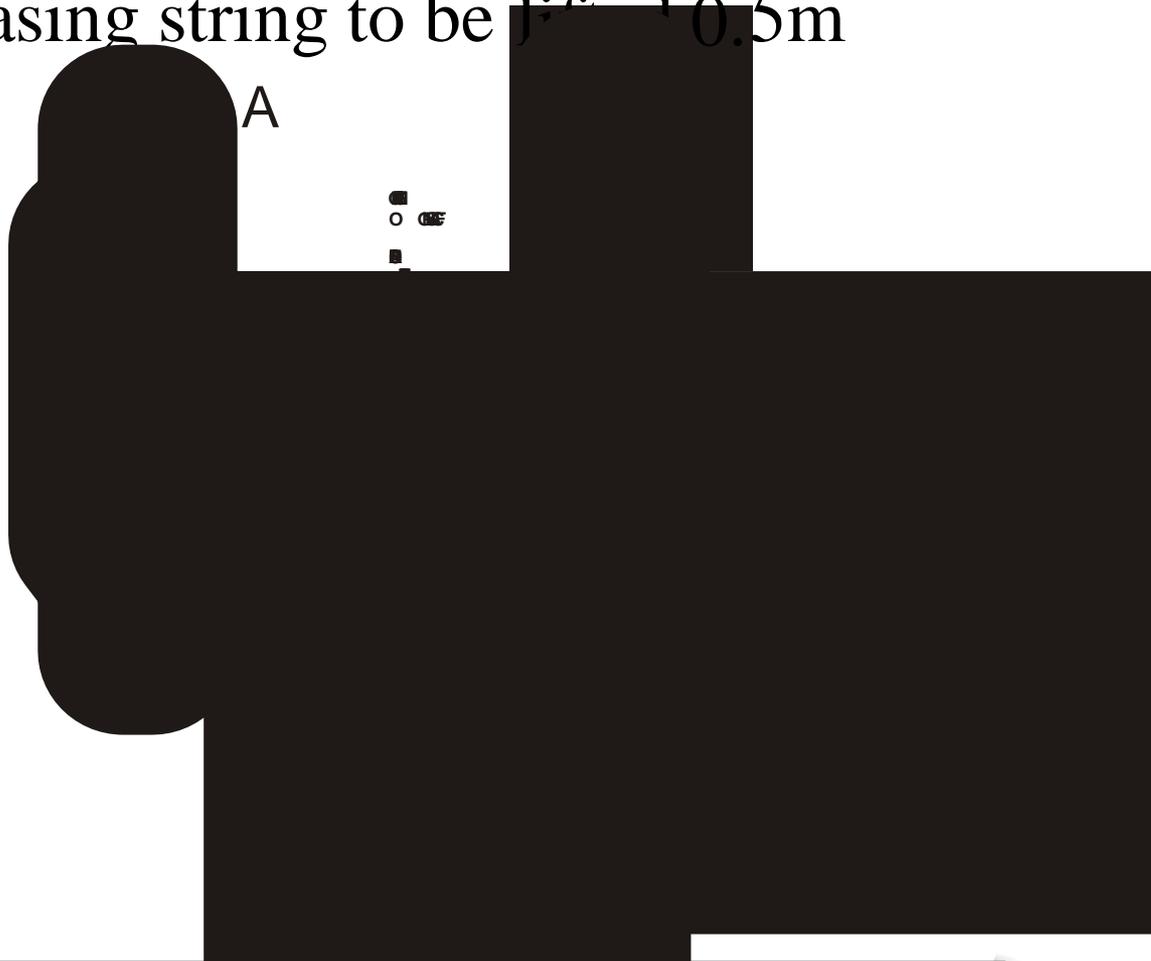
Borehole Installation and Collapse

What happens if there is a collapse?



Casing Must Hang

- Casing string to be 1:6 = 1 0.5m



Gravel Pack in Unstable Formations



Formation Stabiliser

Technical Specifications

- Diameter of Borehole
 - EOH **ANNULAR**
 - Telescoping **SPACE**
 - Sedimentary section min - 200mm
 - Hard Rocks EOH - 165 to 176mm

Development and Pumping Tests

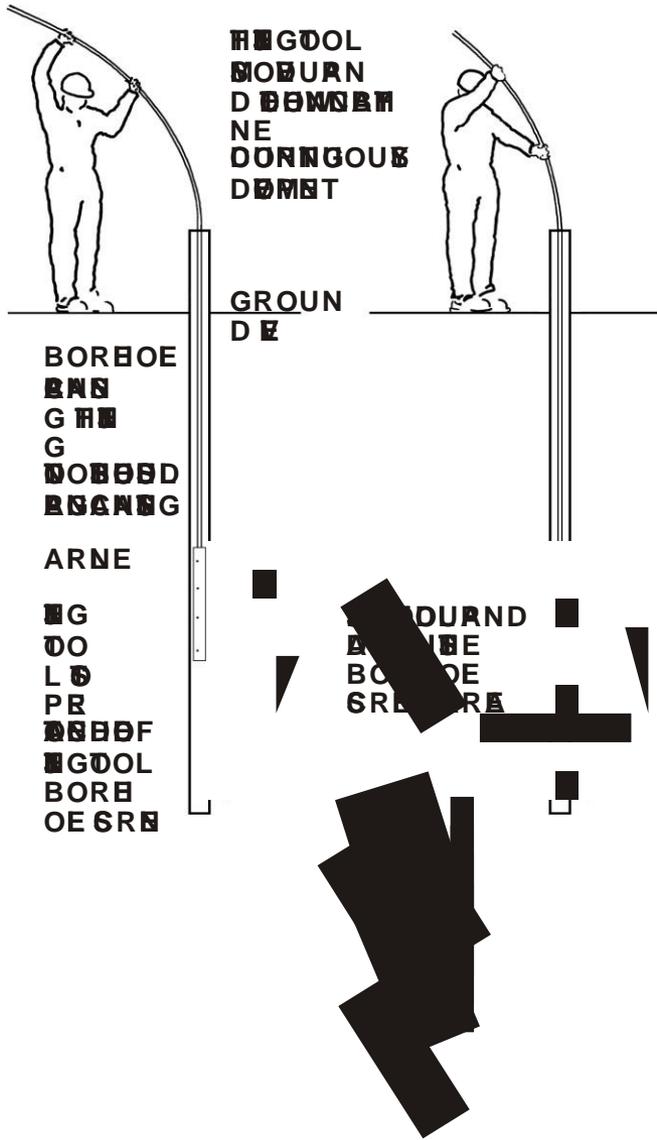
Development

- Removing drilling fluids
- Fine grained material from the pack
- Developing natural pack
- Removing material from the sump
- No Maximum time





Horizontal air
over the
PN015
M



B O R E O B Ø R Ø M M
T

B O R E O E R D Ø M M
T

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W W L
PU
■ ■ E
ADWL ■
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■ P

