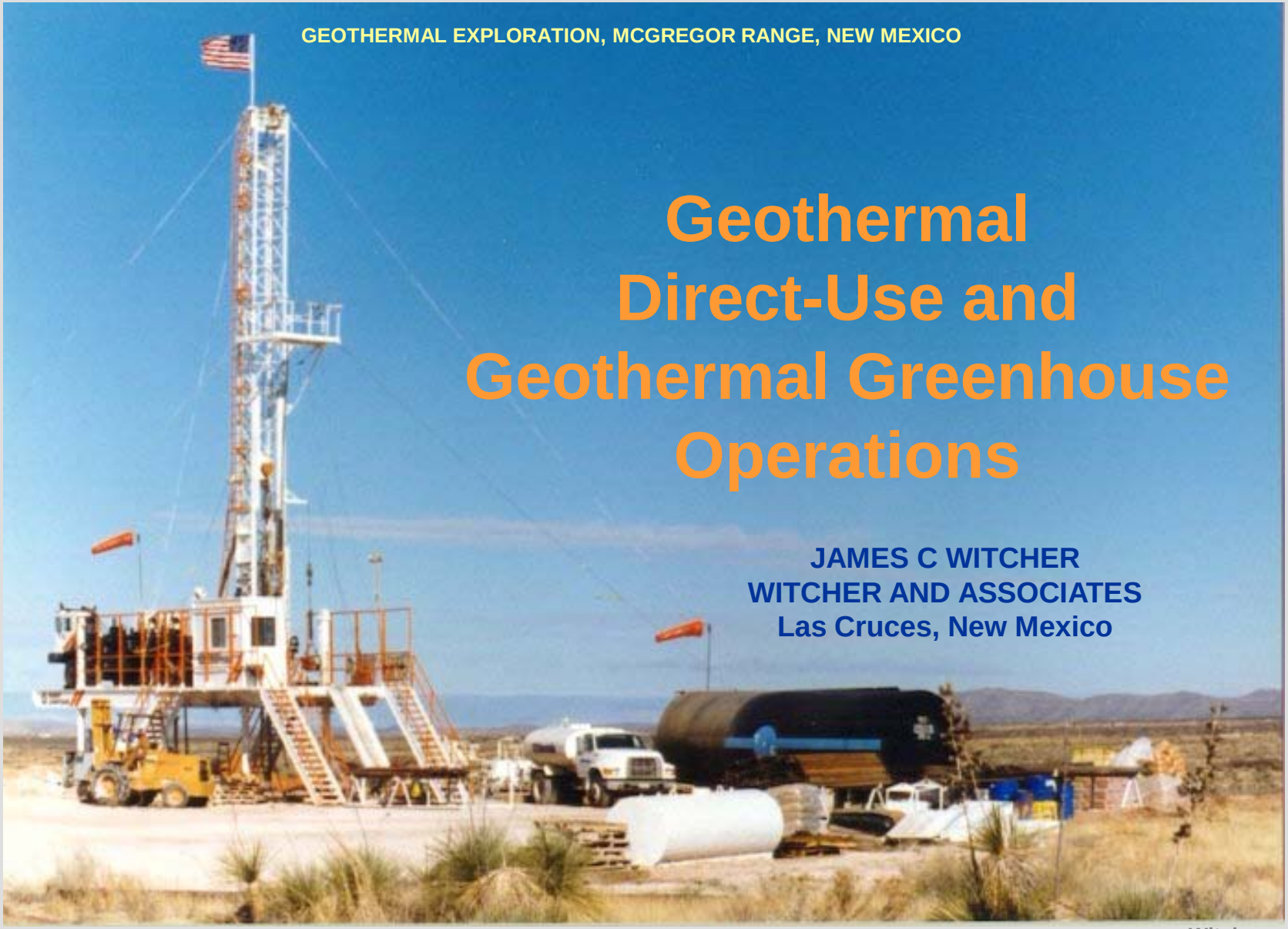
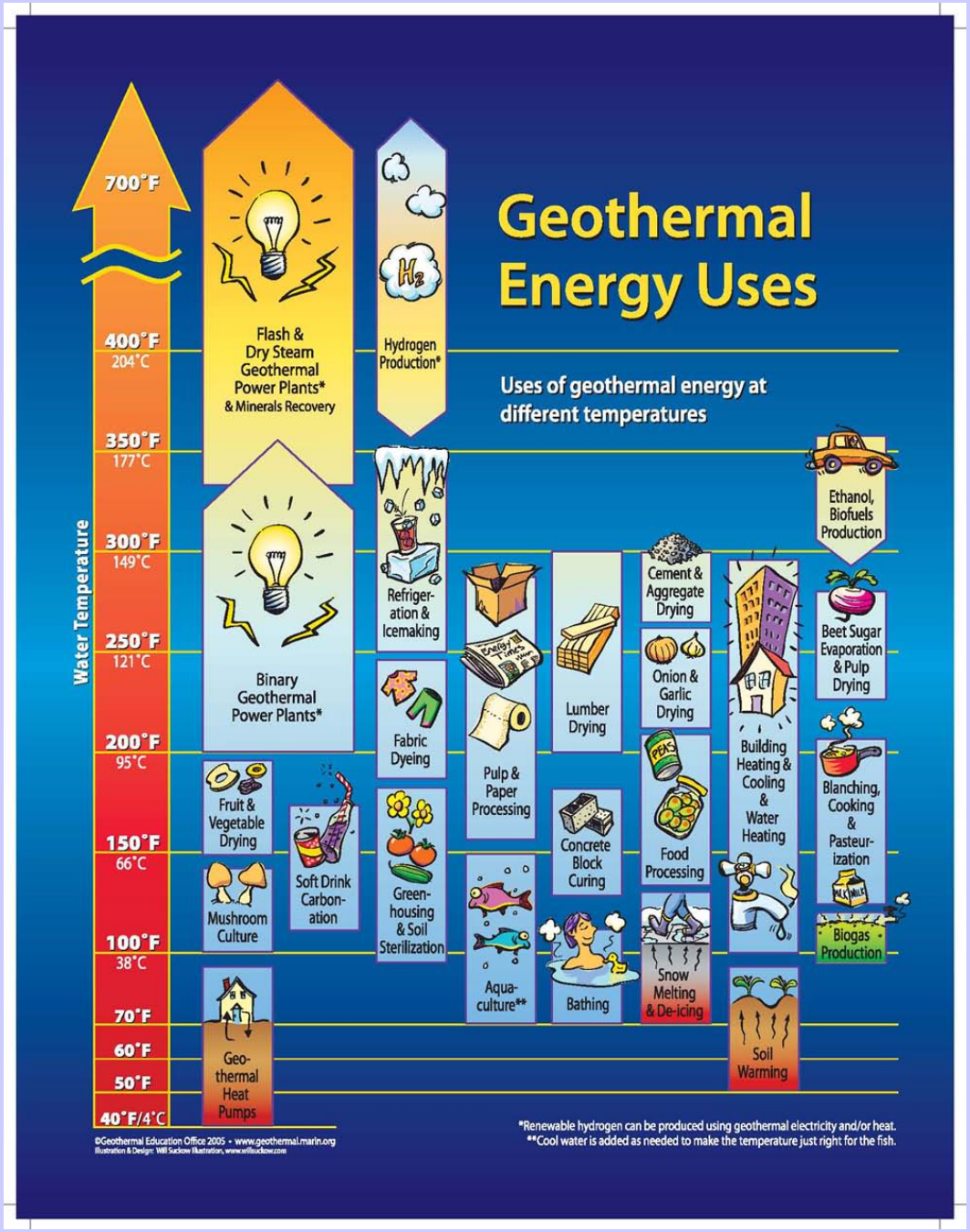


Geothermal Direct-Use and Geothermal Greenhouse Operations

JAMES C WITCHER
WITCHER AND ASSOCIATES
Las Cruces, New Mexico

Main Categories

- Electrical Power
- Agriculture
- Industrial
- Heating & Cooling
- Cascaded Energy Use
- Ground-Coupled Heat Pumps
- Combined Heat & Power (CHP)



