Journal of Scientific Exploration, Vol. 9, No. 1, pp. 1–43, 1995 0892-3310/94
© 1995 Society for Scientific Exploration

Unconventional Water Detection: Field Test of the Dowsing Technique in Dry Zones: Part 1*

HANS-DIETER BETZ

***Dept.** of Physics, am Coulombwall 1, University of Munich, D85748 Garching, Germany*

Abstract — This report presents new insights into an unconventional option of locating water reserves which relies on water dowsing. The effectiveness of this method is still rightly disputed. Now, however, extensive field studies — in line with provable and reliable historic accounts — have shown that a few carefully selected dowsers are certainly able to detect faults, fissures and fractures with relative alacrity and surprising accuracy in areas with, say, crystalline or limestone bedrock. A series of *Deutsche Gesellschaft fur Technische Zusammenarbeit* (GTZ) projects involving this technique were carried out in dry zones with unexpectedly high rates of success. In particular, it was possible to locate a large number of relatively small underground aquifers in thinly populated areas and to drill wells at the sites where water is needed; the yields were low but sufficient for hand-pump operation throughout the year. Finding or locating a sufficient number of relatively small fracture zones using conventional techniques would have required a far greater work input.

The relevance of the method used was tested under various aspects. On the one hand, project areas with different geological characteristics were chosen and, on the other hand, the relevant circumstances and project results were carefully examined by geology experts. So far, neither critical consideration of all possible objections nor attempts at reasoning have yielded a conventional explanation for the persistent success of the dowsing technique — an outcome which has been corroborated by a number of specifically designed control experiments and comparative tests. The trend of the reported findings is concordant with that exhibited by the findings from recent scientific research carried out, for example, by a Swedish geological institution and universities in Munich. Provided that certain conditions are met, the results obtained show the dowsing technique to be a serious alternative for groundwater prospecting. It can thus be concluded from these present experiences that the effectiveness of locating ground water in certain hydrogeological situations could be raised significantly if conventionally organized operating teams were to make additional use of appropriately tested and selected dowsers in order to pinpoint drilling spots. Along these lines, a model of integration, which has already been tested on a pilot scale in some of the GTZ projects presented herein, is discussed and proposed for future provisional use. The high success rates described in this report suggest the design of specific tests for future use which may contribute to a scientific clarification of the dowsing phenomenon. At the same time, there is the possibility of an especially useful transfer of practical knowledge concerning water-resource development. Finally, due to its biophysical background the issue might be

*Part 2 of this article will appear in the following issue of JSE.

of importance to bionics; further treatment should aim at technical simulation of the proven — albeit unexplained — effects of the dowsers in order to create new and more effective measuring procedures.

Introduction

Since its inception, the *Deutsche Gesellschaft fur Technische Zusammenarbeit* (GTZ) has supported, at the request of the German Government, appropriate measures for water supply improvement in many countries. Although this activity represents only of a small sector of GTZ's numerous projects, a particular significance has been allocated to it. The availability of sufficient and high-quality drinking water is a basic human requirement; that is why numerous world-wide organized efforts are being pursued within this sector. In addition, it must be kept in mind that polluted water actually causes some 80% of all the diseases in the Third World. As a consequence, it can be anticipated that the already inadequate supplies for at least 2 billion people will become even more problematical in the near future.

For a significant number of countries, mainly in the Third World, the supply conditions deteriorated markedly in the past years. This was mainly due to the population growth in urban areas — which continues to proceed too fast and far too extensively — the increasing per-capita water consumption and the shortage or depletion of appropriate resources available for the water supply. Moreover, the extension of regional arid areas must be taken into account, partly the consequence of inappropriate or incorrect soil management, such as large scale deforestation, or climatic changes resulting from a number of complex chain reactions, partly induced by mankind.

These described conditions show very clearly that it is urgent to exploit the natural available water resources more intensively and more efficiently. In particular, techniques should be improved in their efficiency which aim at the investigation of still unknown subterranean water reserves. This is relevant, to a high degree, for thinly populated areas where a great number of wells are lacking — although delivery of relatively low yields is mostly sufficient here. Altogether it is true that modern techniques offer a rich choice of prospecting methods, but applications cannot be pursued to the desired extent because in most cases they turn out to be too time-consuming and too costly, and are often inadequate to guarantee a high rate of success. Experiences with classic methods has shown that, particularly in moderately fractured crystalline rock basement, the rate of dry drillings must be considered as being relatively high. It is therefore advisable to examine all available techniques with respect to their potential to allow an increase of the success rates for identifying proper well sites.

In 1986, GTZ presented in its series of publications a special report number 183 on a project in the northern dry zone districts of Sri Lanka, where dowsing techniques have been implemented on a large scale for the identification of well sites [1]. The resulting success and the economic benefit turned out to be unexpectedly high, thus justifying this unconventional technique despite all initial doubts and reservations, put forward from various parties,

Since the dowsing technique is neither scientifically recognized nor understood in its functioning, however spectacular an isolated project success is not sufficient to warrant its further implementation without further discussion. For this reason, GTZ tried to provide more data to contribute to a clarification of the performance of the referred method, realized on three different levels.

- The dowsing competence of an expert appointed by GTZ, Dipl.-Ing. Hans Schroter, was checked within a large scientific research program. A detailed final report of the investigation has been published [2]. It contains all practical procedures and results of the project, performed by a team of 14 scientists from 9 different institutions situated in and around Munich; the financing and control of the study was executed by the German Ministry for Research and Technology, along with another scientific group appointed by the Ministry. A series of rigorous tests showed that Schroter was, amongst some 50 tested persons, the most successful participant and his dowsing talent could be proven with a great statistical significance.
- GTZ examined the speculation that the dowsing technique may also be of practical usefulness in other representative field programs, namely with respect to the increase of success rates. The results obtained up to now are contained in the following report: despite all possible objections, these results lead us to the conclusion that the said speculation is largely corroborated by the facts.
- Within a framework of cooperation between GTZ and a project team from Munich who participated in the above mentioned dowsing investigation, it was agreed to adopt a more scientific approach with regard to relevant future GTZ projects. This includes a field test of particular measuring devices and detailed discussions amongst specialists in the field of earth sciences, regarding the dowsing technique and the corresponding results obtained from GTZ projects.