AT
■ ■ ■
■ ■ ■
■ ■ W ■
■



Development Issues

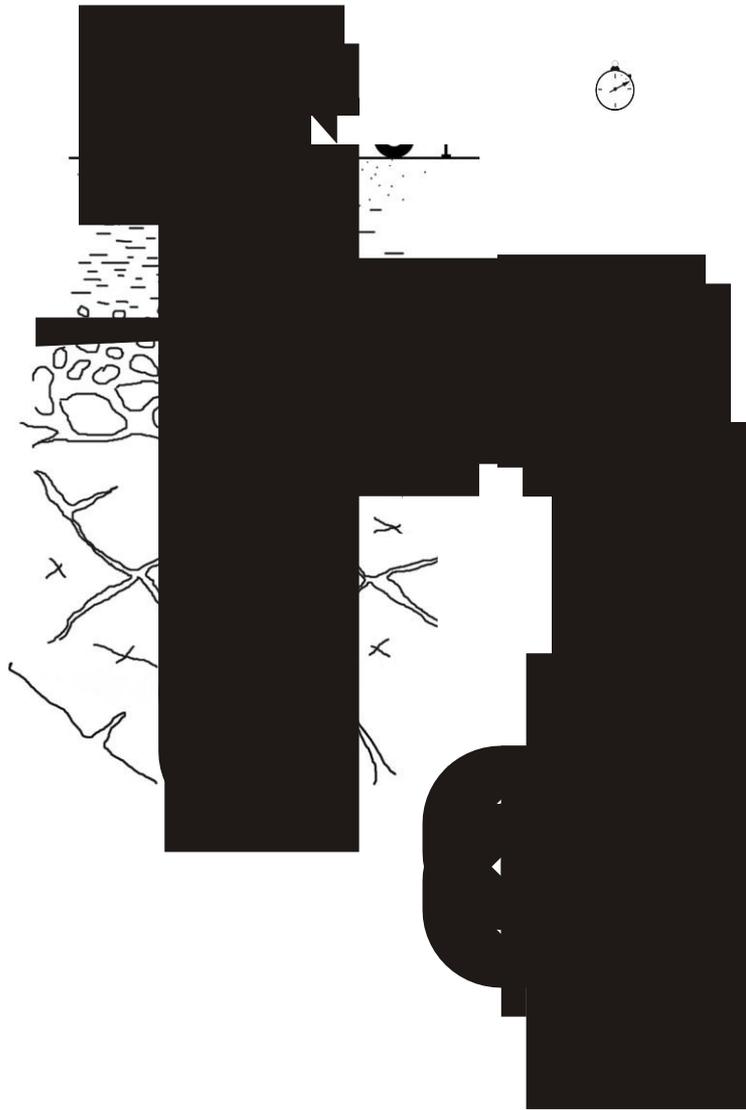
- Jetting tool not moved
- Finished too soon - supervision
- Done with drilling compressor
- Water stays dirty - pack not clean
- Very boring - but **ESSENTIAL**

Pumping Tests

- Assessing GW Resource
- Response of Aquifer to Pumping
- Objective - Sustainable Yield
- Aquifer Parameters
- Data for future projects

Pumping Tests Procedure

- Controlled Abstraction
- Pumping Test NOT Pump Test
- Change in Water Levels - Drawdown
- Large Variety of Tests
- Sophistication Level

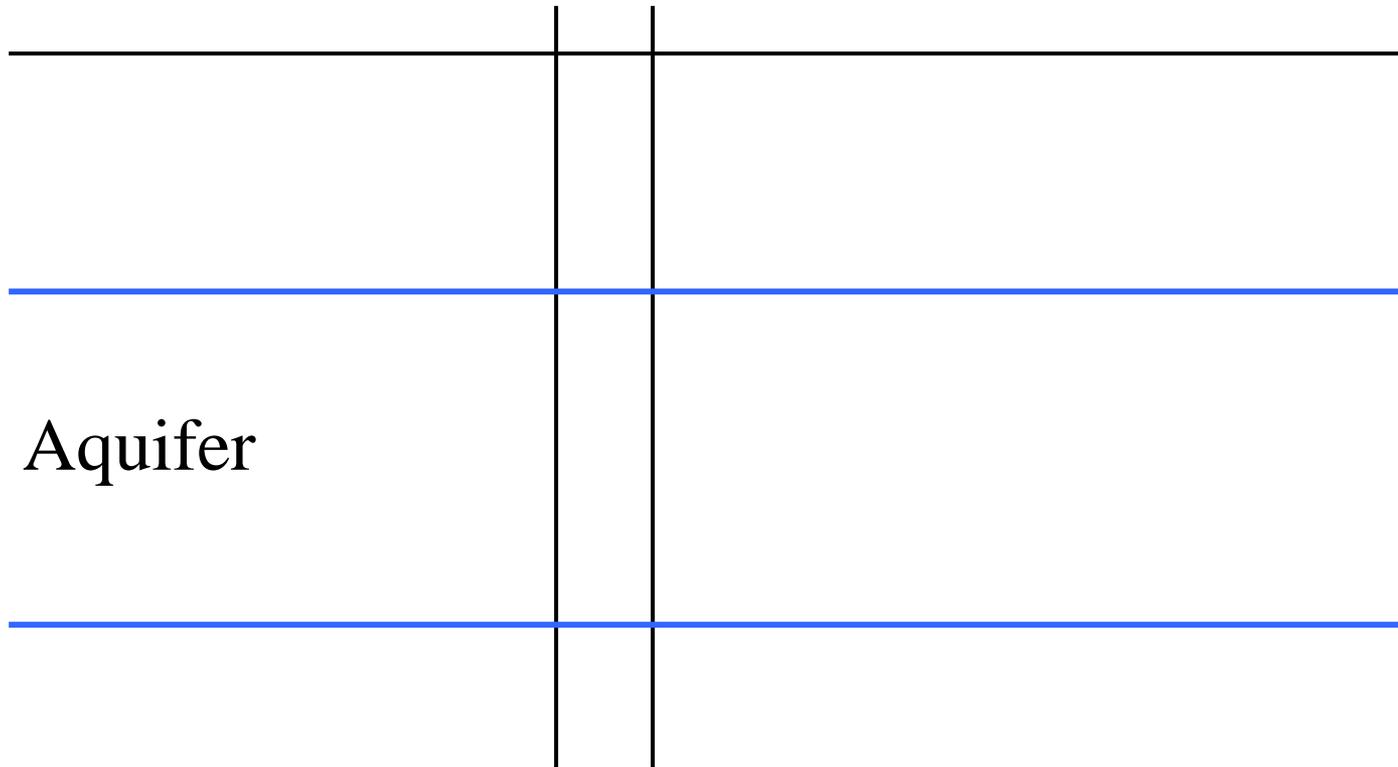


Pumping Tests Procedure

Pumping Test Parameters

- Water Level - S_w mbgl, mbtc, mamsl
- Time - T sec, min, hours, days
- Flow Rate - Q litres/sec m^3 /hour

Theory



Parameters for Success

- Long Term Sustainability
- Water Supply to How Many People?
- Patience?
- Alternatives?
- Seasonal Variation in WL