Geothermal Education Office
www.geothermal.marin.org

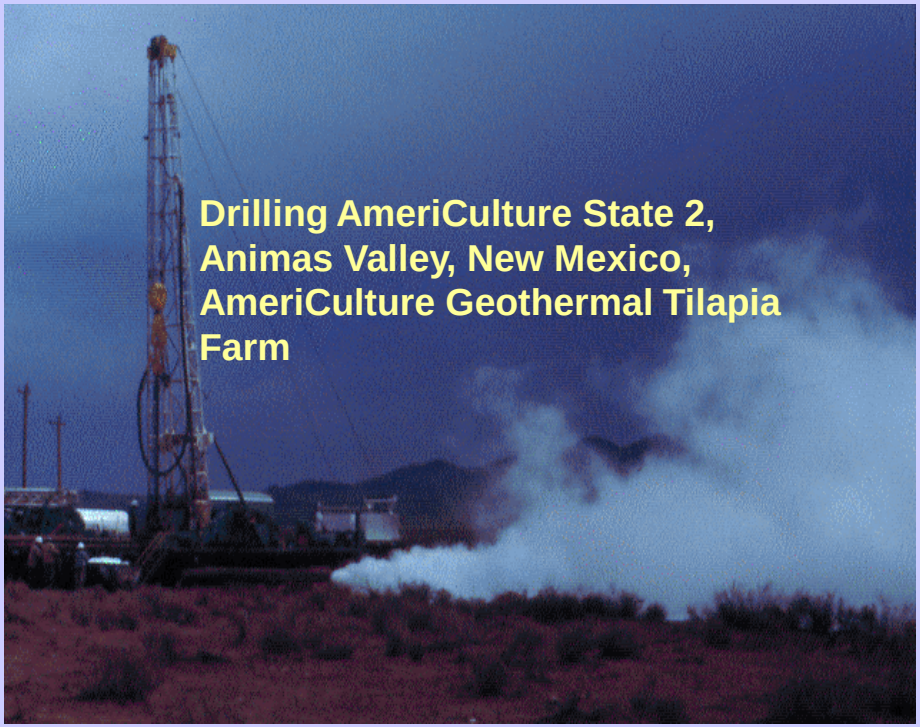
IMPORTANT PARAMETERS

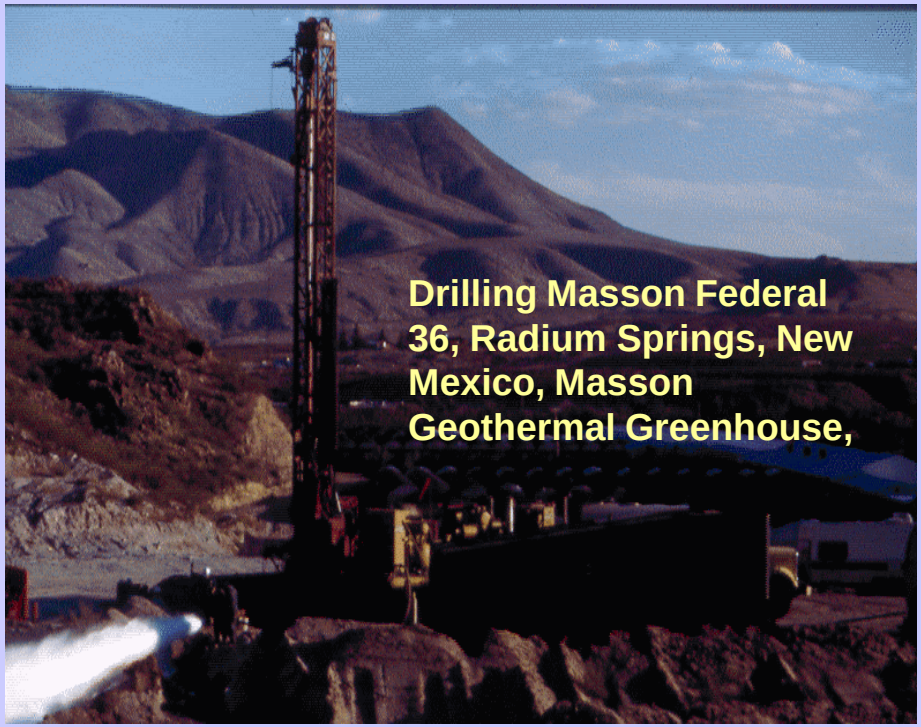
- Land
  - Location and Infrastructure
  - Ownership
  - Institutional Setting
- Water
  - Sufficient for reservoir sustainability
  - Adequate for surface requirements
- Temperature
- Economics

NPS, Saguaro National Monument

DEVELOPMENT INFRASTRUCTURE

- PRODUCTION WELLS
- INJECTION WELLS
- HEAT EXCHANGERS
- PIPE LINES


Drilling AmeriCulture State 2, Animas Valley, New Mexico, AmeriCulture Geothermal Tilapia Farm


Drilling Masson Federal 36, Radium Springs, New Mexico, Masson Geothermal Greenhouse,

PURPOSE OF GEOTHERMAL GREENHOUSING

THE PRIMARY OBJECT OF GEOTHERMAL GREENHOUSING IS TO GROW THE BEST QUALITY CROP PROFITABLY WITH ENERGY SAVINGS

WHY USE GEOTHERMAL?

DRAWBACKS

1) up front capital costs
2) approach unfamiliar
3) acceptance of risk
4) can require more effort

WHY USE GEOTHERMAL?

ADVANTAGES

1) significant savings in energy cost
2) energy costs are stable and predictable over the long haul

MOST IMPORTANT REQUIREMENTS

- SOUND BUSINESS PLAN
- EXPERT GROWER AND GREENHOUSE MANAGER
- MARKETS TO SELL PRODUCT

GEOTHERMAL GREENHOUSING REQUIREMENTS

CO-LOCATION OF

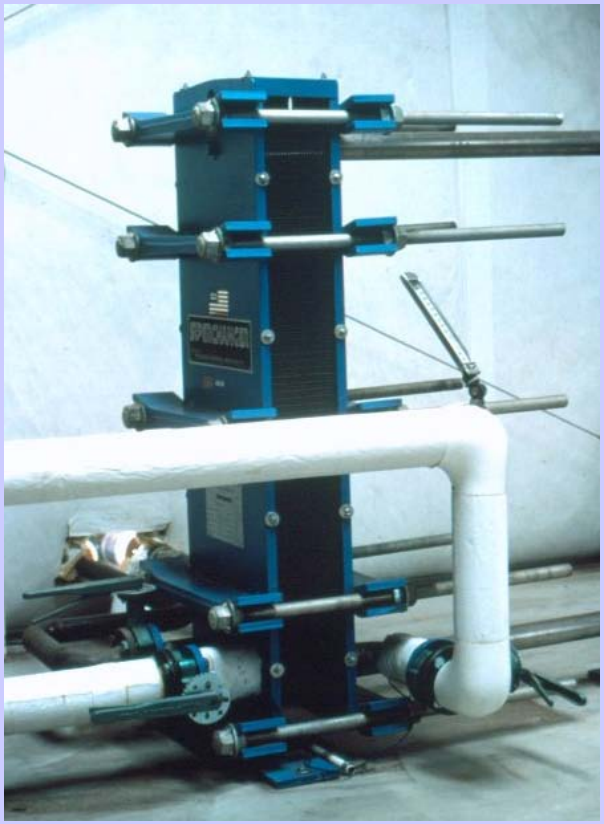
1) suitable land
2) geothermal resource
3) fresh water source
4) labor force

GEOTHERMAL SYSTEM COMPONENTS

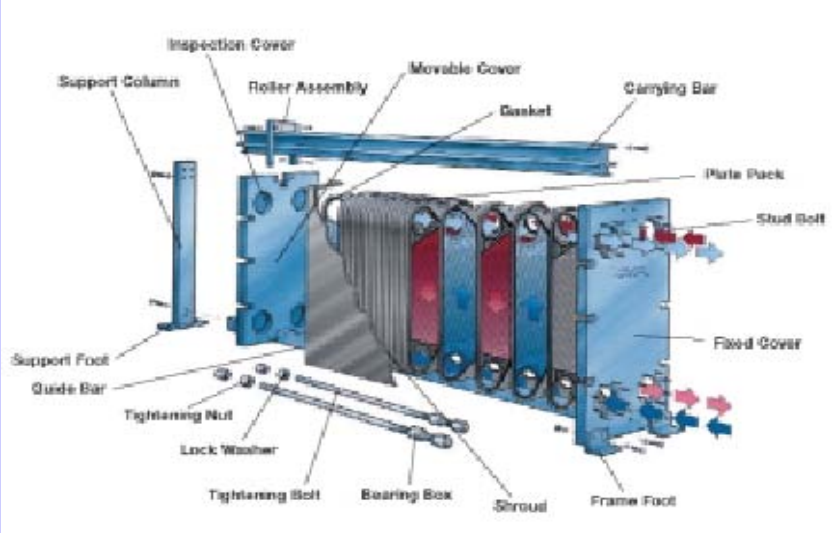
- Geothermal production wells
- Geothermal pump
- Geothermal pipe line
- Heat exchangers
- Geothermal injection well
- Proper sizing and materials selection

HEAT EXCHANGERS

- Prevent scaling and corrosion
- Isolate geothermal fluids from heating equipment and environment
- Plate and frame heat are very efficient



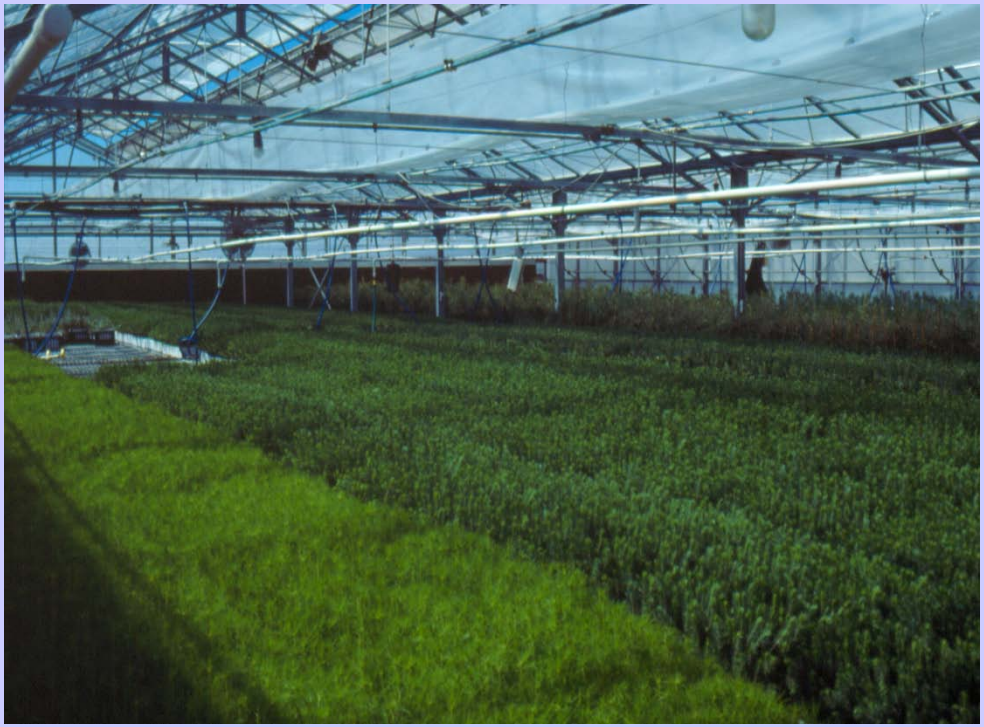
NMSU



Haslego and Polley (2002)

GEOTHERMAL GREENHOUSE HEATING

- CENTRAL HOT WATER SYSTEM
- A GEOTHERMAL WELL AND HEAT EXCHANGER REPLACE A CONVENTIONAL FOSSIL FUEL BOILER



GEOTHERMAL GREENHOUSE HEATING

WHERE TO HEAT?