Of course, it cannot be expected that an extremely complex and historically developed problem, such as dowsing in conjunction with its immediate environment, may be satisfactorily solved within a short time and rendered acceptable on a general basis. Nevertheless, it clearly appears that this technique has been gaining more importance for particular, well specified tasks [2]. Former experiences already showed that it could be gainfully and reproducibly implemented in the field of geohydrology, provided that some careful precautions and controls were considered [3].

One of the aims of this report is to provide more information, by means of practical and well-documented examples, about this poorly known technique and, thereby, to provide a rational basis for future discussions. To underline the possible significance of this subject, a preliminary attempt is made to assess the presented results although a more general and final evaluation may only be made after the completion of future, specially designed and purely scientific studies of sufficiently large scale.

In any case, and at the present time, a variety of outlined examples from GTZ projects and other reports suggest the relevance of the recommendation that the success of water resource development measures in special arid areas may be increased, sometimes quite significantly, when appropriately selected dowsers are implemented. For example, we report on projects with success rates above 80% — results which, according to responsible experts, could not be reached by means of classical methods, except with disproportionate input. The final aim should be the scientific explanation of this technique and its technical simulation, so that adequately sophisticated instruments would perhaps be suited to replace the "detector"-function of appointed dowsers. Such efforts can be traced back as far as 60 years, but could not, till now, be followed with all the possible and available technical methods.

1. GTZ Projects Using Dowsing Techniques

The unexpectedly high success rate due to the first implementation of the dowsing technique in the initial phase of an investigation program to supply potable water in the northern arid area of Sri Lanka encouraged the GTZ to explore the possibilities of that unconventional procedure in other practical field tests. That happened within a period of three years in two other areas of Sri Lanka, thereafter in nine further countries (Philippines, Dominican Republic, Congo, Niger, Yemen, Verde Island, Kenya, Egypt and Namibia). The present report presents the results of these field projects as they have become available until March 1993. However, only aspects relevant to dowsing are communicated. The total data and information on the relevant background aspects are contained in the respective project reports.

As GTZ had no research funds at its disposal, the field work to examine the method in question had to be integrated into existing or otherwise suitable projects. The fact must therefore be emphasized that there were no pure research projects which could have been planned and executed according to generally accepted scientific criteria and exigencies. It rather consisted in a series of projects afflicted with several unavoidable restrictions and reductions of management competence, enforced through cooperation with many participating institutions and authorities. Concretely, it means that e. g. the final selection of drilling points and the control of the executed drillings could not always be effected by the GTZ team — insofar as the drilling points determined by the dowsing technique were actually included at all into the final drilling program. For such reasons, some of the data which would be desirable are not yet available for evaluation and interpretation.

Such partial incompleteness of the data base of reported individual projects could only be avoided within a well financed and specially designed research project. Nevertheless, the results described here are unprecedented with respect to completeness and, due to the steady trend, permit preliminary but solid statements with respect to the practical usefulness of the dowsing technique and, thus, promising conclusions for further concerted actions.

1.1 Sri Lanka

Extensive results from the first phase of the Sri Lanka project are contained in the previously mentioned documentation of 1986 [1] and will, in relation to the unconventional water detection, be treated and completed here in more detail. Regarding the first phase of this project, we have to keep in mind that no proper hydrogeological preliminary study could have been planned and realized in the normal way because of a series of strictly imposed conditions. In the present case, geophysical studies of moderate extent took place only at the start of the project [4]. Sufficient knowledge of the underground at depths below 10 m (the average depth of existing, typically dug wells) did not previously exist and could not be provided beforehand. In the central project area, no type of deep well drilling was known; only on the coast, had a few drillings down to 250 m been carried out at earlier times, but no further details were known or documented.

Available geological planning documents depicted drainage patterns on topographical maps on a scale of 1 : 63,330 and on stereoscopic aerial photographs on a scale of 1 : 25,000. The latter were only accessible to local geologists, but not to the GTZ team. The available geological maps from 196411974 on a scale of 1 : 500,000 were virtually blank in the relevant districts of Vavuniya and Mullaitivu. The only presumed depicted 16 km long fault line later turned out to be unfounded.

As the implementation of the project was behind schedule, GTZ proceeded with its newly introduced goal-oriented project planning method (Ziel-Orientierte Projekt-Planung, ZOPP) which enabled an efficient adaptation to local conditions. Immediately after the project beginning a geological inventory showed unambiguously severe complications: it was not as easy as one had previously assumed to detect hidden drinking water reserves which could be exploited throughout the year. For this reason, the project manager, Hans Schroter, began to combine the classical methods with dowsing techniques. The conventional methods involved the interpretation of the above mentioned topographic and geomorphological indications, as well as the application of geoelectrical soundings. The information collected along these lines, however, was not sufficiently reliable to determine unambiguous locations for appropriate wells, so that the final pinpointing was exclusively carried out by means of the dowsing technique. Later on, that procedure and its general problematic will be further elaborated.

Geological Situation

The following geological and hydrogeological information for the target areas is taken from reports [4-7] prepared by the locally participating geologists after initiation and completion of the respective parts of the program. The continuous assistance of a versatile and internationally experienced hydrogeologist ensured a competent evaluation and documentation of the local conditions, the applied procedures and the obtained results.