Pumping Tests Parameters

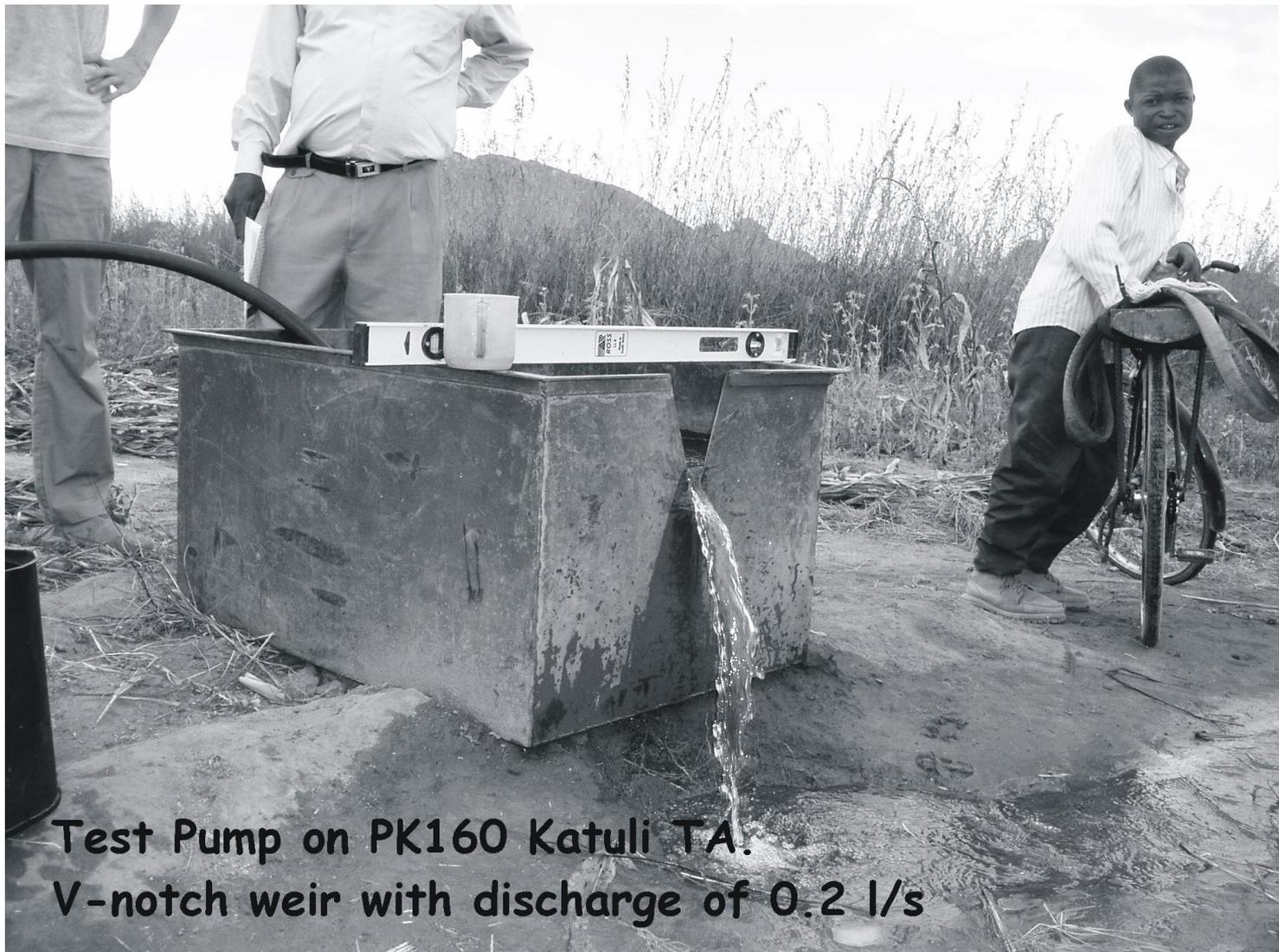
- Step Test
- Recovery
- Constant Rate Test
- Recovery

Measuring Water Levels





Super
M



**Test Pump on PK160 Katuli TA.
V-notch weir with discharge of 0.2 l/s**

Recovery Test Procedure

Pumping Tests Parameters

- Recovery

What is recovery?

90% sufficient

ESSENTIAL TO HAVE NON RETURN VALVE

Constant Rate Test Procedure

Pumping Tests Parameters

- Measurement of what?
- Why so long?

Test Criteria from the Contract

- 6 hour CRT
- 50 - 90% of air lift yield
- 3 hour recovery
- Less than 10% variation
- Breakdown - recover first before restart
- Discharge 50m

Definitions Of Success

How do we define success in the context of the pumping test?

Marginal Boreholes

- Water Strike $> 25\text{m}$?
- 0.2l/s lasts 70 minutes?
- 5m in 1st 5 minutes
- Relative to existing source

Pump Installation Depth

- Minimise Installation Cost
- Ensure intake below DWL
- Pump intake and screens
- Maximum Installation depth for ordinary India Mark II
- Maximum Installation depth for extra deep India Mark II

Technical Specifications

Practical

Borehole Completion Report

NORTH WESTERN PROVINCE RURAL WATER SUPPLY PROJECT - BOREHOLE COMPLETION REPORT

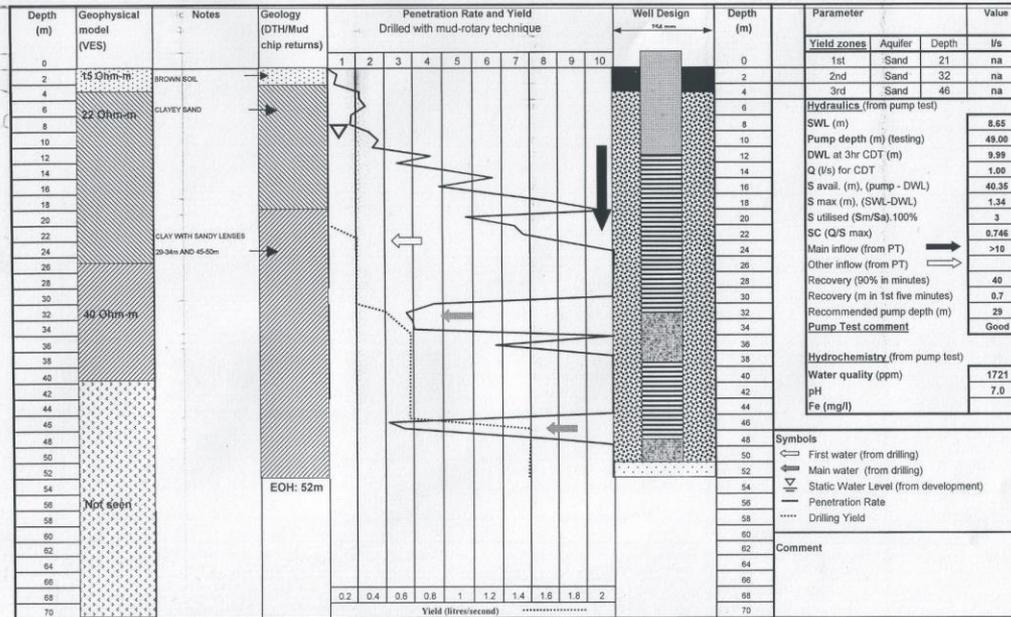
Code: 0
 Name: 0
 Ward: 0
 District: 0
 Depth(m): 0
 Drilling date: 0
 Coordinates: (Decimal Degrees, Arc1950)
 Easting: 0
 Southing: 0

S - Soil (laterite, sand)
 W - Weathered Bedrock
 FI - Fine Grained Rock (Mudstone/Siltstone)
 UHS - Unconsolidated Sandstone
 CoS - Consolidated Sandstone
 Mx - Mixed material (collapse)

CIS - Clay rich sand
 Oth - Other
 PVC plain casing (incl.centralizers)
 PVC slotted casing (0.75mm slots)
 Cement sanitary seal
 Formation stabiliser (gravel 2 - 5 mm)

Lithological Profile and Well Design

Aquifer and Well Data



Construction of Civil Works

- Superstructure
- Quality of materials
- Quality of works and workmanship

Superstructure

- Drawings
- Quality of materials
- Quality of works and workmanship

Quality of materials

- Aggregates
- Water
- Cement
- Steel Reinforcement

Quality of materials



SAN D G R A I N S
M A D E U P Q U A R T Z
B W O O N M

Aggregates

- Clean
- Unweathered
- Well graded
- Hard
- Size 9.5 - 20mm

Water and Cement

- Water to be free from:
 - Organics, oil etc
- Cement
 - 50kg Portland Cement, unbroken, <3 months
- Steel Reinforcement
 - Free of rust, max 9”