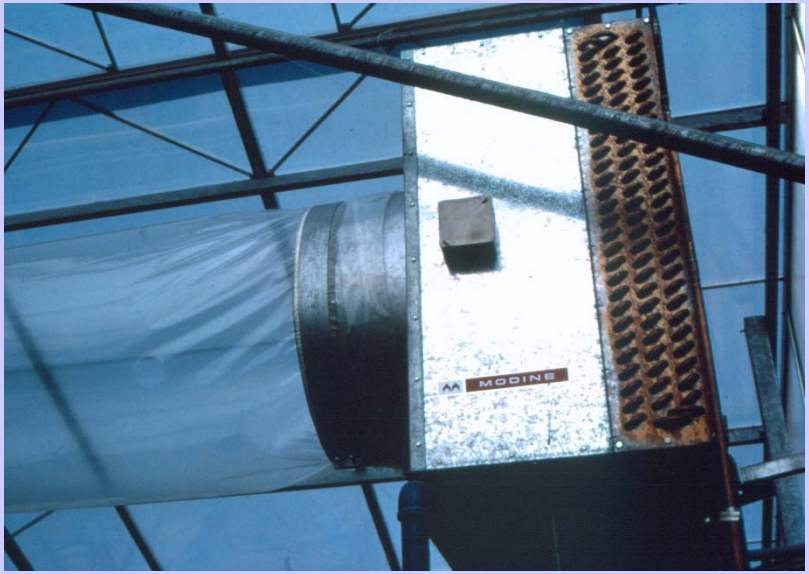
1) floor heating and soil heating
2) bench top heating
3) overhead heating
4) perimeter heating
5) crop irrigation water

HEATING EQUIPMENT

- Circulation pumps
- Fan-coil unit heaters
- Plain pipe
- Finned pipe
- Plastic tubing for bench top heating
- Small tube heat exchanger for heating irrigation water

OVERHEAD HEATING

- Fan-coil heating unit
- Unobtrusive installation
- Efficient
- Assists with snow melt



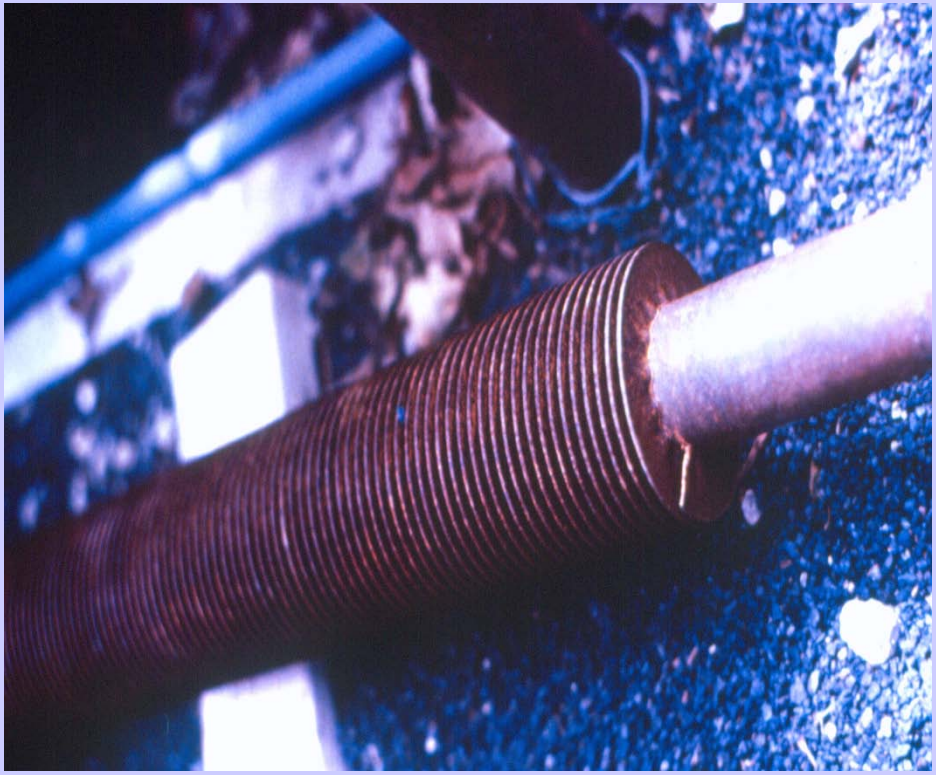
PERIMETER HEATING

FINNED PIPE

Prevents cold spots

Can be used in first stage heating

Use with other heating such and floor, overhead and benchtop heating



DRILLING OVERVIEW

- ELEMENTS
- METHODS
- TYPES OF WELLS
- MANAGEMENT

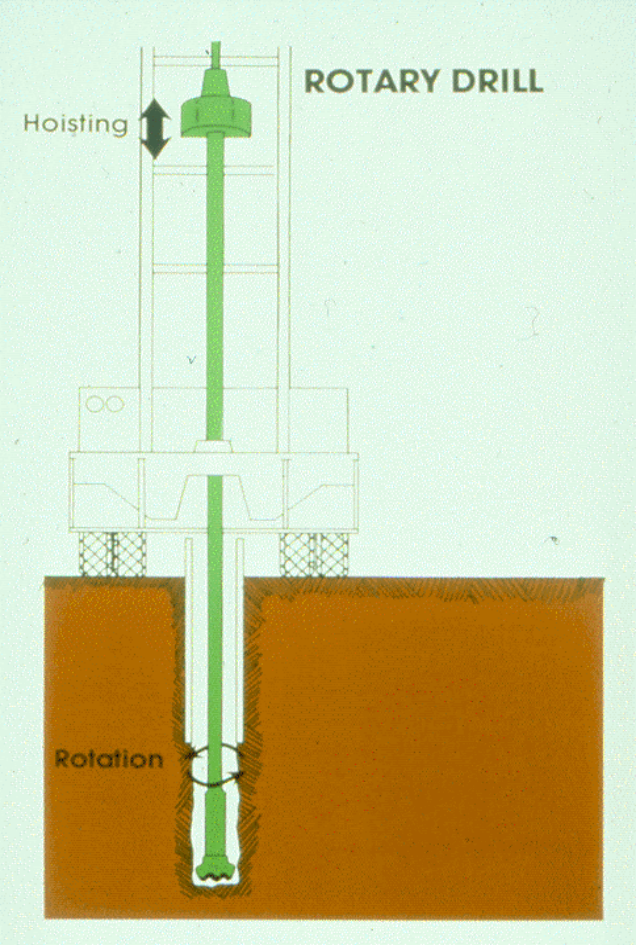
ESSENTIAL ELEMENTS OF DRILLING

- DRILL RIG (STABLE PLATFORM)
- DRILL STRING
- DRILLING FLUIDS
- CASING
- WELL CONTROL
- STORAGE FACILITIES
- SUPPLIERS AND VENDORS
- KEY PEOPLE
- SITE PREPARATION

DRILL RIG

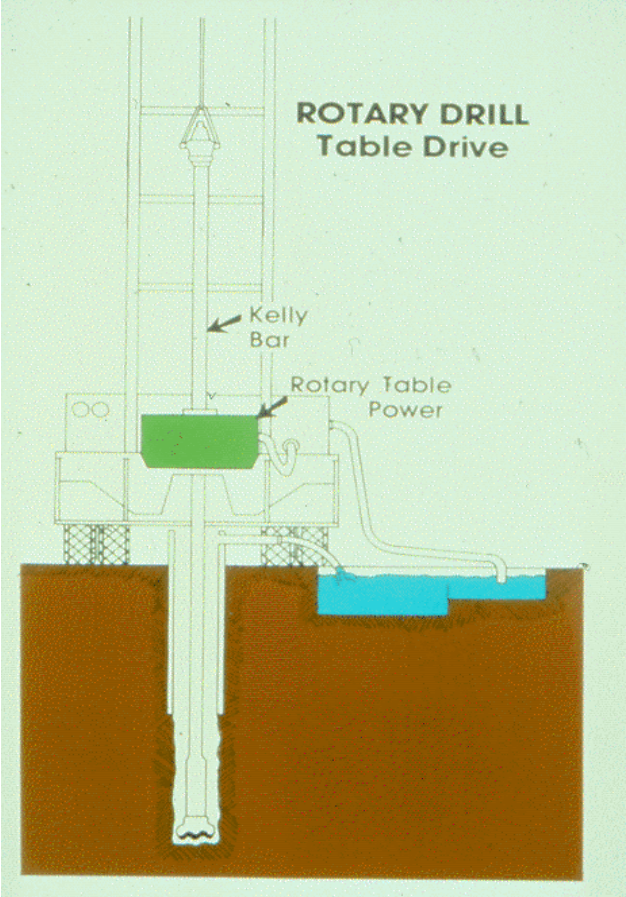
- STABLE PLATFORM
- ENGINES AND COMPRESSORS FOR MECHANICAL OR HYDRAULIC DRIVE OF ROTARY DRILL STRING AND DRAW WORKS
- STRUCTURALLY SOUND MAST FOR DRAW WORKS AND TEMPORARY STORAGE OF DRILL STRING
- PUMPS FOR DRILL FLUID AND CEMENT
- WORKING PLATFORM WITH DRAW WORKS AND CONTROLS