The project area spreads over more than 4000 sq. km including the poorest districts of northern Sri Lanka, as well as the town of Vavuniya and 350 selected villages. All over the country, water is obtained from traditional dug wells located in the 5 to 10 m deep residual soil. These typical wells reach depths of 5 to 9 m and are generally still above the hard crystalline basement, 90% of which is attributed to rocks of the Cambrian system. During the dry season, from January to September, about 90% of these wells dry up, especially from May on when the water table declines on account of the lack of precipitation, until it reaches the crystalline zone.

When that occurs, there is no longer an extended water table horizon. The remaining wells of which only a few are sustainable throughout the year are either situated in lower lying areas and are connected to potable water hollows or they reach (by chance) a sufficiently fractured zone and have in this way a greater catchment area. In lower lying areas, and especially near the coast, the declining water table during the dry season may cause a deterioration of the water quality, especially due to increasing salinity on account of sea water intrusion.

The mean annual precipitation is quoted to amount to values slightly above 1250 mm. The major rainfall occurs during the monsoon months of November and December, but it must be kept in mind that the evaporation rate is very high. However, the infiltrating water quantities are by all means sufficient, so that we may conclude that the actually needed subterranean water reserves are indeed available. Except for the coastal lands, the project area rises on the average to 35 – 60 m above sea level, the greatest differences between large valley bottoms and gently sloped hill chains seldom reach 90 m. In Mullaitivu District, for example, the highest points are some 80 m above sea level.

The crystalline underground consists especially of granite and gneiss with marble intercalations. Only a few larger fault zones can be seen and recognized on aerial photographs. Under the 5 – 10 m thick surface cover which consists of earth, gravel and loam, an important crystalline zone of several meters thickness begins and shows differentiated weathering. Beneath this layer, the weathering is reduced to a lesser extent but pronounced fractures partly exist. Beneath 10 – 20 m, the rock shows complex and irregular fractures on account of its tectonic past which may be important within sharply defined locations. Given these cases, the water struck there may be highly mineralized; especially when the circulation is hindered the water may be found inappropriate for drinking. At a depth of 30 m it is possible to find, in isolated areas, moderately exploitable ground water accumulations. The existing rock formations do not primarily reveal any transmissivity and the

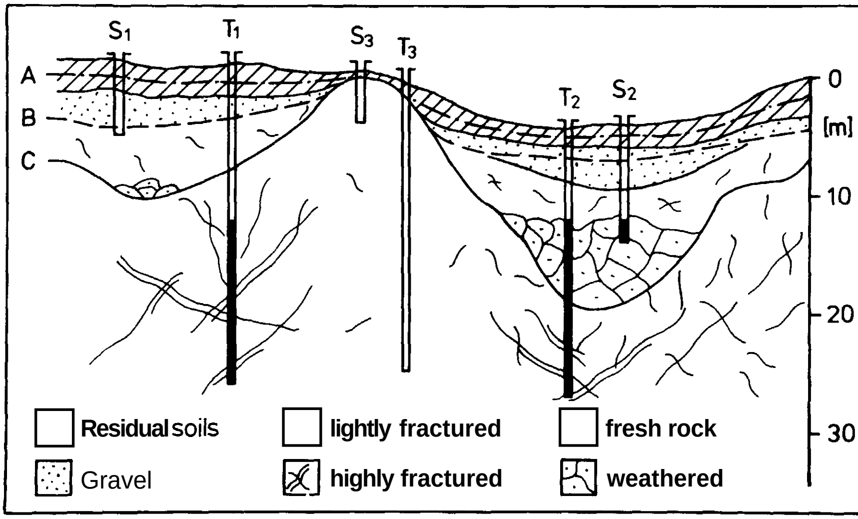

Fig. 1. Schematic cross-sectional view of the bedrock composition in northern Sri Lanka (GTZ project area). Notations: S — dug well; T — deep drilling into the crystalline rock basement; S1, S2 — wells with seasonally restricted production; T1, T2 — deep wells productive all-year; S3, T3 — dry dug well and deep drilling (except for some influx of surface water); **A** — subsoil water table during the rainy season; B — lowest limit of the water table; C — boundary line to the hard, partly fractured rock basement.

permeability is related to the occurrence of secondary fissures open for water circulation.

As a project aim is to obtain a sustainable water supply throughout the year, shallow dug wells (up to some 10 m) could not be envisaged. Alternatively, deeper drillings in the crystalline rock basement seemed to be appropriate. In view of the experiences gathered with the many actual effective deep drillings that followed (number including project phase III: about 2000), the areas encountered within this project may be characterized by three statements, which initially had to be considered as mere guesses.

From a hydrogeological point of view, this region must be considered as being difficult as larger aquifers are exceptions. Ground water reserves which are usable throughout the year can be recognized only in some single cases, but not in general, through terrain characteristics and an analysis of data related to the surface cover.

- Locally significant water reserves cannot be expected anywhere in the undisturbed crystalline rock basement formation (deeper than 20–30 m).
- In crystalline zones, successful drillings must reach fractures associated with water-bearing strata; as the fracture intensity may be locally very

variable, the choice of the drilling point, even on a small scale, will generally determine the success or failure of the drilling.

*Water **Supply** for Vavuniya Town*

A daily consumption of 50 - 75 liters per capita was calculated for the approximately 20,000 inhabitants of Vavuniya town which is spread over more than 10 sq. km. The existing water supply system was absolutely insufficient and could not be practically incorporated into the current water demand planning scheme. For this reason, it was necessary to build a certain number of wells with a permanent yield totaling 20 l/s.

In view of the previously mentioned geological features, it was not possible to obtain this water quantity with one or a few wells. It seemed better to look for several particularly appropriate fracture formations at depths of more than 30 m, in order to be able to drill a series of independent deep wells. The following discussions focus on the use of a combined method which — contrary to general expectations — turned out to allow a remarkably reliable detection of relatively narrow fracture zones.