Quality of Works and Workmanship

- Formwork

Max deviation of 10mm over 2m

- Concrete Mix

Set Ratios and cement content

- Curing

14 days covered and daily watering

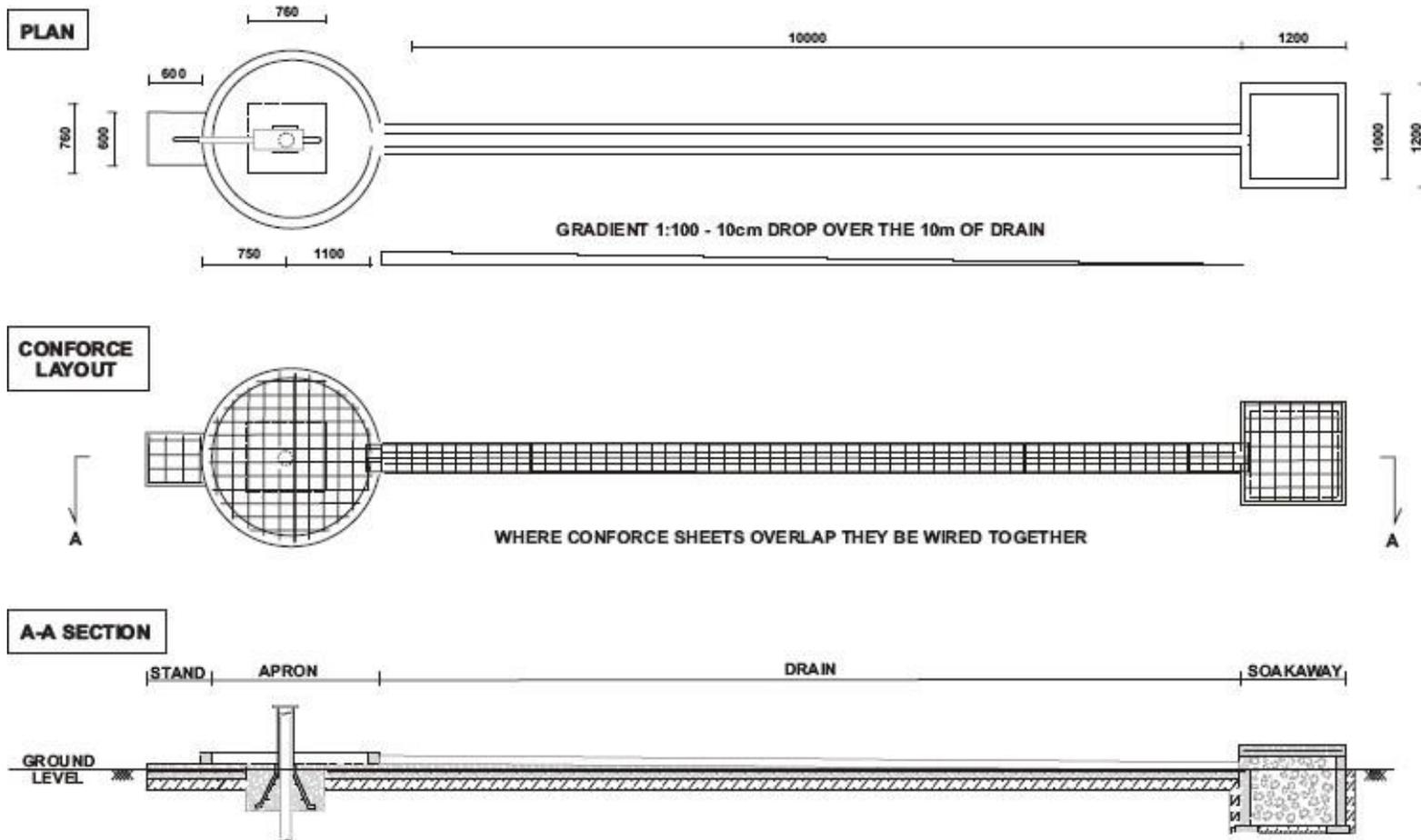
Formwork

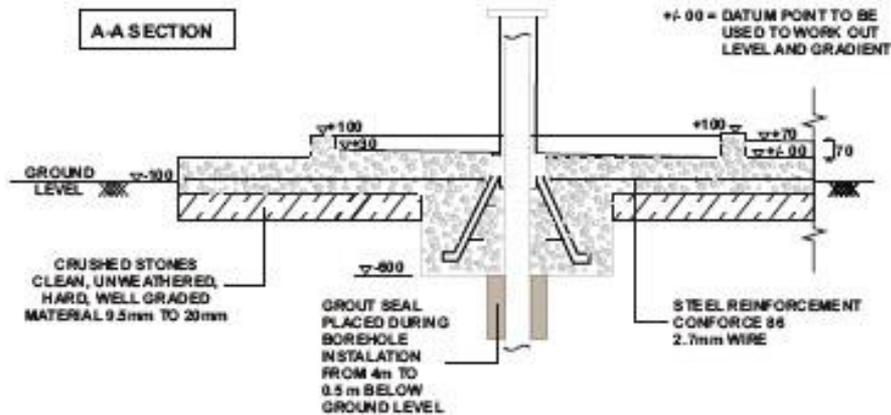
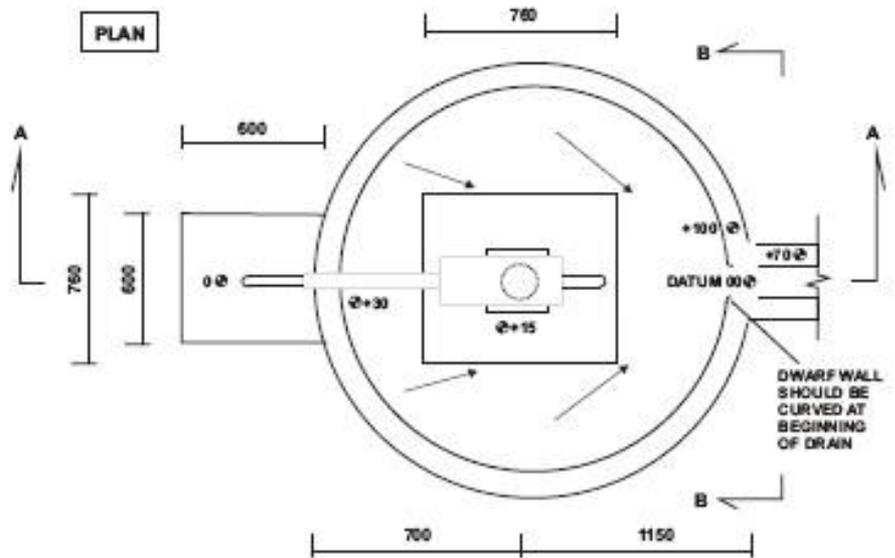
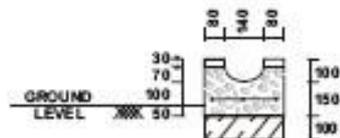
- Formwork max deviation of 10mm over 2m
- Concrete Mix
- Curing

Levels - Gradient

- Drain must be above ground
- Gradient 10cm over 10m drain
- Builders line and spirit level
- Water level