ROTARY DRILLING



NGWA

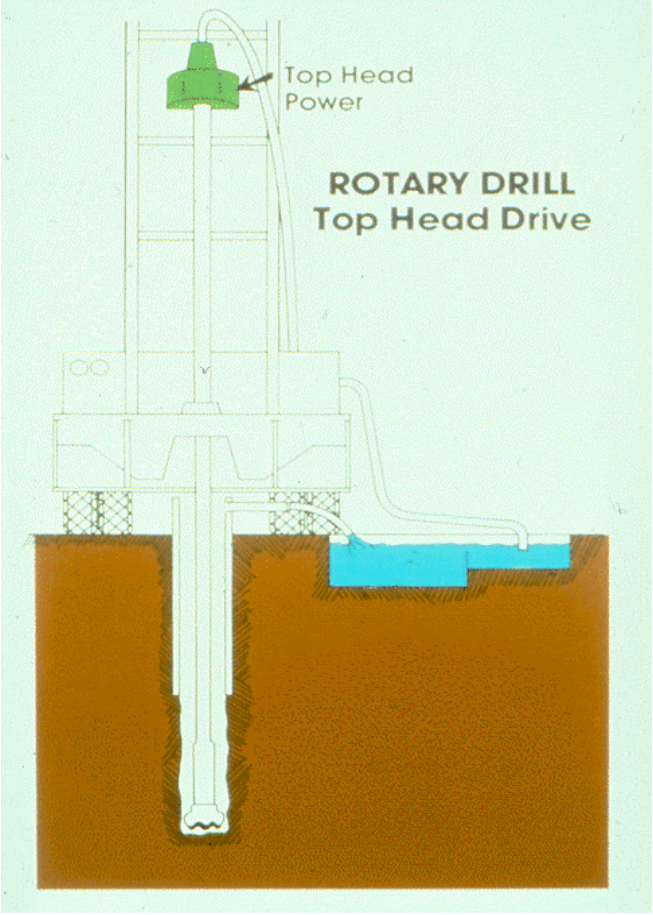
ROTARY TABLE DRIVE



NGWA

- MECHANICAL
- MOST COMMON ON OLDER AND LARGER DRILLING RIGS

ROTARY TOP HEAD DRIVE



NGWA

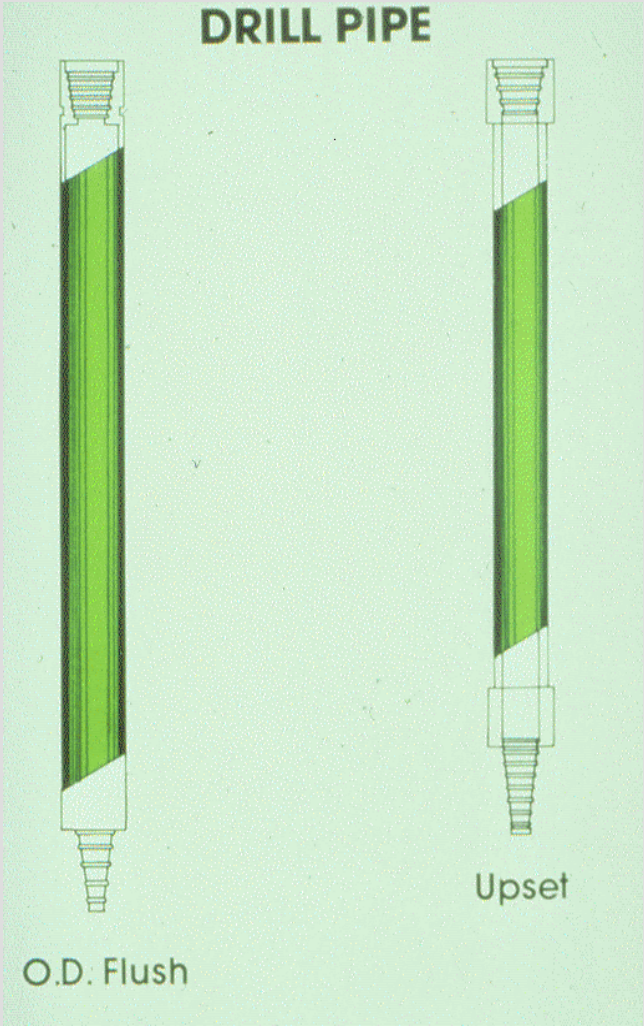
- HYDRAULIC (PNUEMATIC) DRIVE
- GREATER SENSITIVITY IN DRILLING CONTROL

DRILL STRING

- **TRANSFERS MECHANICAL ENERGY FROM SURFACE TO THE BIT IN A METHODICAL, PREDICTABLE, AND <u>CONTROLLED</u> MANNER**

- **DRILL STRING ELEMENTS**
  - ***DRILL PIPE***
  - ***COLLARS AND STABILIZERS***
  - ***BIT AND REAMERS***

DRILL PIPE



- O. D. FLUSH
- UPSET

COLLARS AND STABILIZERS

NGWA

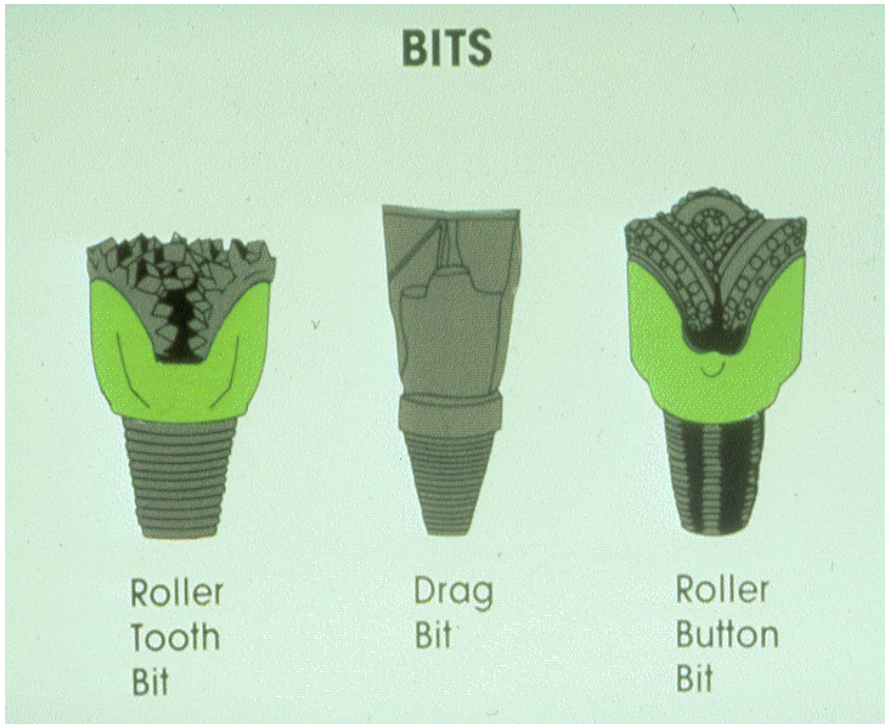
- **COLLARS**

  WEIGHT

- **STABILIZERS**

  DIRECTION

DRILL BITS



NGWA

- DRAG BITS (BLADE BITS)
- ROLLER BITS (TRI-CONE)
- HAMMER BITS
- DIAMOND BITS
- SPECIAL PURPOSE BITS (CORING, REAMING, ETC)

DRILLING FLUID (MUD)

- COOL AND LUBRICATE BIT AND DRILL STRING
- CONTROL FORMATION PRESSURES
- REMOVE CUTTINGS FROM HOLE
- REDUCE CORROSION
- STABILIZE HOLE (PREVENT CAVING)
- SEAL HOLE (HEAL LOST CIRCULATION)
- INHIBIT (SWELLING CLAYS)

TYPES OF DRILLING FLUID

- WATER OR AIR
- BENTONITE/WATER
- POLYMER/WATER
- LOST CIRCULATION MATERIAL (LCM)
- OTHER (SODA ASH, BARITE, DETERGENT, ETC)

CASING

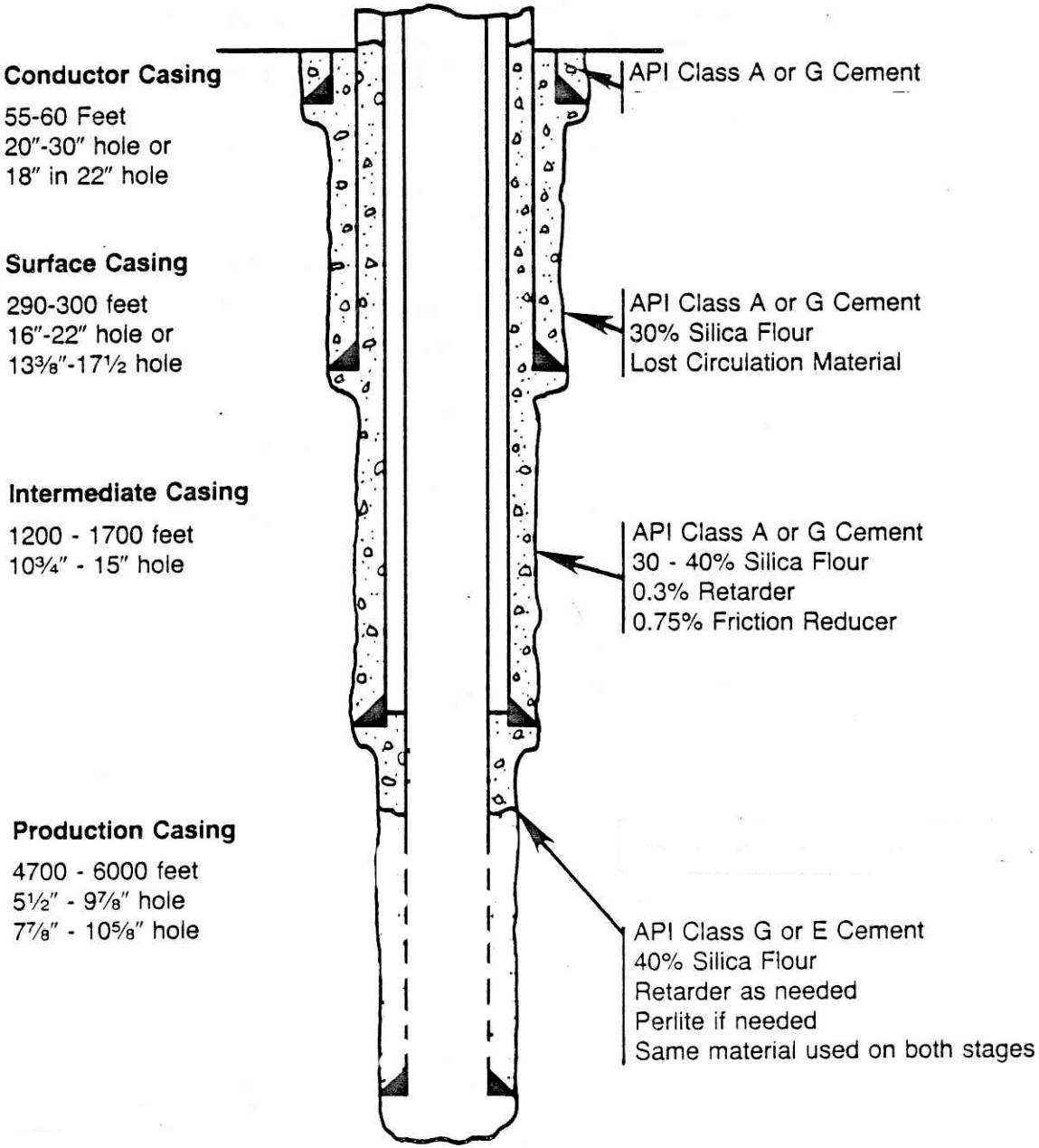
- STABILIZES HOLE
- PROVIDES HOUSING FOR WELL EQUIPMENT (PUMPS, ETC)
- ASSISTS IN WELL CONTROL

