Water Finder Guide

Procedure with examples to reduce and simplify interpretation of Electrical and Gamma Ray logs to quickly and accurately identify fresh water producing formations.

Originally Published by Mineral Logging Systems

Delta Epsilon Instruments, Inc.
2591 B ¾ Road
Grand Junction, CO 81503 USA

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Mineral Logging Systems, Inc. issued this publication in order to reduce and simplify the interpretation of Electrical and Gamma Ray logs to a quick and accurate method of determining fresh water producing formations.

This method was developed and refined by Dr. Hubert Guyod, eminent well log analyst, widely recognized as an authority by professional people in the geological and geophysical fields.

No mathematics is used. No previous experience is required. The procedures are set forth in a step by step sequence easily followed by anyone.

It should be pointed out that the logs do not replace the driller's local experience or the driller's logs. Local experience and the driller's log are extremely valuable and are indeed used in the following method. Rather, the logs provide the driller an invaluable set of downhole "eyes" which enable him to see the critical characteristics of the well, not otherwise obtainable from any source.

- **HE CAN POSITIVELY IDENTIFY THE FRESH WATER FORMATION HE IS SEEKING.**
- **HE CAN FIND THE TRUE THICKNESS AND DEPTH OF THIS FORMATION TO A ONE FOOT ACCURACY.**
- **HE CAN FIND UNDESIRABLE CLAY OR DENSE ROCK LENSES IN THE FRESH WATER FORMATION.**
- **HE CAN DETERMINE WHEN THE WATER FORMATION TURNS BRACKISH.**

These are things the driller cannot possibly know from one well to the next for sure without logs. Logs, therefore, used with this water finder technique, eliminate erroneous completions and resulting wasted costs and enable the driller to find more and better fresh water.

THE INTERPRETATION METHOD
TYPES OF LOGS USED

SPONTANEOUS POTENTIAL (SP)

This log is a continuous recording made by an logger of the natural voltage potential between surface ground and a point electrode as the electrode is lowered Into or raised out of a borehole. Scales are normally available for recording potential differences of 5 to 2000 millivolts full scale values. The log is normally recorded simultaneously with resistivity and is displayed on the left hand log track on the pen recorder. This log can only be recorded by the logger in open, uncased holes filled with liquid. The SP is used here only to correlate degree of water brackishness in Interpretation Situation I having clay and sand formations only.

SINGLE POINT RESISTIVITY (R or SPR)

This log is a continuous recording made by an logger of the resistance between surface ground and an electrode as the electrode is lowered into or raised out of the borehole. Scales are normally available for recording resistance of 2.200 ohms full scale. This log is normally recorded on the right-hand logging track on the pen recorders. This log may only be recorded by the logger in open, uncased wells filled with liquid.

GAMMA RA Y (NGAM)

This log is a continuous recording made by a logger of the natural gamma ray radioactivity of the subsurface formation as the gamma ray probe is lowered into or raised out of the well. This log is normally recorded on the right-hand logging track. Scales are normally available for recording 1,100 micro-roentgens per hour radiation intensity full scale values. This log may be run in open or cased holes with or without liquid content. The Gamma Ray log is used here to Identify Clay Formations.

DRILLER'S LOG

This is a continuous record made by the driller of the following two factors:

- Identification of formations being cut by the bit obtained by examination of cutting returns, recorded with the approximate depths of these formation changes.
- Notation of major drilling breaks and depths of each with relative penetration rate noted between each break.

STEP-BY-STEP PROCEDURE

STEP ONE - The general Formation Types listed below which are encountered in the well should be noted. This determination should come from a driller's general knowledge of the area or, much better, the driller's log.

CLASSIFICATION

Type A (called Sand Formations)

1. Un-cemented sand
2. Gravel
3. Cemented sand or sandstone

Type B (called Clay Formations)

Fine tight sediments, never found producing fresh water:

1. Clay
2. Shale
3. Marl

Type C (called Rock Formations)

These formations can be water-bearing if sufficiently porous or fractured. Otherwise, they are dense, hard and impermeable.

1. Limestone
2. Dolomite

Type D

Special formations rarefy found:

1. Radioactive sand (feldspathic)
2. Gypsum
3. Anhydrite

STEP TWO – Determine whether or not brackish water can be expected in adjacent zones to the fresh water formation. This should be a matter of local knowledge or may be determined by contacting the local government office of Geology.