Recognizable topographic and morphologic features were exploited to preselect an area in the immediate proximity of the town, which was tentatively considered as being appropriate; this area was then analyzed in detail by means of two different techniques. In the selected area, the project manager first determined the suspected exact locations of promising fracture zones by means of the dowsing technique. Then, geo-electrical techniques were used in the predefined area, which extended over a couple of kilometers [1,7], in order to investigate general information on the underground structure and the possible existence of larger fracture zones up to a depth of some 50 m. The result showed that up to a depth of 25 m the soil resistivity was very high and exceeded 500 Ohm meter; only underneath, could numerous inhomogeneities be noted along with values of the order of 100 Ohm meter in some areas, which indicated the possible availability of larger aquifers.

To get additional and more reliable information about the area, Schroter determined 13 spots for systematic test drillings in the spatially confined area. For that purpose, he used mainly the dowsing technique, which allowed him also to roughly predict the respective expected yields; the latter information was due to his ability to evaluate and differentiate his subjective dowsing reactions, a particular aspect of dowsing, which will be treated in part 3.2. After this, drillings were carried out up to a depth of 50 m. In most cases usable water strata were struck, roughly as predicted. Schroter claimed to have used the information on the actually encountered yields to improve the future interpretation of his subjective dowsing perceptions in the actual working area.

The interpretation of the geo-electrical measurements and the results of the consecutive test drillings revealed that abundant aquifers could not be found at arbitrary locations in the crystalline bedrock, and that yields exceeding 1 l/s per borehole might only be obtained in exceptional cases. All the test drillings reached fracture zones, but their yields were different from each other; eight of these drillings were later equipped with hand pumps. The geo-electrical technique in particular seemed not to be able to locate the best drilling sites with sufficient accuracy and to differentiate excellent from less productive spots.

Subsequently, Schroter determined by means of his dowsing technique seven other spots where fractures were particularly extended. He managed to locate these points in the proximity of the town to avoid long water pipelines. At each position three to five closely spaced drillings were carried out to a depth of approximately 50 m in order to enlarge the respective well surfaces. As the detected fractures were apparently very narrow and without good connections to each other, small blastings at the bottom of the boreholes helped to increase the yield from typically 0.3 l/s to 1.6 l/s through an enlargement of the well surface, whereby the draw-down remained moderate. Ultimately, for all the 21 drillings relatively large water quantities could be obtained, in one case over 7 l/s for a group of three boreholes, and always of excellent drinking water quality. Out of the 34 initially drilled holes (including all test drillings) 29 were converted into individual wells or so-called star-wells and were integrated into the water supply distribution network.

Overall, the well system provided a maximum of 25 l/s for permanent use and was therefore sufficient for the water supply of the whole town. Utilizing many pump tests and the water table decline observed as a function of the drained yields, sufficient data could be collected to establish a hydrogeologic model for the investigated area [7]. Accordingly, the precipitation quantity, as well as the permeability of the partly fractured underground up to a depth of 50 m should be sufficient to ensure on a long term basis a sustainable potable bulk water supply from all the new wells.

Experimental results and theoretical calculations revealed that deep borehole drilling yields, exceeding 1 l/sec, can only be obtained in particularly extended fracture zones. But those are rather rare and do not show up clearly enough at the surface to be found easily or even by high chance. With respect to this conclusion, and in view of the evaluation of underlying problems, all the specialists involved in the project have come to essentially the same opinion and agree.

It is worth mentioning that the necessary expenditures for the water program designed and set up by means of the described combined procedure — with inclusion of the installation — only amounted to one tenth of the initially estimated input. The former plan was to treat the water of the Malvatu Oya River and to pump water over 32 km distance through pipelines to the town. The actually adopted solution, however, allowed saving of much time, avoided expenditure on treatment of shallow lying water and maintenance of a long water pipe with pump stations, and led to a long term sustainable water supply actually exceeding the initially planned quantities.

Following the experiences and successes gathered during the first part of the project, the following facts may be mentioned:

- Allowing for generally acceptable efforts and expenditures, the classically available procedures were appropriate for the usual and very rough approximate drilling spot location; more exact siting within, say, a meter was not possible, but would have been necessary in the case of very narrow fractures. The complementary use of the dowsing technique filled this prospecting gap and enabled higher rates of success in locating fractures and related drilling spots which ultimately led to an optimum borehole yield.

At this stage, the described results do not yet provide **proof** of the relevance of the dowsing technique, but the quoted findings could also be corroborated in various subsequently executed GTZ projects. Accordingly, the conjecture finds increasing support that the use of dowsers in hydrogeological exploration may substantially increase the success rate of a water development project.

Water Supply in Rural Zones and Shore Lines

Except for the immediate coastal region, one found in the districts of Vavuniya and Mullaitivu the same geological features as in the already described environment of Vavuniya Town. But the exigencies of the water supply differed in an essential point from the conditions relevant for the urban zone of Vavuniya Town.

The project area covered 4160 sq. km of the thinly and least populated zones of Sri Lanka (44 inhabitants/sq. km) and 350 of the most problematic villages have been selected whose 50,000 inhabitants should have an all-year-round water supply. As the village populations amounted to a few hundred inhabitants respectively, spread over a large area, more than one well per village had to be built. For an estimated consumption of 15 – 35 l per person and day, a relatively low mean well yield of 5 – 10 l/min. could be considered as adequate. Consequently, it was possible to equip the wells with handy, economical and low-maintenance hand pumps.