CASING ELEMENTS

- PIPE (VARIETY OF MATERIALS WITH DIFFERENT STRENGTHS AND CONNECTIVE CONFIGURATIONS)
- CEMENT (VARIOUS TYPES DEPENDING UPON TEMPERATURE, FLUID CHEMISTRY, PURPOSE, AND RATE OF CURING OR SETTING)
- CASING SHOES AND CEMENTING SHOES OR CEMENT CHECK VALVES
- CENTRALIZERS

TYPES OF CASING

- CONDUCTOR
- SURFACE
- INTERMEDIATE
- PRODUCTION



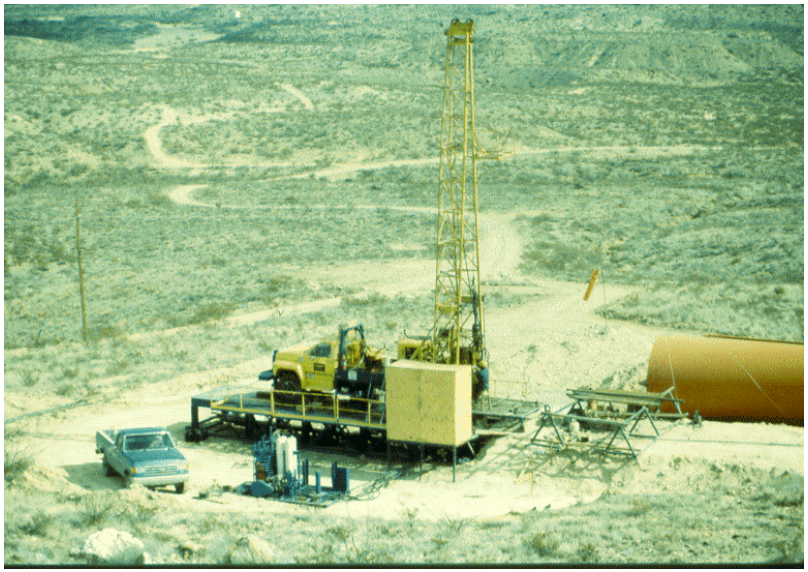
WELL CONTROL

- CASING
- DRILL FLUID
- BOPE (BLOWOUT PREVENTION EQUIPMENT)
- DISCHARGE MANIFOLDS
- MUD PUMPS AND AIR COMPRESSORS
- DRILLING WELL HEAD WITH KILL AND DISCHARGE LINES

DRILLING WELL HEAD

- KILL LINE
- DISCHARGE LINE
- FLANGE FOR ANNULAR BOPE
- MAY ADD A GATE VALVE

STORAGE FACILITIES



- TANKS AND PITS FOR DRILLING FLUIDS
- STORAGE TANKS FOR WATER AND FUEL
- PIPE RACKS
- TOOLS AND ASSORTED SUPPLIES AND PARTS

SUPPLIERS AND VENDORS

- WATER
- MUD
- CASING
- BITS AND DRILLING SUPPLIES
- SITE PREPARATION
- CASING CREWS
- CEMENT OPERATIONS
- GEOPHYSICAL LOGGING
- MUD LOGGING AND ENGINEERING SUPPORT
- GEOLOGIC LOGGING
- HYDROGEN SULFIDE MONITORING AND ALARMS
- DRILL FLUIDS DISPOSAL

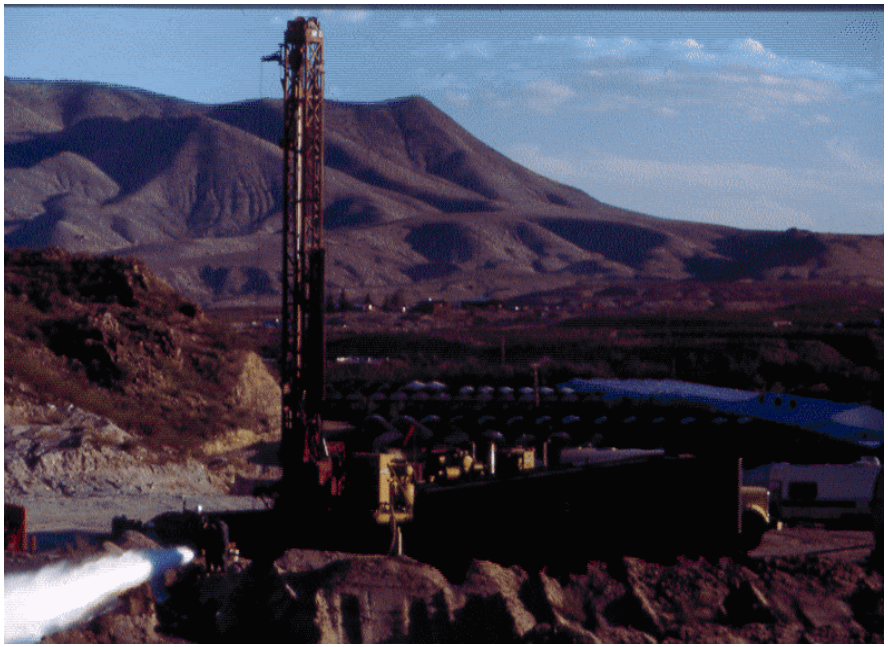
KEY PEOPLE

- COMPANY MAN
- TOOL PUSHER
- DRILLER
- HELPERS
- CASING CREW
- MUD ENGINEER
- MUD LOGGER
- GEOLOGIST
- GOVERNMENT MAN

SITE PREPARATION

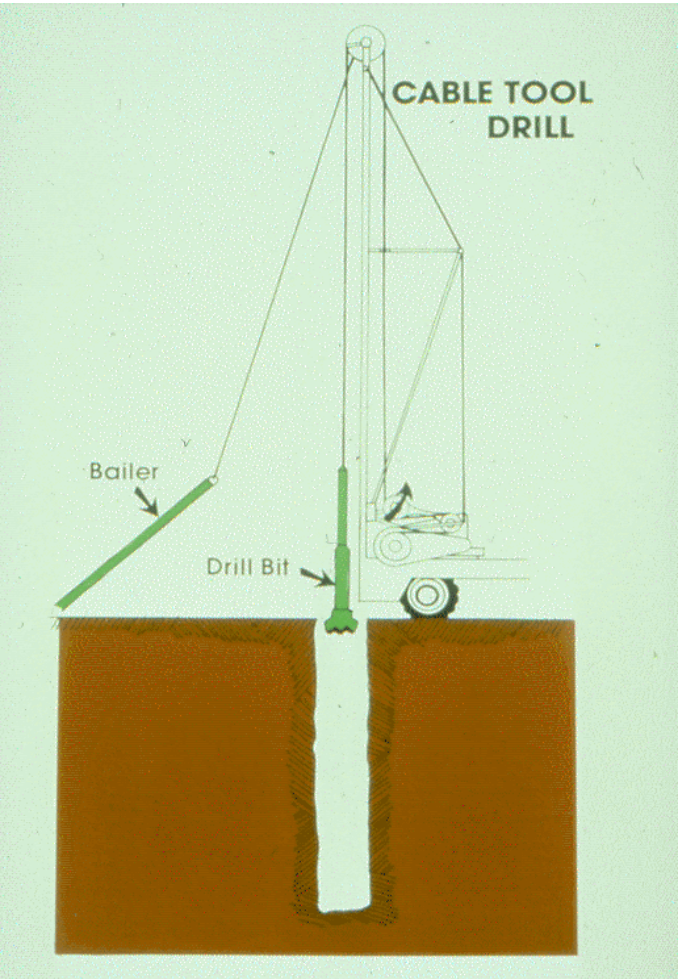
- ACCESSIBLE FOR ALL EQUIPMENT AND SUPPLIERS
- ADEQUATE SIZE FOR OPERATIONS
- MINIMAL ENVIRONMENTAL IMPACT
- ALL WEATHER SUITABILITY