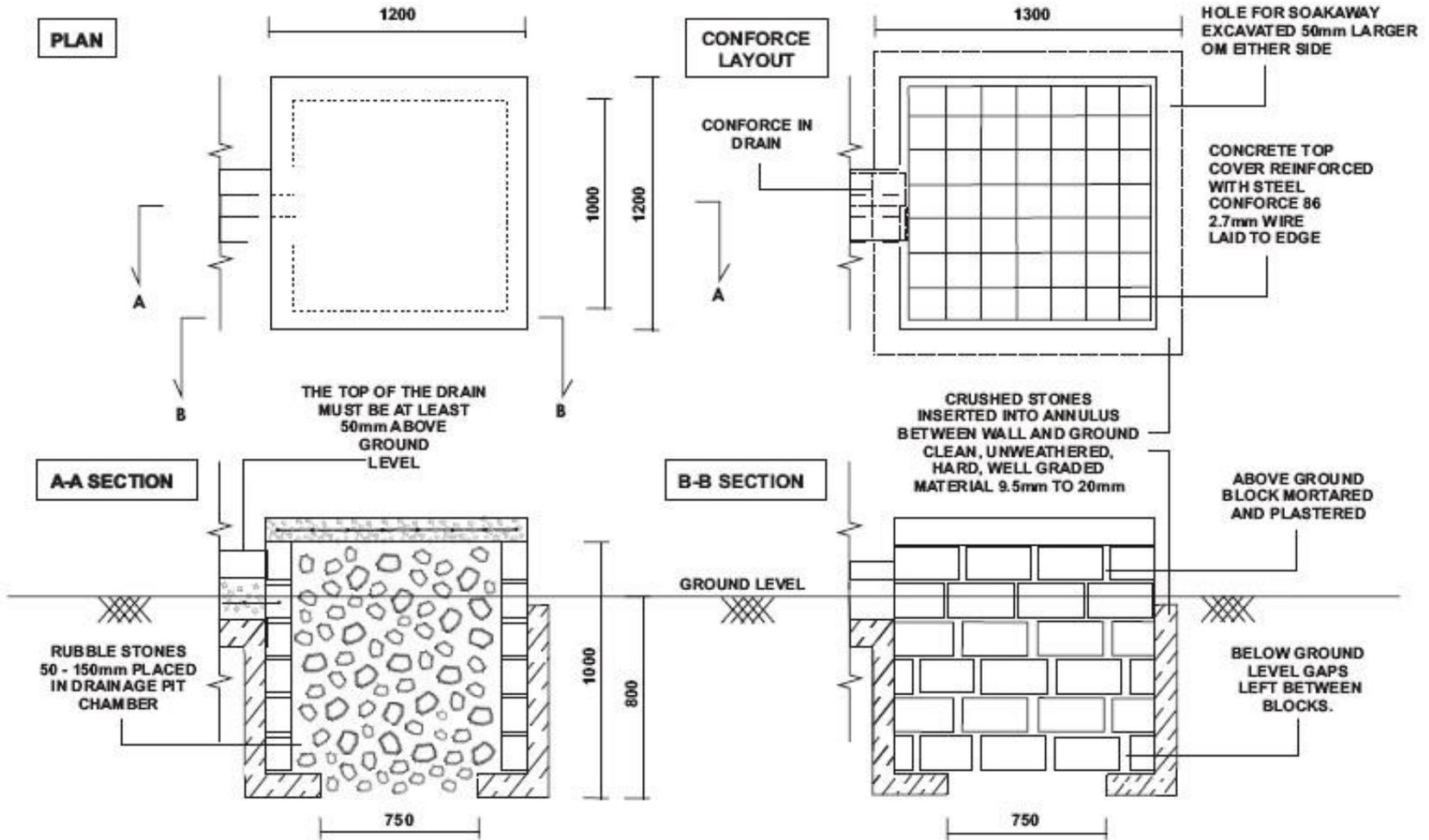
Layout of Superstructure



**B-B SECTION**

Apron

Soakaway



Setting Out



Compaction



Formwork





Rejected Borehole

Iron Filters

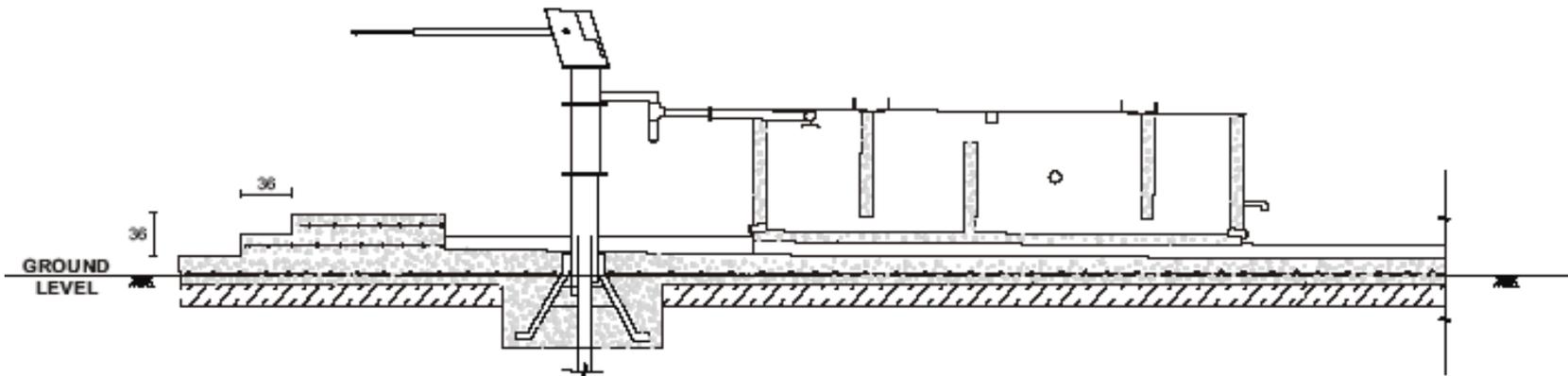
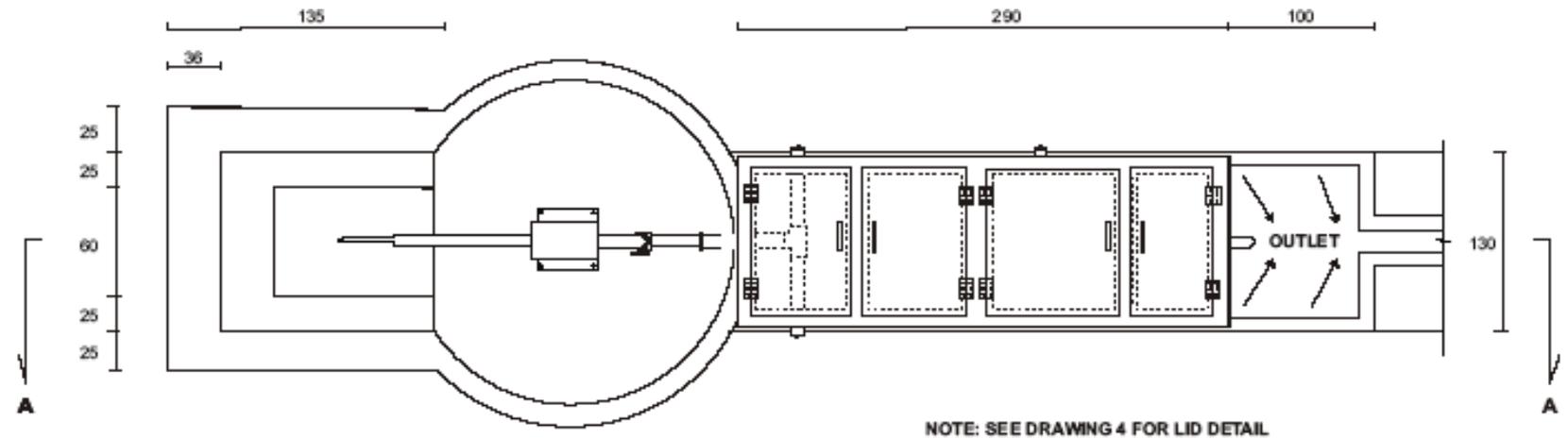
- Why are they necessary
- How are they proven
- Do they work
- Are they sustainable

IRON IS NOT TOXIC

Iron Filters



Iron Filters Layout



Iron Filter Detail

- Level of construction much higher
- Essential to have enough head
- How to avoid cracks
- Are they sustainable
- Operation and Maintenance