STEP THREE - Summation of formation types and determination of INTERPRETATION SITUATION to be used.

DETERMINATION OF INTERPRETATION SITUATION
Situation 1.
This situation is indicated when one or more of Sand and Clay Formations (types A and B) only are found in the well (A plus B).

Situation 2.
This situation is indicated when one or more Rock Formations of type C only are found in the well (C).

Situation 3.
This situation is indicated when one or more Clay and rock Formations (types B and C), with a Sand Formation also a possibility, are found in the well (B plus C - A possible).

STEP FOUR - Run Spontaneous Potential, Resistivity and for Gamma Ray logs of the well in accordance with your loggers instructions. The Gamma Ray log is considered necessary if there are brackish water zones anticipated to be encountered in the well along with fresh water zones of interest and if the well contains Clay Formations, which are normally the only formations exhibiting natural gamma ray intensity.

It is of special importance that the operator observes the pen amplitude of each log as the probe is run into the hole. This will allow proper setting of the Basing and Sensitivity Scale of each log so that the maximum amplitude encountered in the well will find the pen close to the right-hand margin of the track and the minimum amplitude will be close to the left-hand margin. This gives the log maximum sensitivity. In the following interpretation, pen amplitudes will be described only qualitatively as follows:

- Low
- Intermediate
- High
- Very High

It should be remembered the above pen amplitudes are relative and depend upon the amount of basing and sensitivity set into the recorder.
The recorded log is always run coming out of the hole with the probe. The scale value, set so that the maximum pen amplitude will fall almost on the right-hand margin, should be noted, as it gives an indication of the quantitative value of the maximum measurement, valuable for any given locality.

STEP FIVE - Obtain the penetration rate recorded from the driller's log. All that is necessary is that each formation be described as having a bit penetration rate either slow, medium or fast.

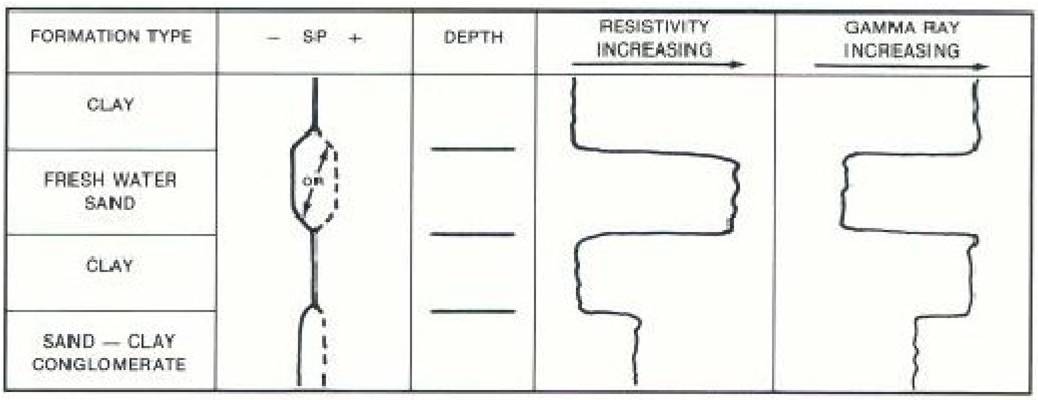
STEP SIX - Utilizing the determination in Steps Two and Three above, plus the logs run per Step Four above and the driller's chart of bit penetration rate per Step Five above, we proceed to the simple interpretation of each situation.

INTERPRETATION SITUATION I.

This situation has been previously defined as the combination of one or more Sand and Clay Formation (types A and B) only. We first consider the situation with only fresh water formations anticipated to be encountered. The following chart indicates the relative log amplitudes differentiating between Sand and Clay Formations. Sand Formations will be the fresh water formations of interest since Clay Formations contain no fresh water.

FORMATION TYPE	SP (COMPARED TO CLAY)	RESISTIVITY	GAMMA RAY	BIT PENETRATION RATE
FRESH WATER SAND	SMALL	HIGH	LOW	FAST
CLAY	——	LOW	HIGH	FAST
SAND-CLAY CONGLOMERATE	SMALL	LOW TO INTERMEDIATE	INTERMEDIATE	FAST

The following is an artificial log approximating the log appearance corresponding to each formation type.