The advantage compared with the prospecting in Vavuniya Town consisted of the fact that maximum yields were not at all necessary; it appeared sufficient to locate much smaller fracture zones. Because of the desire to secure the water supply throughout the year, these sites had to be found in the crystalline rock basement. Unlike high-yielding springs, a more frequent presence of such smaller aquifers could be expected. The possibility of a greater choice of well locations meant that features such as the desires of the local beneficiaries, the hygienic aspects, access or improvement of access and a central situation in the village could be incorporated. The disadvantage was that less productive aquifers, which may exhibit partly only a few centimeters wide fractures, represent in general smaller perturbations in the basement and are more difficult to locate with classical methods; in parts, detection is virtually impossible with the available techniques. Likewise, similar difficulties showed up in many projects carried out by other institutions, where very small fractures and weathered zones had to be located exclusively by conventional procedures (see below).

The location of the first hundred well points followed the previously mentioned combined procedure [5, 6]. Whenever possible, the formerly mentioned classical indications were used to recognize basement structures and eventually promising zones which had to be roughly preselected in the area chosen by local responsible authorities. One has to take into account the fact that this procedure was difficult: wells had to be located in populated areas according to the desires of the village people, i.e. in civilized and topographically modified areas, where the use of classical procedures was problematic or impossible. In view of this situation, Schroter employed his dowsing technique and located such places which should be situated, in his opinion and according to his experience, quite precisely on appropriate, weakly developed fracture zones. The next step was, if technically possible, the checking of such places by means of methods such as the geo-electrical technique (Schlumberger method). In almost all the areas checked by this method, it was revealed that the fracture sites first determined by Schroter could be confirmed by anomalies of the soil resistivity. More precisely: on the one hand, these measurements by themselves could, of course, not be uniquely interpreted in terms of precise and safe drilling points; on the other hand, the places could not be clearly excluded on account of a complete lack of soil resistivity gradients.

The combined procedure appeared to be economically optimal as enough water could be found in apparently small shallow fractures at depths below 30 m. Not a single drilling hole had been deepened when the expected average yield could be proven after a six hours pump test. That meant, though, that the respective maximum and sustainable permanent yields, as well as the corresponding water drawdown were generally unknown; otherwise, one should have drilled deeper as envisaged and the pump tests including well construction should have been done with much more effort. With regard to the objectives of the project, both procedures were not necessary, nor could they be carried out within the given time scale and the financial cost constraints.

Results from the first 100 drillings in Vavuniya District, obtained under the above-mentioned restrictive conditions, are compiled in Table 1, ordered in nine yield categories. It is revealed that the effectively encountered water quantities were very variable, but mostly exceeded the necessary minimum yield. Nevertheless, it is noteworthy that the wells delivered, on the average, relatively low yields *according to the requirements stated beforehand*, contrary to the situation in Vavuniya Town where much higher yields were demanded and obtained. Furthermore, it is interesting to point out that the yield distribution displayed in Table 1 differs from the one which would be expected when only conventional prospecting methods are used: due to the spatially extended distribution of the productivity of fractured rock domains, the

TABLE 1

Yield	Number
0 - 5 m/min.	6
5 - 10	8
10-20	21
20 - 30	18
30 - 40	10
40 - 50 llmin.	24
50 - 60	7
60 - 70	5
>70	1

Results from the first 100 drillings in and around villages in Vavuniya District in the north of Sri Lanka. In all cases the borehole depths ranged from 12 to 28 meters. The aim was to attain yields of at least 5 l/min. in order to allow installation of hand pumps; this was attained in 94% of the cases. The wells ensured an all-year water supply; even during the extremely dry season of 1985 no reduction of the delivered quantities was noticed.

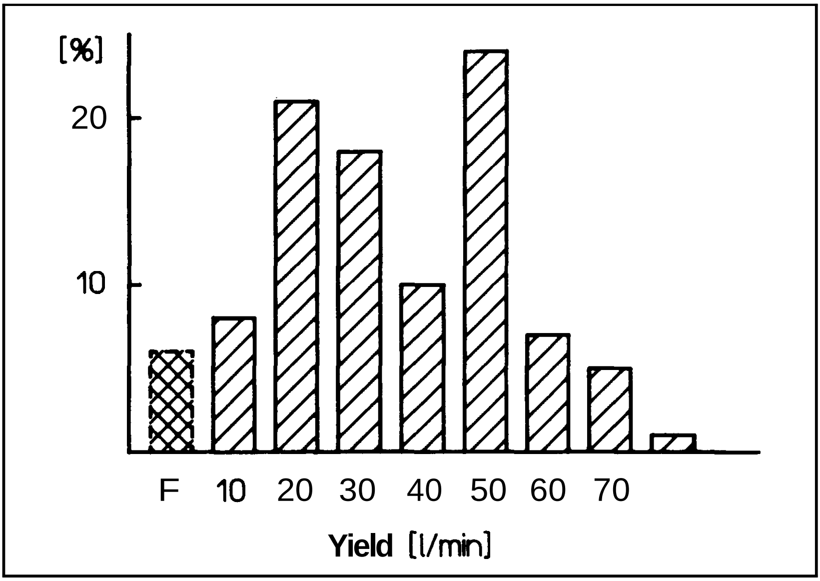

Fig. 2. Yield distribution according to Table 1. (F: dry drillings, i.e. below 5 llmin.). For conventional well prospecting with relatively low production, one would expect, contrary to the observed distribution, continuously decreasing parts. The clearly visible deviation from this points to a different mechanism.

number of smaller yields should first dominate and then decrease with increasing yield of the wells. But as the actually resulting distribution partly reveals a contrary behavior, it seems fair to conclude that a different, goal-oriented mechanism may lie behind the applied dowsing procedure.

It should be kept in mind that only ***drinking* water** counted as success. **A** too high percentage of salt, iron, nitrate, nitrogen and fluorides would have led to the abandonment of the borehole. Thanks to the ability to interpret his subjective dowsing reaction, Schroter was able to give at least indirect hints in this respect before drillings took place; in this way the number of wells which presented a bad water quality were insignificant. This part of the dowsing spectrum turned out to be significant especially for finding sites on shore lines, but its real significance is not yet well proven and should be checked in further tests, along with consideration of future new theories.