DRILLING METHODS



- MUD ROTARY
- AIR ROTARY
- CABLE TOOL

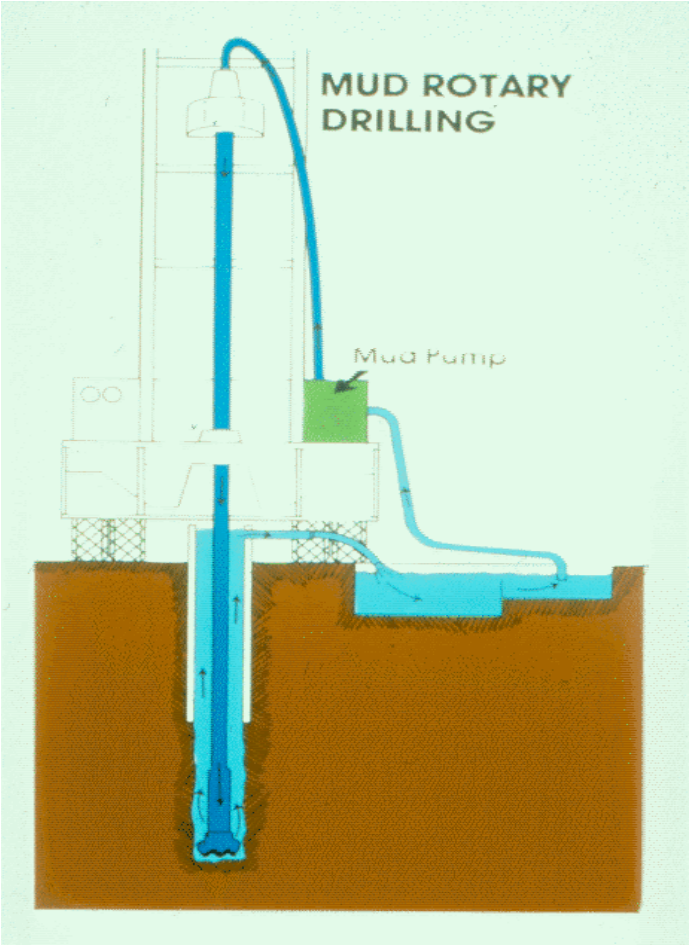
CABLE TOOL



NGWA

- SLOW !
- INEXPENSIVE
- GOOD IDENTIFICATION OF WATER BEARING ZONES
- MINIMAL FORMATION DAMAGE
- GOOD MOBILITY
- MAY NOT BE SUITABLE FOR HIGHER TEMPERATURE (>100 ^{o}C)

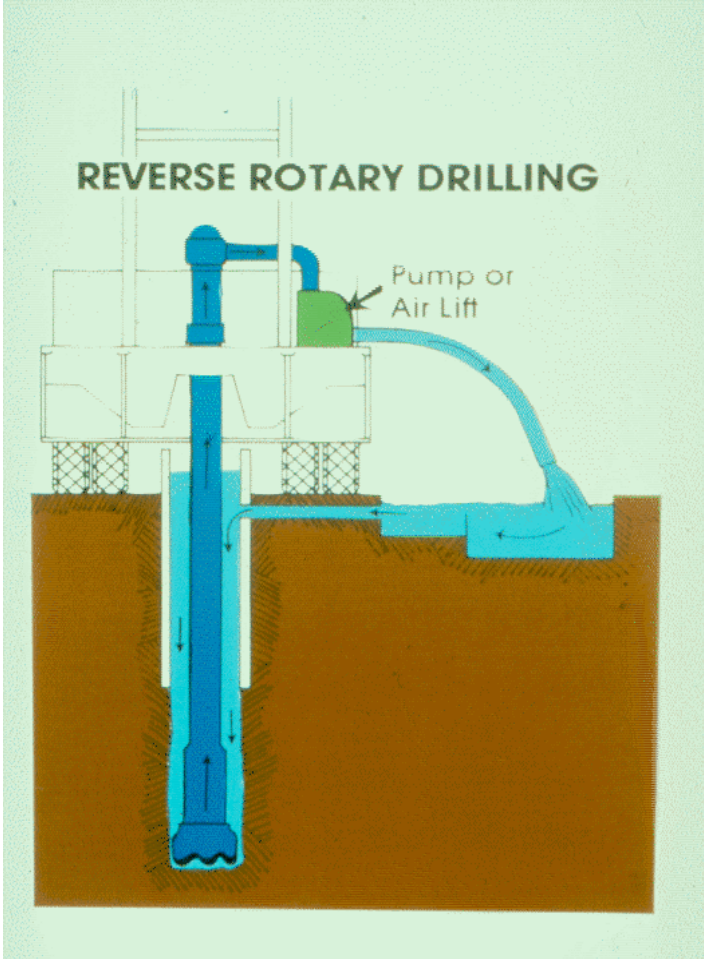
MUD ROTARY DRILLING



NGWA

- BEST AVAILABILITY
- MODEST COST
- CAN DRILL TO GREAT DEPTH
- MAY CONTRIBUTE TO FORMATION DAMAGE (DRILL MUD INFILTRATION INTO TO RESERVOIR OR AQUIFER)

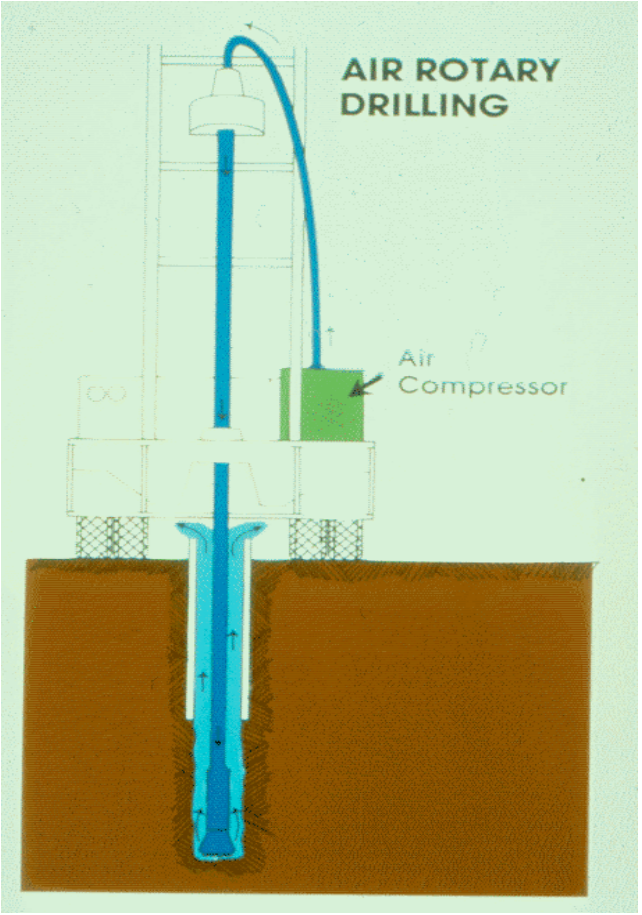
REVERSE MUD ROTARY



NGWA

- MINIMAL FORMATION DAMAGE
- GOOD SAMPLE RETURNS
- NOT READILY AVAILABLE
- HIGHER TEMPERATURE DRILLING MAY NOT BE FEASIBLE (>100 ^{o}C)

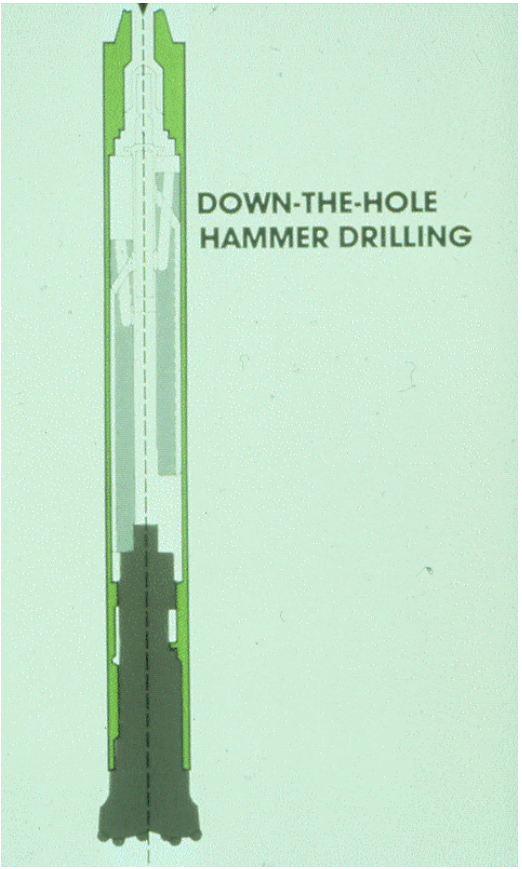
AIR ROTARY



NGWA

- MINIMAL FORMATION DAMAGE
- MAY BE LIMITED IN DEPTH BY WATER COLUMN PRESSURE
- MAY USE DOWN HOLE AIR HAMMER

DOWN HOLE AIR HAMMER



NGWA

- **EFFICIENT DRILLING OF HARD FORMATIONS**

TEMPERATURE GRADIENT AND HEAT FLOW HOLES

Temperature Gradient/Heat Flow Drilling
Safford, Arizona

- SHALLOW (100 TO 300 ft)
- 6 in OR SMALLER HOLE IS TYPICAL
- ONLY REQUIRES A SMALL DRILL RIG
- COMPLETE WITH 1-2 in PVC OR BLACK IRON PIPE FILLED WITH WATER AND ANNULUS BACKFILLED
- MAY BE ABLE TO DRILL AND COMPLETE TWO OR THREE WELLS PER DAY
- COSTS ($15 TO $35/ft)
- CAN DRILL 3 TO 10 HOLES FOR COST A RESISTIVITY SURVEY

Witcher

SLIM-HOLE EXPLORATION HOLES

Alpine Geothermal Test Hole, Alpine, Arizona

Witcher

- SMALLER DIAMETER ROTARY HOLES
- 500 TO 5,000 ft DEPTH
- CONTINUOUS WIRE-LINE ROTARY CORE DRILLING
- COSTS ($75 TO $150/ft)

PRODUCTION WELLS AND INJECTION WELLS

AmeriCulture #2, Lightning Dock,
Animas Valley, New Mexico

Witcher

- LARGER DIAMETER
- DESIGNED TO HOST PUMP EQUIPMENT
- DRILLED TO MINIMIZE FORMATION DAMAGE
- COST HIGHLY VARIABLE ($75 TO $400/ft)

RESERVOIR TESTING AND MONITORING

- Determine reservoir hydraulic properties
- Obtain water chemistry and isotopic data
- Estimate long-term drawdown (sustainability)
- Manage reservoir
  - Monitor chemistry
  - Monitor water levels
  - Monitor temperature
  - Record production

Pump Test, AmeriCulture 1, Lightning Dock, Animas, New Mexico

Witcher

MANAGEMENT FRAMEWORK

- **PLAN AHEAD**
  Match geology, drilling method, contractor availibility and budget.
- **COSTS**
  Track costs.
  Understand cost inflection points, drilling costs are not linear
- **REGULATORY COMPLIANCE**
- **SUPPLIERS AND VENDORS**
- **OPERATIONS**
  Maintain good coordination and communication.
  Require drillers keep tally books of tools in hole.
  Have driller, geologist, and engineer maintain a detailed log.
- **TESTING AND SAMPLING**
  Have a planned schedule and alert geophysical log contractors at various stages of drilling.