NOTE THE FOLLOWING:

1. The distinct resistivity contrast between Sand Formations and Clay Formations.
2. The distinct gamma ray contrast between Sand Formations and Clay Formations.
3. Little change in either the SP or the bit penetration rate. (While bit penetration rate may vary between formations, this factor has little bearing on the determination of Formation type here in this Situation.)
4. Identification of Sand-Clay Conglomerate. Sand-Clay Conglomerate is normally found in the form of clay lensed sand or with interstitial clay slurry saturating the individual sand particles. In either case the resistivity curve will indicate low to intermediate, normally increasing with decreasing clay content. However, brackish water sand-clay lens condition or clay slurry will keep the resistivity low. On the other hand the Gamma Ray Curve will give a good indication of relative clay content, increasing almost proportionately. This curve and the driller's log should positively identify these zones qualitatively.

BRACKISH WATER ZONES

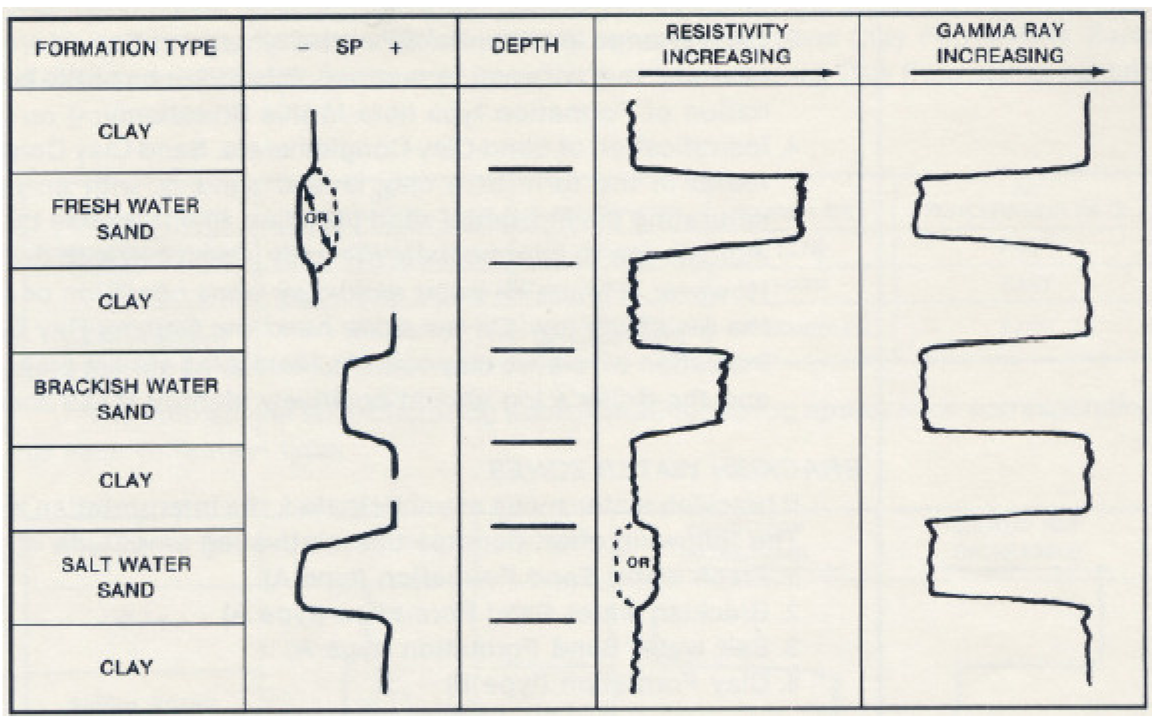
If brackish water zones are anticipated, the interpretation is modified as follows:

The following chart denotes the relative log amplitude of:

1. Fresh water Sand Formation (type A)
2. Brackish water Sand Formation (type A)
3. Salt water Sand Formation (type A)
4. Clay Formation (type B)

FORMATION TYPE	SP (COMPARED TO CLAY)	RESISTIVITY	GAMMA RAY	BIT PENETRATION RATE
FRESH WATER SAND	SMALL	HIGH	LOW	FAST
BRACKISH WATER SAND	INTERMEDIATE (LEFT)	INTERMEDIATE	LOW	FAST
SALT WATER SAND	LARGE (LEFT)	LOW	LOW	FAST
CLAY	— —	LOW	HIGH	FAST

Following is an artificial log approximating the log appearance corresponding to each formation type and degree of formation water brackishness.