Wells in the Coastal Zone

On coastal zones, some older shallow boreholes existed which did not dry up but could not satisfy the demand due to two different reasons. First, polluted surface water was infiltrating and, secondly, the water table dropped during the dry season, so that too much salt water intruded and lowered the water quality. The target of the new project was therefore to find potable water from aquifers which, on the one hand, are deep enough to be fed through fractures by sufficient amounts of water from higher lying parts of the country and, thus, provide drinking water in acceptable quantity all-year round. On the other hand, the boreholes should not reach too far down in order to avoid any significant salt water intrusion from the nearby sea.

In this region, it was not possible to rely only on the geo-electrical measurements. It is certainly possible to establish vertical soil resistivity profiles by means of this technique and to locate the transition from salt water to fresh water. The risk will however exist that brackish water cannot be recognized beforehand with the necessary certainty. In addition, if the measurements are carried out during the rainy season, the conditions may change unfavorably in the dry season.

To solve that problem, Schroter tried to find fracture zones lying as shallow as possible. Some spots, located along these lines of argument, have been once again checked by means of geo-electrical techniques and turned out to be promising. Out of some 80 wells with depths between 6 and 23 m, situated on the coast of Mullaitivu, as many as 72 provided good drinking water, five produced slightly saline water still appropriate for cooking and washing, and only three could not be used due to a too high salt content. In some cases, salty water infiltrating above the actual fresh water zone could be impeded by means of a special casing technique applied during the borehole development.

Summary of Project Phase I

Just as for the urban water supply of Vavuniya Town it appeared that the first 100 drilling sites, determined by Schroter for wells in the rural areas, could be reasonably well confirmed as being promising by the geo-electric assessments; moreover, the acquired drilling results revealed that in more than 90% of the cases these spots were pinpointed most effectively. These practical experiences and their interpretation were confirmed by the geologist team involved. For this reason, it was then decided to use the dowsing technique almost exclusively for the larger part of the subsequently determined (557) locations of well sites in areas with comparable underground conditions. As most of the desired sites had to be situated in the middle of the most populated and urbanized regions, an optimal use of conventional methods, above all of the geo-electrical technique, would have suffered from a number of perturbation effects which would have led to either considerable complications or practical inapplicability.

The hydrogeological factors which had been determined in the meantime and had allowed a general characterization of the area, constituted of course an important basis for the use of the unconventional procedure; even when the dowsing was exclusively applied, these factors had not at all been neglected and they continued to play an important part for the further work and subsequent, fundamental discussions. In any case, the selected decision with respect to intensive use of the dowsing technique allowed for an impressive optimization of both time and cost inputs into the project. As a consequence, up to 10 drilling points could sometimes be located within one day and handed over to the drilling team. In many cases, the time elapsed between first inspection and selection of a site and subsequent successfully completed pump tests amounted to less than a few days or weeks only.

The effective increase of the success rate due to water detection by means of the dowsing technique continued (and turned out to be well reproducible in later projects performed under varying local conditions). The vast project phase 1 had been implemented in Sri Lanka within a record time of three years and, regarding the prevailing conditions, with a convincing unprecedented success. Apart from the establishment of effective sanitary measures, some 691 drillings had been carried out, of which 34 were related to the town of Vavuniya and 604 were equipped with hand pumps and handed over in operating conditions to the different villages of Vavuniya and Mullaitivu Districts (the difference of 53 drillings will be discussed below). It is notable that the mean yield of 30 l/min., which was established for 557 wells in the last part of project phase 1, largely exceeded the minimum requirement of 5-10 l/minute and showed a yield distribution displayed in Table 1. The maximum yields, though, which could have been safely taken from the wells, have not been determined and may be estimated as ranging, on the average, up to about twice the indicated yields.

For completeness, it must be clearly noted that the 691 mentioned drillings include all the control and test drillings. Of these, only 13 sites had been drilled, all in the area of Vavuniya Town and at the beginning of the project, and could be integrated with few exceptions into the new well system.

Furthermore, one has succeeded not only to place the majority of the well spots in the proximity of the locations desired by the population, but also to recognize very shallow lying fracture zones. The latter point allowed a reduction of the necessary drilling depths; the well depths essentially varied between 20 and 30 meters only, whereas other exploration companies resorted to drilling depths ranging up to 90 m in the same area or in comparable prospecting zones.

The value of this result has to be highly appreciated: in a terrain largely unknown from a hydrogeological point of view, proving to be particularly difficult on account of its principally crystalline bedrock of variable and mostly light fracture intensity, 654 wells have been ***successfully*** constructed within a short time and without any noteworthy precursory studies, partly under very difficult imposed conditions, and with a small staff and two relatively simple and medium-capacity rigs.

It remains to detail the remaining above-mentioned 53 drillings which, for three different reasons, could not be put into service:

- 10 wells were dry. A re-evaluation showed, however, that the actual drilling sites did not correspond to the initially indicated locations. Schröter's original points had been displaced, in some cases by a considerable distance, not noticed in time by the drill team or the project manager.
- 16 production wells have been intentionally destroyed as a result of conflicts amongst the village people with respect to the selected sites.
- 27 boreholes either provided too low yields (18), or revealed a lower water quality (9 of them contained a too high percentage of salt or minerals).

Within the final evaluation of the entire program, only 27 of the 691 drillings can be considered as classical dry holes; that constitutes a failure rate of 4%. Not only for that particular area, a success rate of 96% must be considered as being untypically high; no prospecting area with comparable sub-soil conditions is known where such outstanding results have ever been attained. But before trying to make a reliable judgment about the question to what part the success, achieved in project phase 1, can be really attributed to the dowsing technique, one should pay attention to the information gained from various subsequently performed control tests and competing projects.