FINAL THOUGHTS

- **DRILLING CREATES AN UNNATURAL AND HIGHLY EFFICIENT VERTICAL PATHWAY FOR FLUID FLOW INTO OR OUT OF THE BOREHOLE**
- **ALWAYS TRY TO UNDERSTAND THE GEOLOGY AND HYDROGEOLOGY AND POTENTIAL DRILLING PROBLEMS BEFORE DRILLING**
- **COMPLETELY PLAN THE DRILLING, TESTING, AND WELL COMPLETION OR ABANDONMENT**
- **HAVE CONTINGENCY PLANS, APPROACHES, AND BUDGET**
- ***DRILLING PROJECTS ALMOST NEVER PROCEED AS PLANNED***

GEOTHERMAL HEATING OF A LARGE COMMERCIAL GREENHOUSE
a case study

Williamson, NREL

Masson Geothermal Greenhouse, Radium Springs, New Mexico

LOCATION

Radium Springs
15 miles north
Las Cruces

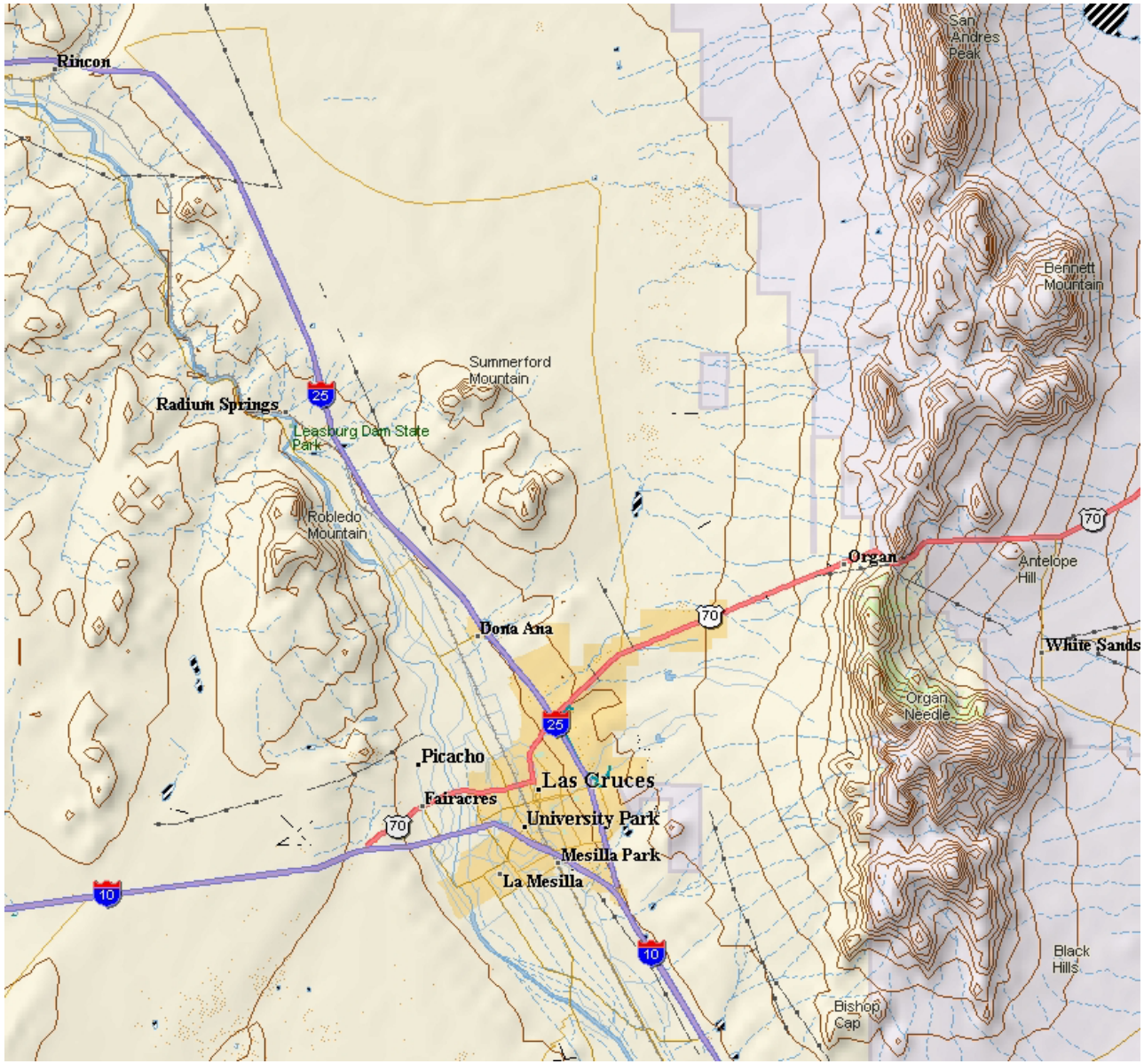
South-central
New Mexico
(Rio Grande Rift)

4,000 ft Elevation

3,400 Degree
Heating Days

1,450 Degree
Cooling Days

Mean Annual
Temperature
15.5^{o} C (60° F)



DeLorme Topo USA 5.0

GEOTHERMAL GREENHOUSE HEATING

- CENTRAL HOT WATER SYSTEM
- GEOTHERMAL WELLS AND HEAT EXCHANGERS <u>REPLACE CONVENTIONAL FOSSIL FUEL BOILER</u>

GEOTHERMAL INFRASTRUCTURE

- PRODUCTION WELLS
- INJECTION WELLS
- HEAT EXCHANGERS
- PIPE LINES

Geothermal Heating Distribution Manifold, Masson Geothermal Greenhouse, Radium Springs, New Mexico

Williamson, NREL

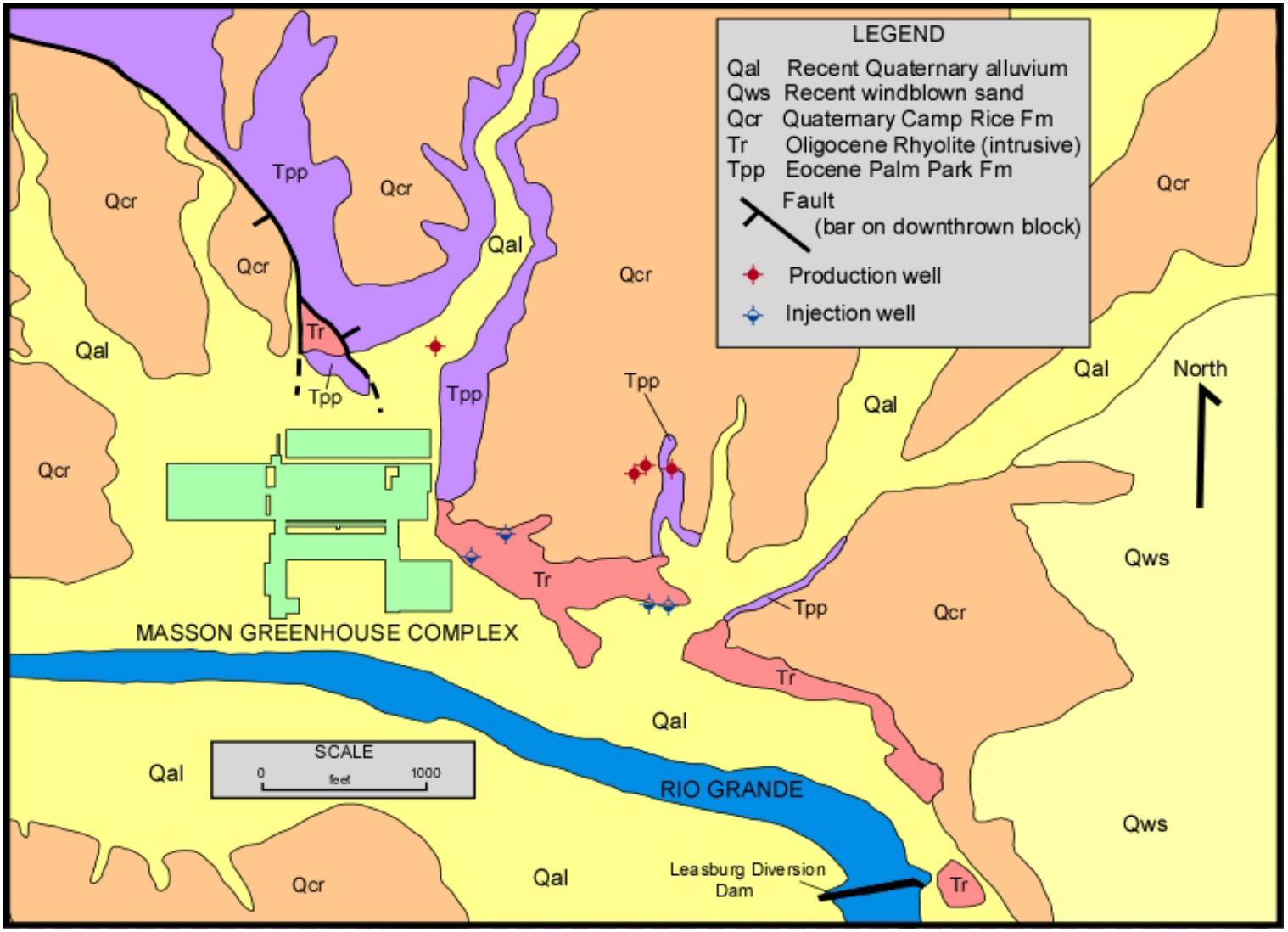
SITE ATTRIBUTES

- Geothermal and fresh water supplies co-located
- Shallow reservoir and deep reservoir
  - Injection
  - Production
- Private surface
- Level land