Construction of Civil Works

- Superstructure
- Quality of materials

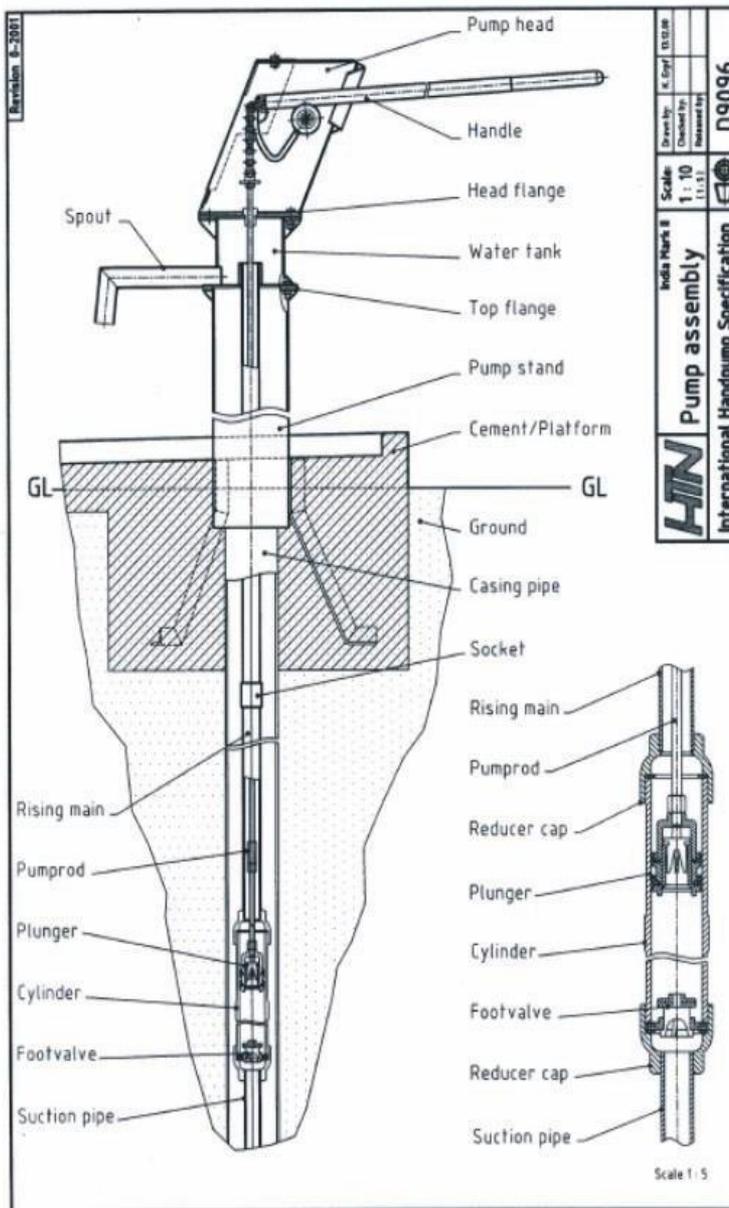
Aggregates, water, cement, reinforcement

- Quality of works and workmanship If
not happy with work - DO NOT SIGN

Handpump Design and Maintenance

Abstraction of water

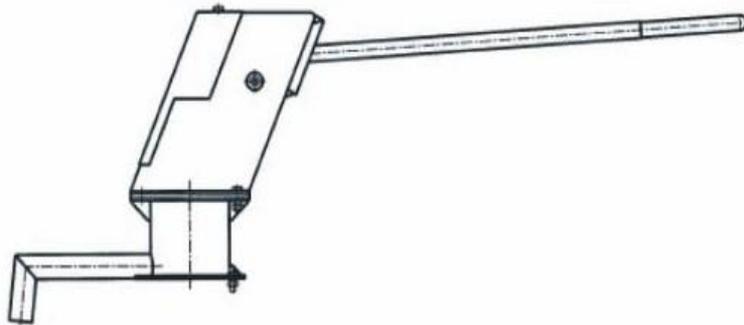
- **Cost Effective**
- **Robust**
- **Spare Parts Availability**



India Mark II Handpump

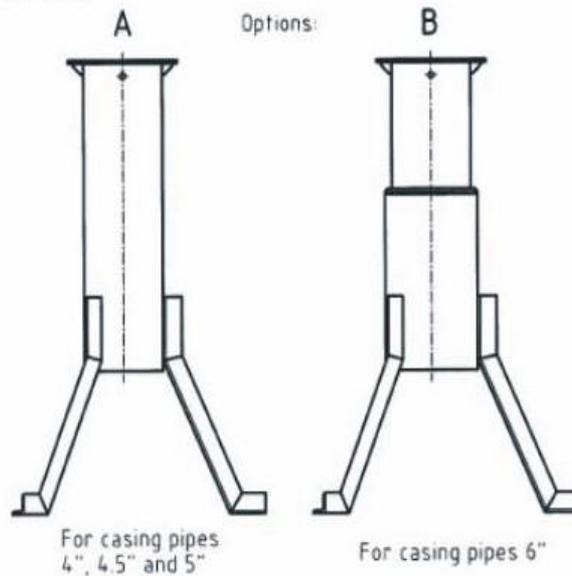
Pump head, Handle and Water tank

(approx. scale = 1 : 10)



Pump stand types

(approx. scale = 1 : 10)



India Mark II Pedestal

- Pedestal
- Head

Rising main arrangement
(approx. scale = 1 : 5)



GI Riser pipes
are available
in 3 m lengths

Cylinder arrangement
(approx. scale = 1 : 5)



Pumprod arrangement
(approx. scale = 1 : 5)



Pumprods are
available in
3 m lengths

India Mark II Cylinder

- Rising Main
- Cylinder
- Rods

Software and Handpumps

Handpump Failures - based on a good borehole with a properly installed handpump

- Lack of knowledge of how they work
- Lack of tools to fix pump
- Lack of spare parts

O & M Flaws

Even if a borehole is constructed well it can still fail due to O & M flaws

- Interference by non qualified person
- Alien blockages
- Poor or non existent spare parts chain
- Inconsistent community contribution
- Vandalism/Theft

VLOM

Village Level Operation and Maintenance

- Breakdown due to a combination of problems
- Village Caretaker and APM
- Local level O & M responsibility

Ownership

Most Important Element in RWS Projects

- Good Borehole with a good pump
- Trained APM
- Spare parts availability
- Sense of ownership by the community more important than the above