Comparison and Control Experiments

As has been conjectured by various parties before, a detailed analysis of the well documented facts concerning expenditure, planning, implementation and results of the first project phase, clearly showed the relevance of the applied technique. However, in view of the prejudices and comprehension difficulties related to the field of dowsing in general, it appeared necessary to present numerous and especially simple experiments in order to allow assessment and eventual confirmation on a broader basis. The three following tests point towards such a conclusion, for they have been purposely timed and yielded clear results, easy to evaluate.

Test 1: Successful Well Near Dry Drillings

Due to favorable circumstances, a significant test of the envisaged kind could be carried out very early in the first project area. If separately considered from a scientific point of view, the result can only be taken as a single and isolated case, but within the whole mosaic, it gets an appreciable practical value (a more precise repetition of that kind of experiment will be discussed in part 1.10).

In a 200 x 200 meters school yard, two 90 m deep boreholes had been drilled into the crystalline rock basement by a project team financed by Norway — in both drillings no water was encountered at that depth. Geo-electrical soundings had not been carried out. On account of that situation, responsible persons from GTZ and the Bundesministerium für Wirtschaftliche Zusammenarbeit (BMZ: Federal Ministry for Economic Cooperation) asked Schroter to make use of his dowsing ability to solve the current problem and to locate a successful well as close as possible to the dry borehole drillings.

Schroter therefore examined the test area by means of dowsing. On the flat and restricted area almost out of vegetation an "intelligent guessing" of appropriate drilling points was visibly hopeless — as conceded by skeptical hydrologists — as no signs were present at the surface which could be exploited to reveal the presence of underground fracture zones (see part 3.1). According to this local situation, it clearly appeared to all participants that no success could be expected here by adherence to experience and conventional intuitions, often imputed to successful dowsers — and without introducing measuring techniques. After a short time, Schroter found, thanks to his subjective dowsing reaction, a place where he supposed that drinking water could be found at a depth of as low as 35 m and with a yield of at least 10 l/minute. The allegedly productive spot was located some 30 m from the one and 80 m from the other dry borehole.

A light mobile drilling rig could immediately carry out the test drilling and finished it by dawn of the same day. The result was unequivocal: water was found just as predicted. In this case, the value of the dowsing technique was confirmed, regarding not only the location but, to general surprise, also the depth and deliverable water quantity.

This clear-cut experiment contributed towards a more progressive attitude: GTZ and BMZ could no longer ignore this economical and successful method which promised a reduction of time and expenditure; it appeared no longer justified to stick exclusively to classical procedures because of principles and the lack of understanding the allegedly unconventional method applied by Schroter.

Test 2: Intentional Dry Borehole Drilling

At the end of the project phase 1, the cooperation between GTZ and the involved institutions of the University of Munich was put into effect; as one result of discussions with experts of earth sciences, GTZ was requested to carry out two different further experiments. The first one was to perform a dry borehole drilling, if possible near a successful well, the second one was to establish a direct and appropriate comparison between results obtained with conventional procedures and the dowsing technique.

Because of the prevailing imposed conditions and the rigorously controlled and appropriated financial allowance, it was of course impossible to proceed with intentional dry borehole drillings. Nevertheless, as an alternative it became possible to arrange for an exploration well very near a drilling which had been located by Schroter and produced more than 200 l/min. from a depth of 50 m. After intensive discussions, this test was put on the agenda and it was hoped to obtain both some information about the extension of the fracture zone and to complete the hydrogeological model representation for the area by means of quantitative data.

For that purpose, Schroter was requested to locate such a site by means of his dowsing technique, where he would expect a yield of less than 5 l/min. up to a comparable depth of 50 m, reaching into the bed rock. After having scoured the concerned area, Schroter thought that he had found an appropriate site 38 m from the said existing well. Of course, some water may be found within the surface layer of moderate thickness, at least for some time of the year, but that was not the issue. If that test succeeded, it could be shown once more by means of these two neighboring boreholes that the dowser exhibits special capabilities and that the relevant project area cannot be characterized by a homogeneous aquifer in the proximity of a successful drilling into the crystalline bedrock; instead, permeability is moderate and water may only be found in apparently small fracture zones. By the way, experienced dowsers claim to be able to differentiate water lying close to the surface (which is, thus, of less interest) from other water resources originating much deeper; evidently, the relevant biological sensations during dowsing are sufficiently different to allow for the required process of distinction and elimination.

According to Schroter's hypothesis — and in accordance with elementary geological evidence — such a distance could be viewed as being relatively large in a particular rock formation, so that it might determine success or failure of water detection. Unfortunately, the environment of the existing borehole had not been checked by geo-electrical techniques. From a conventional point of view, and without employment of sophisticated technical measurements, i.e. as long as sufficient information is not available about the presence of fractures, their extension and permeability, it can not be decided whether a site A or a site B which is 38 m distant from A would be more or less appropriate.

It should be stressed that according to the assessment of the participating experts, the selected test area did not, even after a thorough visual examination, allow good or bad drilling spots to be differentiated and pinpointed by intelligent observation or guessing within a radius of, say, 40 m.

The new drilling was carried out up to a depth of 50 m, similarly to the previous procedure. Between 9 and 11 m, i. e. within the superficial layer overlying the hard base rock, a relatively low yield of 13 l/min. was encountered — not unusual for the current season — but no measurable yield improvement could be detected while penetrating the underlying bedrock — there, the drilling was dry. By contrast, the neighboring successful well, fed by the crystalline zone, exhibits a yield of 237 l/minute at a depth of up to 50 m. Both wells, as well as their respective water tables have been thoroughly examined during the pump tests. No connection due to fractures could be noticed between the two wells. This result, typical for many areas, demonstrated that water may not be found anywhere in hard rock, because the expected groundwater accumulates mainly in narrow fractures and fracture systems. It is therefore necessary to attain a precise location of the drill sites; this seems to be possible by means of the method employed by Schroter and attributed to dowsing. Beyond doubt, these findings give more credibility to dowsing technique, provided that other remaining objections can be overcome (see the discussion in part 3.1).