NOTE THE FOLLOWING:

1. The high resistivity of the fresh water Sand Formation.
2. The intermediate resistivity of the brackish water Sand Formation.
3. The low resistivity of the salt water Sand Formation.
4. The low resistivity of the Clay Formation.
5. The gamma ray differentiation between salt water Sand Formation and Clay Formation.
6. The increasing difference (to the left) in SP between clay and water-bearing Sand Formations as the degree of water brackishness increases.
7. The lack of significant change in the drilling penetration rate between formations.

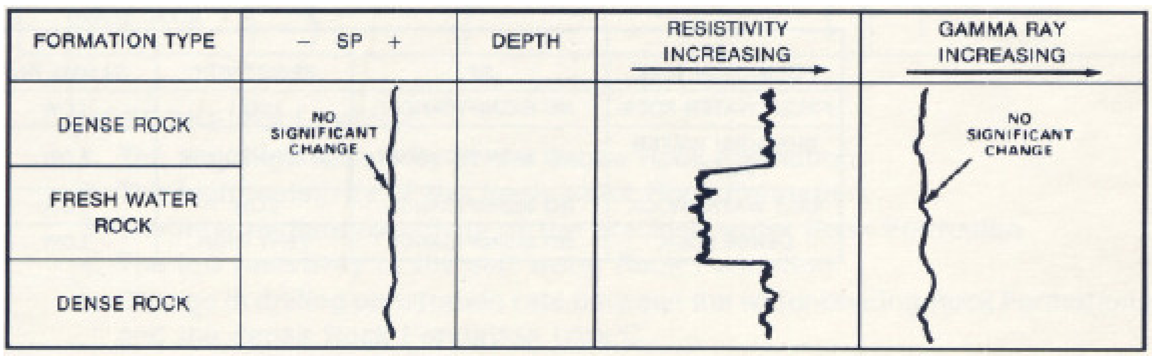
INTERPRETATION SITUATION II.

This situation has been defined as a well containing Rock Formations (type C) only, (limestone and/or dolomite).Water is found in either porous sections or in fractured sections. Log responses are nearly the same in either case. These formations are termed hard and, if no water is found, are termed dense, i.e., low porosity and no fracturing.

The following chart indicates the relative log amplitudes differentiating between dense and fresh water producing formation type C.

FORMATION TYPE	SP	RESISTIVITY	GAMMA RAY	BIT PENETRATION RATE
FRESH WATER ROCK	NO SIGNIFICANCE	HIGH	LOW	MEDIUM
DENSE ROCK	NO SIGNIFICANCE	VERY HIGH	LOW	VERY SLOW

The following artificial log approximating the log appearance corresponding to dense and fresh water producing Rock Formations (type C).



NOTE THE FOLLOWING:

1. The very high resistivity of the dense Rock Formation.
2. The high resistivity of fresh water Rock Formation; however, having enough amplitude difference to efficiently define the fresh water formation.
3. The lack of change in the SP and the gamma ray logs.
4. The change in bit penetration rate between the two formations.