Witcher

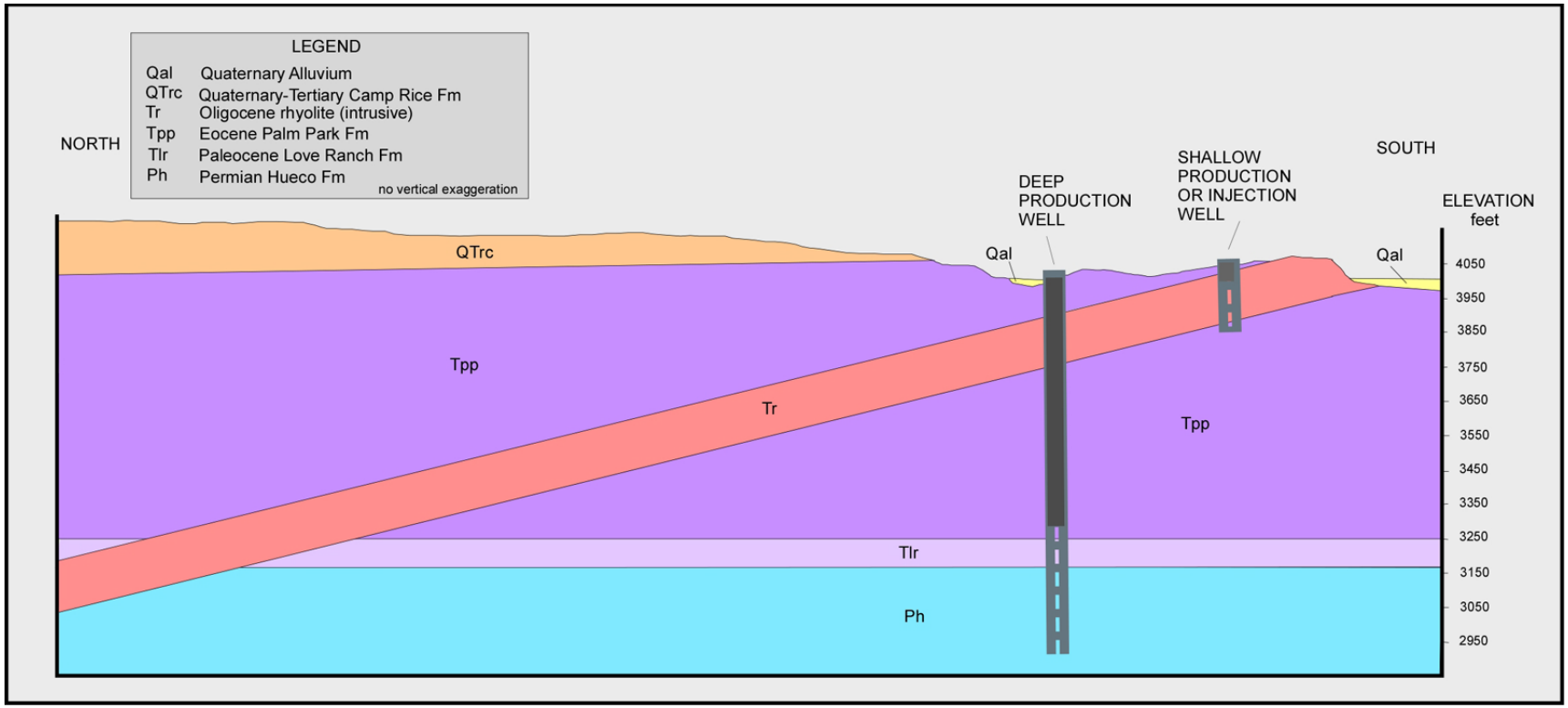
Drilling Masson Federal 36, Radium Springs, New Mexico, Masson Geothermal Greenhouse

GEOLOGY



Geology modified from Seager, 1975

PRODUCTION AND INJECTION WELLS



Witcher

PROBLEMS

- Production temperature decreases
- Injection wells not taking full production

SOLUTIONS

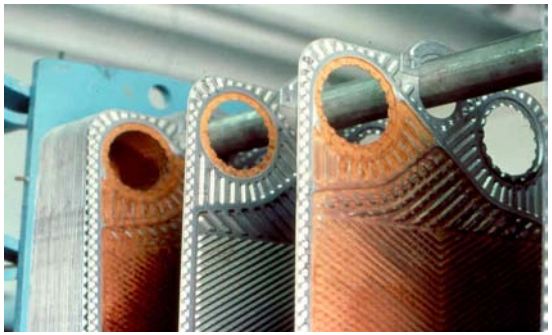
- Site production wells further from injection wells
- Add production from the deep parent reservoir
- Eliminate open hole completions for injection wells and add liners
- Use larger diameter injection wells

CORROSION

Original plate and frame heat exchanger, Masson Geothermal Greenhouse, Radium Springs, New Mexico

Williamson, NREL

Plate and frame heat exchanger dismantled for cleaning



NMSU

FLUID CHEMISTRY

TDS – 3,600 to 3,700 mg/L

Cl – 1,500 to 1,700 mg/L

PROBLEMS

- Pitting of stainless steel heat exchangers
- Corroded well casing adjacent fluctuating water level

SOLUTIONS

- Titanium steel heat exchangers
- High temperature fiberglass casing

HOT WATER STORAGE

Hot water storage tank,
Masson Geothermal Greenhouse,
Radium Springs, New Mexico

Williamson, NREL

PROBLEMS

- Slow heating response to rapid temperature/weather changes
- Continue optimal heating if one of the well pumps fails on a winter night

SOLUTIONS

- Use large 167,000 gallon insulated hot water storage tank to buffer heating system
- Use radiant floor heating

RADIANT FLOOR HEATING

Williamson, NREL

Construction of new 2-acre greenhouse range with radiant floor heating, Masson Geothermal Greenhouse, Radium Springs, New Mexico

ADVANTAGES

- Provides thermal mass and stabilized heating system
- Decreases geothermal well production
- Places uniform heat at plant roots
- Allows for flood irrigation

FLOOD IRRIGATION

Williamson, NREL

Completed 2-acre greenhouse range with radiant floor heating and flood irrigation, Masson Geothermal Greenhouse, Radium Springs, New Mexico

PROBLEM

- Irrigation water is treated with reverse osmosis (RO) to remove undesirable minerals and nutrients are added (important cost factors)

SOLUTION

- Flood irrigation conserves water by recycling excess water and nutrients and decreases costs and disposal needs

ECONOMICS

ANNUAL SALES (wholesale)

$325,000 to $850,000 per acre

EMPLOYMENT

4 to 8 employees per acre

ENERGY SAVINGS

$46,200/yr per acre

4,200 MMbtu/yr/acre at less than $1.50/MMbtu

Natural gas $12.50/MMbtu (boiler inefficiency included)

Williamson, NREL

Masson Geothermal Greenhouse, Radium Springs, New Mexico

SUMMARY

Photo on cover of journal GEOTHERMICS

Williamson, NREL

Masson Geothermal Greenhouse, Radium Springs, New Mexico

- 3rd largest geothermal greenhouse in US (18 acres)
- Installed heating capacity 44.1 x 10^6 Btu/hr (12.9 MWt)
- Estimated capacity factor 20 percent
- Average annual energy use 76.8 x 10^9 Btu
- Deep Production (800 ft max)

  Winter - 195° F at 750 gpm
- Shallow Production (325 ft max)

  Winter - 165° F at 720 gpm

  Summer -165° F at 430 gpm
- Started at 4 acres in 1987 with plans to grow to 40 acres in future
- Resource has potential to add binary-cycle power for on-site use before greenhouse heating

A GEOTHERMAL PROJECT

- PERMITTING
- RESOURCE OWNERSHIP
- WATER RIGHTS
- ENGINEERING FEASIBILITY
- BUSINESS AND MARKETING PLAN
- FINANCING
- RESOURCE ASSESSMENT AND RESERVOIR CONFIRMATION
- PRODUCTION/INJECTION WELLS
- RESOURCE MANAGEMENT PLAN
- ENVIRONMENT AND PUBLIC RELATIONS

Alligator aquaculture, Mosca, Colorado

NREL

ADDITIONAL INFORMATION

- Texas Geothermal Resource Information
  Southern Methodist University Geothermal Lab
  http://www.smu.edu/geothermal
- Direct-Use Technology and Engineering Design
  Oregon Institute of Technology GeoHeat Center
  http://geoheat.oit.edu/
- Growing, Processing, and Marketing Information
  Texas A&M Agriculture Extension
  http://texasextension.tamu.edu/

  Texas Department of Agriculture
  http://www.agr.state.tx.us/
- Business Plans and Financing
  Bob Lawrence and Associates
  http://www.geothermal-biz.com/
- USDA Grants and Loans
  http://www.rurdev.usda.gov/rd/farmbill/9006resources.html
- USDOE Geothermal Program and Geopowering the West
  http://www.eere.energy.gov/geothermal/
  http://www.eere.energy.gov/geothermal/deployment_gpw.html