Practical

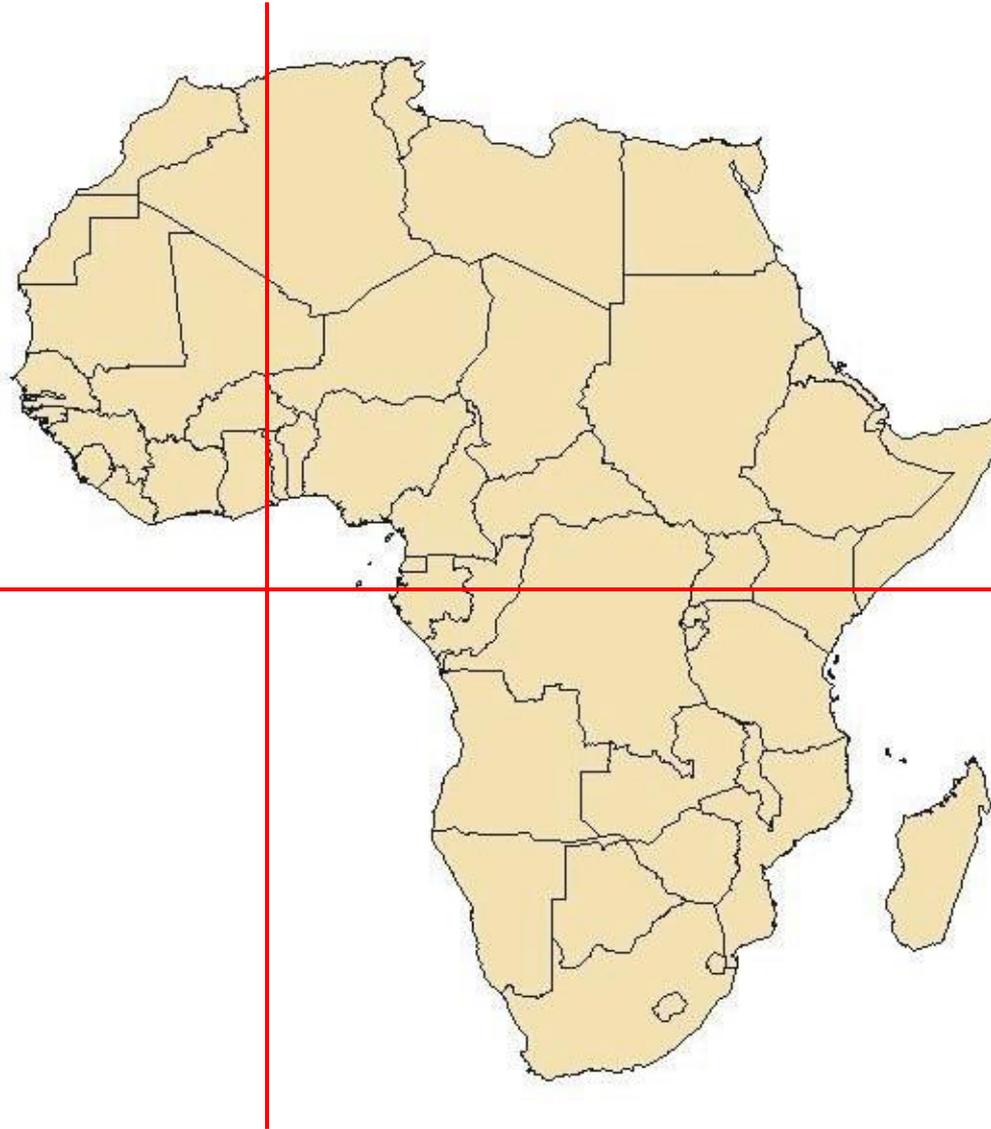
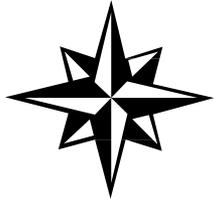
- Flow Rate Practical
- Water Level Practical
- Handpump Cylinder
- Measuring Water Quality
- Locating Gravel Pack
- Maps

Introduction to Mapping and GPS

- Types of Maps
- Finding your position
- Creating flat maps of round earth

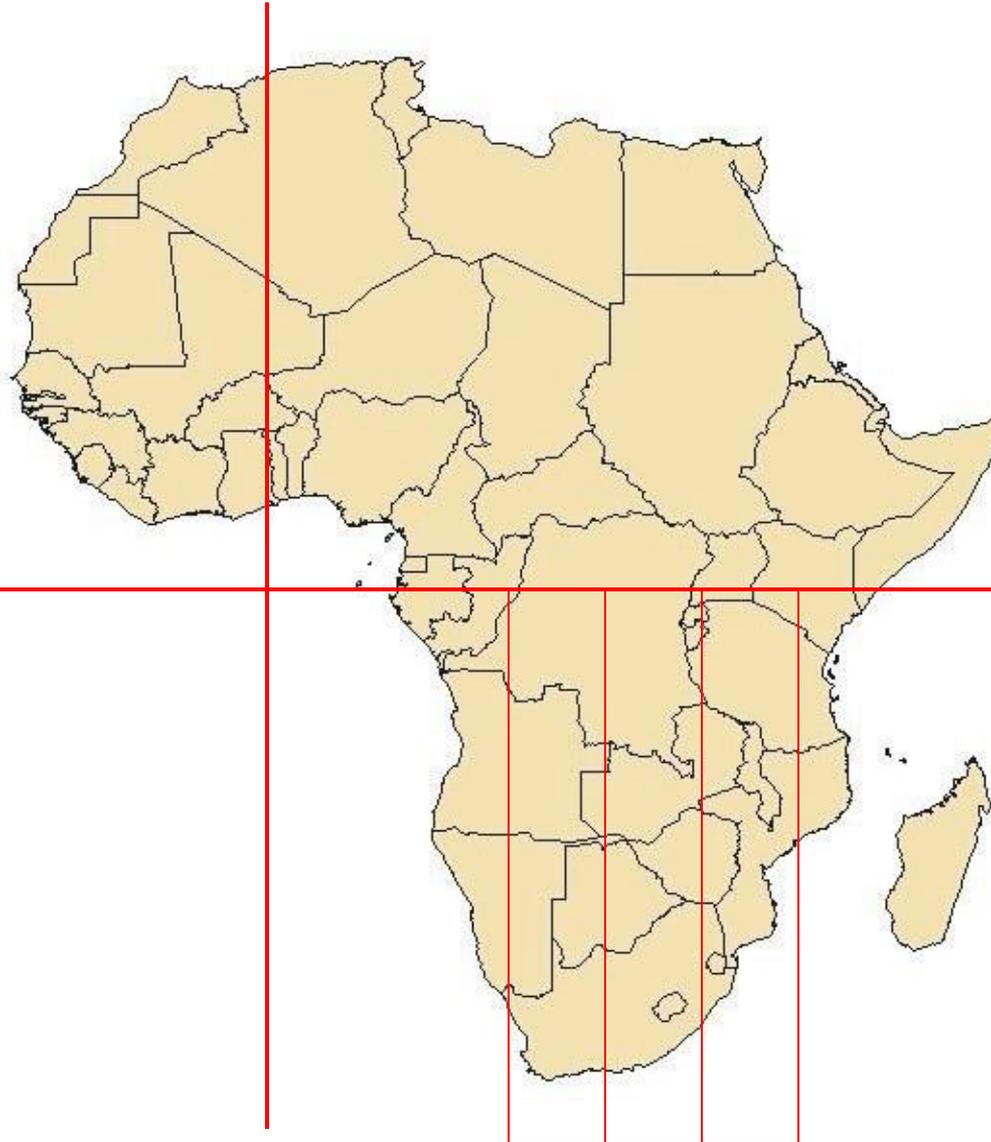
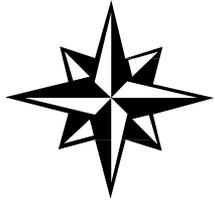