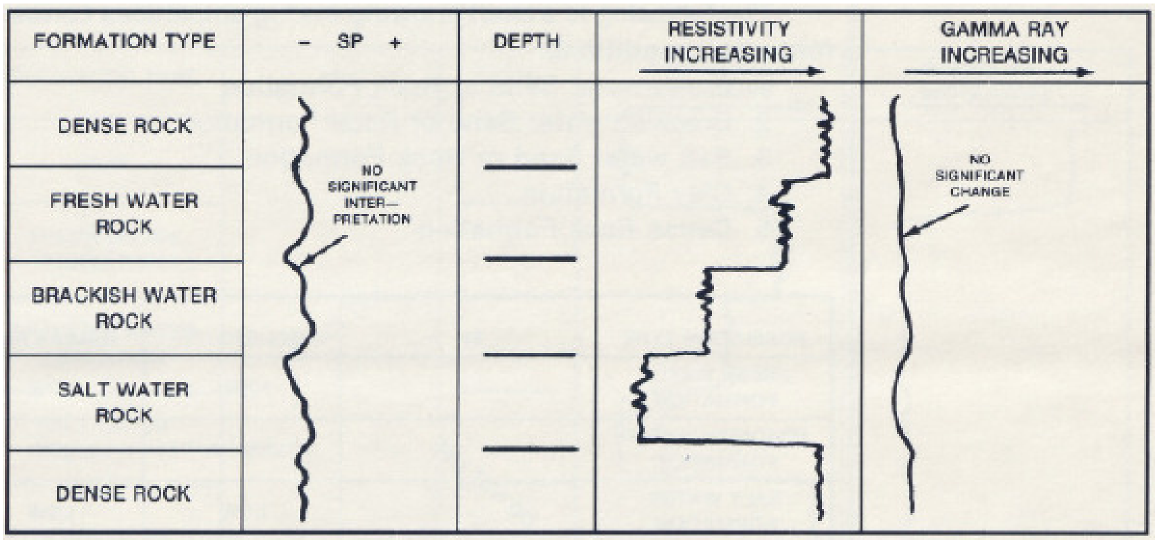
BRACKISH WATERZONES

If brackish water zones are anticipated, interpretation is modified as follows:
The following chart indicates the relative log amplitude responses corresponding to the following:

1. Dense Rock Formation.
2. Fresh water Rock Formation.
3. Brackish water Rock Formation.
4. Salt water Rock Formation.

FORMATION TYPE	SP	RESISTIVITY	GAMMA RAY	BIT PENETRATION RATE
FRESH WATER ROCK	NO SIGNIFICANCE	HIGH	LOW	MEDIUM
BRACKISH WATER ROCK	NO SIGNIFICANCE	INTERMEDIATE	LOW	MEDIUM
SALT WATER ROCK	NO SIGNIFICANCE	LOW	LOW	MEDIUM
DENSE ROCK	NO SIGNIFICANCE	VERY HIGH	LOW	VERY SLOW

The following artificial log approximates the log appearance corresponding to the dense Rock Formation and water-bearing Rock Formations with varying degrees of brackishness.



NOTE THE FOLLOWING:

1. The very high resistivity of the dense Rock Formation.
2. The high resistivity of the fresh water Rock Formation.
3. The intermediate resistivity of the brackish water Rock Formation.
4. The low resistivity of the salt water Rock Formation.
5. Change in drilling penetration rate between the water-bearing Rock Formations and the dense Rock Formation type C.
6. The lack of significant change in either gamma ray or SP.

INTERPRETATION SITUATION III.

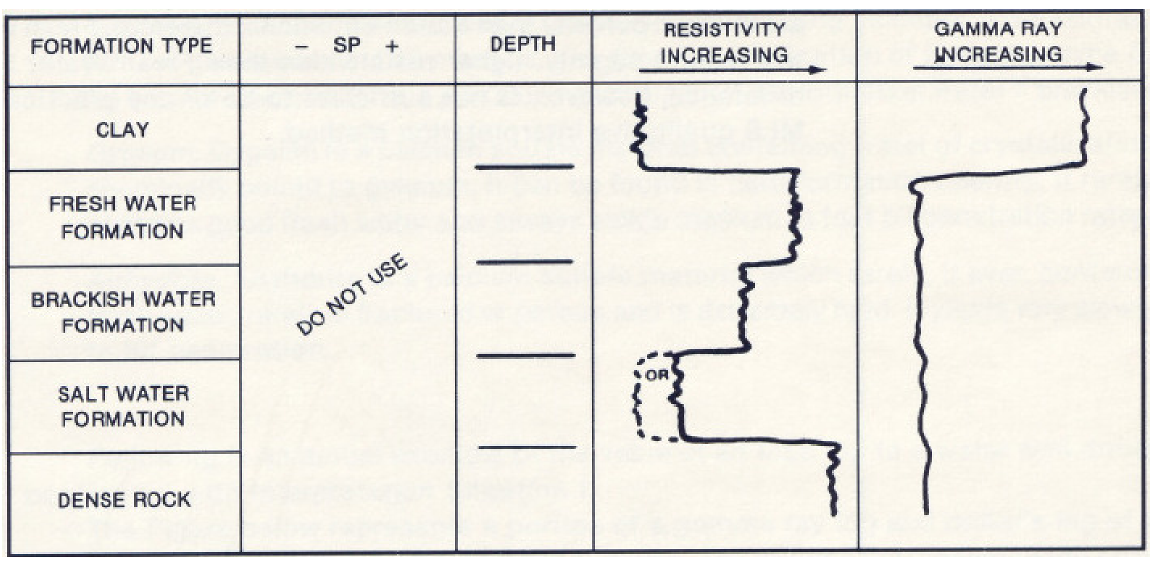
This situation is defined as a well containing Clay Formations and Rock Formations with possible Sand Formations also. We will also include the anticipation of brackish water zones in this situation.

The following is a chart showing the log amplitudes corresponding to the following formation conditions:

1. Fresh water Sand or Rock Formation
2. Brackish water Sand or Rock Formation
3. Salt water Sand or Rock Formation
4. Clay Formation
5. Dense Rock Formation

FORMATION TYPE	SP	RESISTIVITY	GAMMA RAY	BIT PENETRATION RATE
FRESH WATER FORMATION		HIGH	LOW	MEDIUM TO FAST
BRACKISH WATER FORMATION	DO NOT USE	INTERMEDIATE	LOW	MEDIUM TO FAST
SALT WATER FORMATION		LOW	LOW	MEDIUM TO FAST
CLAY		LOW	HIGH	FAST
DENSE ROCK		VERY HIGH	LOW	VERY SLOW

The following artificial log approximates the log appearance corresponding to the Formations types A, B, and C with water-bearing formations types A and C having various degrees of brackishness.



NOTE THE FOLLOWING:

1. The very high resistivity and slow penetration rate for the Dense Rock Formation type C.
2. The high resistivity and medium to fast penetration rate for the Fresh Water Formation.
3. The intermediate resistivity and medium to fast penetration rate for the Brackish Water Formation.
4. The low resistivity and medium to fast penetration rate for the Salt Water Formation.

5. The low resistivity, fast penetration rate and high gamma ray for the Clay Formation.
6. For the water-bearing zones, increased penetration rate indicates increased porosity.
7. Water-bearing formations can be either Sand Formations or Rock Formations with identical resistivity response with equal porosity. Rock Formations normally are lower in porosity than Sand Formations; therefore, Fresh Water Rock Formations will exhibit slightly higher resistivities than Fresh Water Sand Formations. The difference, however, is not sufficient to be of any practical consequence in this qualitative interpretation method.

SPECIAL FORMATIONS

The following special formations should be known to all drillers since they may cause erroneous interpretations. The presence of these formations is rarely found; however, should be known by local experience or by obtaining information from the local office of the State or U.S. Geological Survey.

- Radioactive Sand. Certain sand formations containing feldspar also contain natural gamma ray activity; hence, can give false indication of formation type B. An error in interpretation is particularly imminent if the formation water if brackish.
- Gypsum. Gypsum is a calcium sulfate material containing water of crystallization chemically bound to gypsum. It can be found in hard formation country. It rarely contains good fresh water and always yields medium to fast bit penetration rates.
- Anhydrite. Anhydrite is a calcium sulfate material which rarely, if ever, contains fresh water, rarely is fractured or porous and is extremely hard. It yields very slowly to bit penetration.

EXAMPLE

Following is an actual example of the value of a log to a water well driller confronted with Interpretation Situation I.

The Figure below represents a portion of a gamma ray log and driller's log of a water well in Eastern Oklahoma, cable-tool drilled. The driller's log, shown to the right of the figure, indicates a water sand at 217-231 ft. with clay above and below. It is known from experience by the drillers of the area that this sand has such a good horizontal and vertical permeability that very good production is generally obtained by placing only a few feet of screen near the bottom. Since the sand was fairly thick, the water well contractor did not think it necessary to run an electric log or a gamma ray log in this well and, based on his drilling record, he placed three feet of screen at 228-231 ft. After the well failed to produce the quantity of water expected, the contractor decided to have a gamma ray log run. This log is shown to the left. The sand stands out well as an interval of low gamma ray amplitude from 217 to 230 ft. It shows also, at 227 ft., a thin clay layer that was not noted by the driller. Apparently, this clay has isolated the upper portion of the sand from the lower one and only the lower portion was producing water. The contractor decided to remove the screen previously set at 228-231 ft. and replace it by a longer one at 225-230ft. After this work-over, the well production fell in line with that of the other wells of the area. From this experience, the water well contractor decided to run an electric log or a gamma ray log in every well before setting the screen.