Location



- Latitude
- Longitude

Location

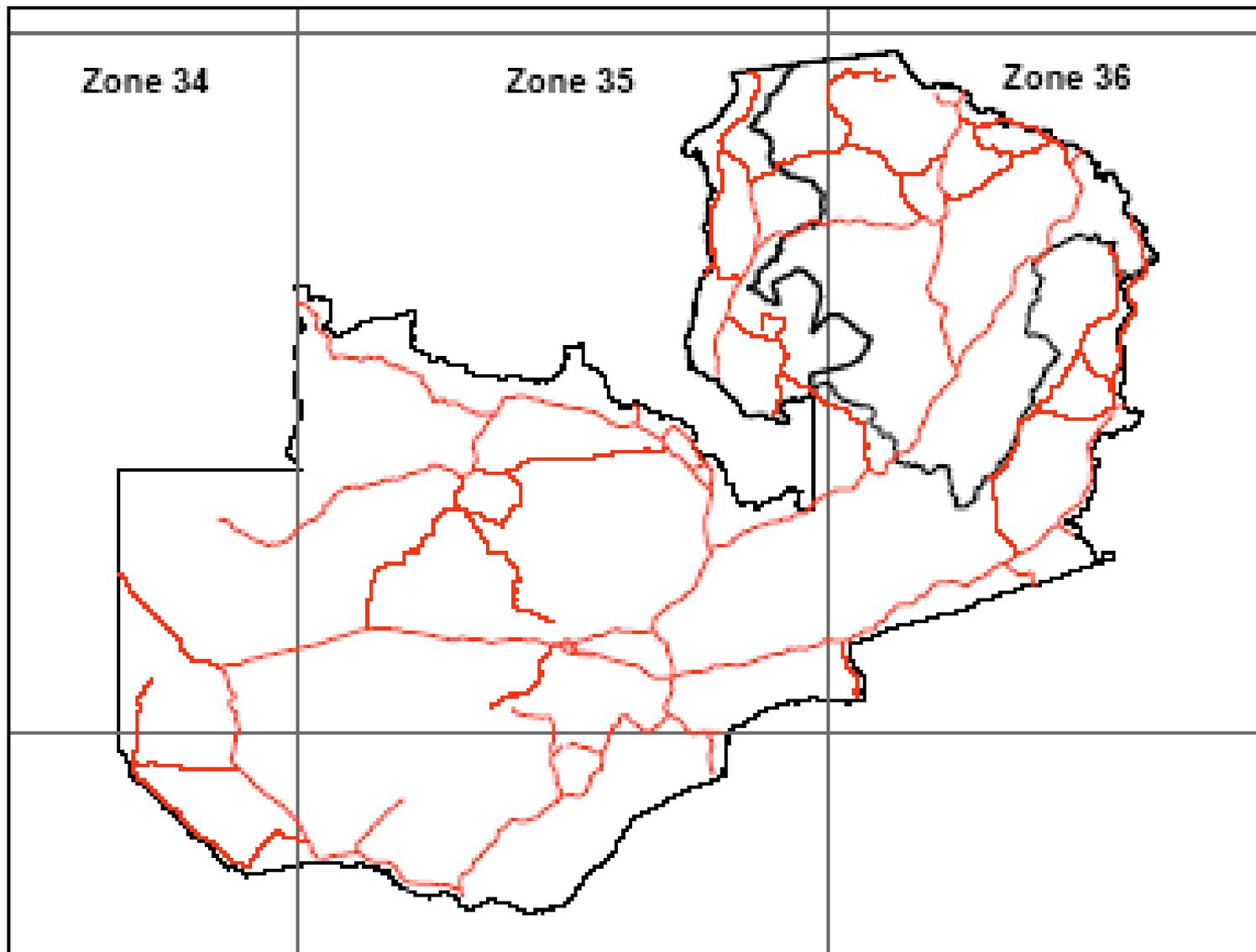


UTM

Universal

Transverse

Mercator



UTM Zones

Datum

- Way of dealing with curvature of the earth
- Very important to have the same datum
- Main datum in Zambia - WGS84

Global Positioning Systems

- Where are you now?
- How does it work?
- Why is it important?

Setting Up the GPS

- Decimal Degrees or Degrees, minutes,seconds
- Heading - North Up
- Units - Metric

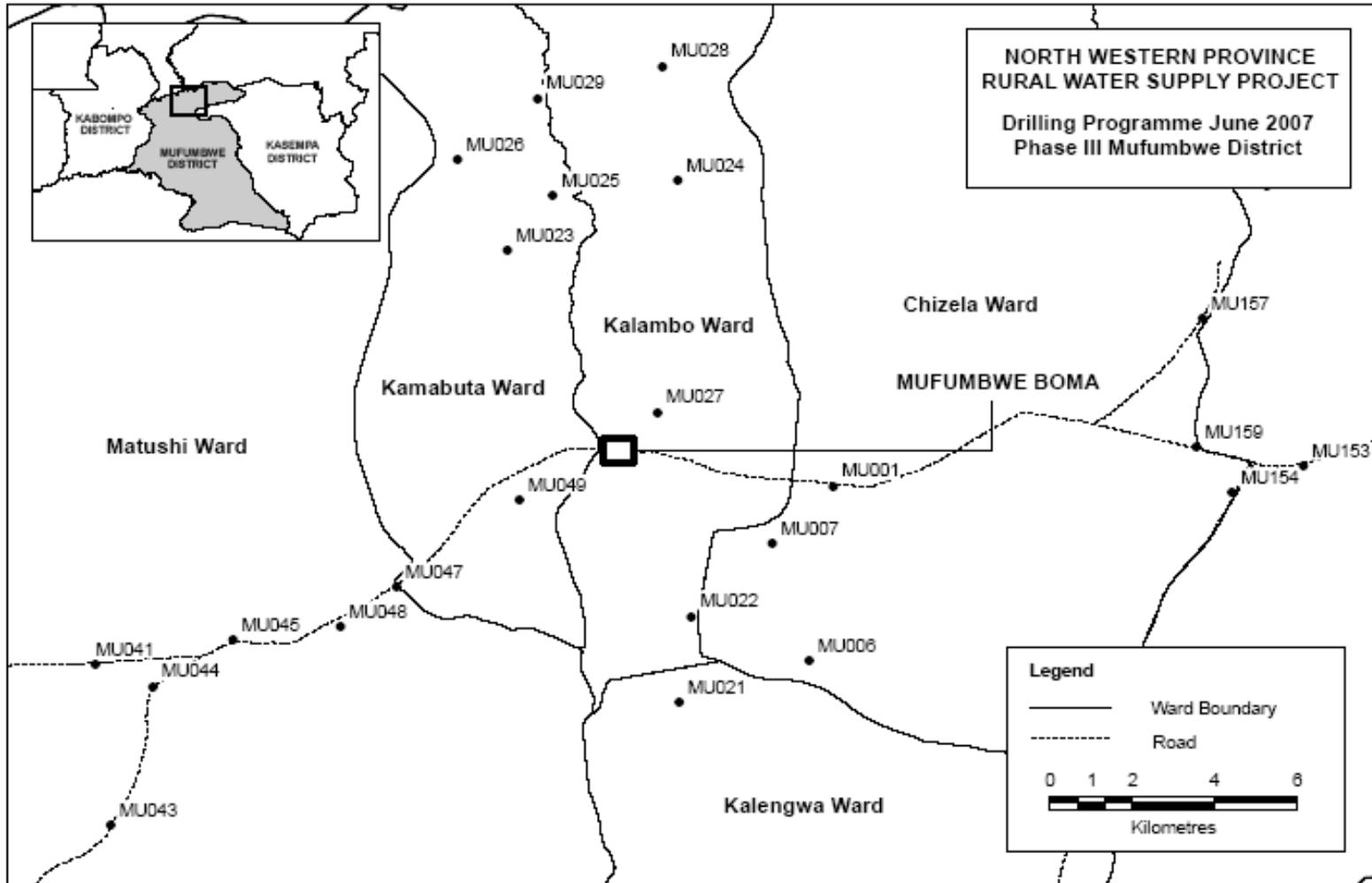
GPS

- Hddd.ddddd - Decimal Degrees
- Hddd^omm.ss.s' - Degrees, Minutes, Seconds
- Hddd^omm.mmm' - Degree and Minutes
- UTM - Universal Transverse Mercator

Use of GPS

- Use of GPS for locating villages
- Geophysical Survey A & B sites
- Tracklogs

GPS for Mapping



Borehole Codes

Essential to have unique ID for each site

- Code to Indicate District
- Code to indicate Ward
- Borehole Site A (Priority) and B (Backup)

Code	District	Province
CM	Choma	Southern
CW	Chongwe	Lusaka
GW	Gwembe	Southern
IT	Itezhi Tezhi	Southern
KF	Kafue	Lusaka
KL	Kalomo	Southern
KZ	Kazungula	Southern
LU	Luangwa	Lusaka
MK	Mazabuka	Southern
MZ	Monze	Southern
NM	Namwala	Southern
SV	Siavonga	Southern
SZ	Sinazongwe	Southern

District Codes

District Codes

CHINSALI DISTRICT

CA

004

A

6 Digits - Why

GPS Data

Transfer by computer ideal

Must make waypoints

When you write down coordinates

DOUBLE CHECK

Use of GPS - Practical

- Creation of Waypoints with Coded ID's
- Tracklogging
- Dumping the data
- Getting the data to Excel