Test 3: Systematic Comparison Experiment

No less significant is a directly arranged and controlled comparison between the two quite different procedures for ground water investigation, geophysics and the alleged dowsing technique, which has been carried out in order to provide a water supply for several small towns in Sri Lanka's Kurunegala District. At this instance, the objective consisted in the location of several wells with much higher yields of at least 100 l/min.

In a first step, a hydrogeologist and his collaborating expert team, already well familiarized with the successful project phase 1 and the local conditions, began to localize drilling points by the employment of modern hydrogeological and geophysical methods. Geo-electrical procedures played the most prominent part, as well as the use of geological maps and the study of aerial photographs. Besides this, the leading geologist, chairman of the Water Resources Board in Sri Lanka, had information at his disposal, which was not easily accessible and concerned former investigations within the relevant area in the Kurunegala District, especially on older wells not easily recognizable today. After several weeks of intensive work, 14 sites were located.

Thereafter, Schroter was requested to inspect exactly the same area in order to determine drilling sites as well, but exclusively by means of the dowsing technique and without having any detailed knowledge of the available geological data. Within a few days, he could indicate 7 points. Then, the drilling of all 21 positions began, in all cases the same drilling team used the same drilling technique and the same criteria for the final depth (42 - 70 meters, dependent on the ground above sea level and the encountered underlying formations). The combined results are summarized in Table 2. Obviously, Schroter obtained the better scores.

The numbers of 14 and 7 locations involved are certainly not very impressive, but because of the very different results there is still a good basis for a practical evaluation. The appraisal of the success rate does not require a particularly sophisticated analysis. First, it must be stated that Schroter had, once more, successfully carried through his allotted task. Second, it was proved again, this time in a very well documented way, that the usual conventional siting method could not be applied with high success rates because of the particularly intricate underground conditions. Of course, one might claim, that the quality of the conventionally working team could be doubted; however, regarding the described conditions, it is rarely expected that other teams could have obtained a fourfold success (namely 80%).

TABLE 2

Conventional Technique		Dowsing Technique	
Number	Liter/Minute	Number	Liter/Minute
1	400 *	1	400 *
2	400 *	2	200 *
3	300 *	3	188 *
4	80	4	150 *
5	60	5	150 *
6	45	6	150 *
7	25	7	30
8	22		
9	17		
10	10		
11	7		
12	6		
13	1		
14	1		

* target quota reached

Comparison between the yields of 21 exploration wells situated in the same area and located by means of conventional techniques (14; left column) and the dowsing procedure (7; right column). The required yield of 100 l/min. was reached, according to usual pump tests, in 3 of 14, and 6 of 7 cases, respectively. Altogether, with a success rate of 86% Schroter significantly surpassed the 21%-result obtained with the conventional method.

Finally, another experiment carried out in the same district of Sri Lanka is worth mentioning and will contribute to complete the insight. In one of the villages where the foregoing comparison test has been carried out, 4 drillings have been done at conventionally determined sites; two of them were practically dry and the two others provided insufficient yields with regard to the required water demand of the village. Due to organizational reasons, Schroter could not locate sites in this village during the former test. Because of the unsatisfactory results of these four drillings, Schroter was afterwards appointed here too in order to investigate the possibilities of the dowsing technique.

Thus, 4 sites could be located in and around this village by means of the dowsing technique at a later time; for two of them he expected particularly good yields exceeding 100 llmin. These additional 4 sites are not mentioned in Table 2 because they could not fulfill the agreed test conditions (drillings had already been carried out meanwhile and results were available). As predicted, the first good site determined by Schroter produced more than 200 llmin. and ensured the required water supply. The second "good" site is situated about 1 km away and has not yet been drilled. Each of the two remaining boreholes, however, produced only some 20 l/min.

Projects of Other Institutions

For different reasons, it was very difficult to establish an objective and fair comparison between the success rates of GTZ projects with the inclusion of dowsing techniques and various other water investigation projects in Sri Lanka. In spite of intensive efforts, it was not possible to get final reports from other organizations which had been active there. According to usual procedure, though, unsuccessful drillings would not have been particularly mentioned in such protocols. A possible comparison between the rates of success therefore must remain incomplete. Limited detailed data could only be obtained until now from two organizations, the Norway Cooperation Redd Barna [8] and a project supported by the World Bank [9] which will be mentioned in the following.

In 1980, two years before the beginning of the GTZ project, Redd Barna began the planning of deep wells (also to be functioning with hand pumps) for communities and villages in the Vavuniya, Mullaitivu and Mannar Districts. Concerning exploration area and purpose, far-reaching possibilities were given for comparison with the GTZ project to be carried through somewhat later. The Redd Barna project was supposed to be operational till 1989, but had already been interrupted in 1985 on account of the low success rate and the relatively high costs.

For a start, a simple drill rig (Hydra Drill) was used, by means of which 38 wells were drilled; from 1981 on, a more modern drill rig (Halco V493) came into operation. During the following 4 years 237 successful drillings were carried out. Nevertheless, only 154 of them were handed over in perfect working order. The report does not provide any details on the number of dry borehole drillings; the project manager, however, indicated by other means of communication a success rate of 50%, but the calculation basis is unknown.

The total average costs per well have been quoted by Redd Barna to amount to 77,000 Rs. Calculated on the same basis, the 654 wells built by GTZ within 3 years with 2 drill rigs (Velco Drill) of moderate capacity, were estimated to 25,000 Rs per well. The efficiency of Redd Barna therefore amounted to only 1/3 of the GTZ costs; this difference cannot only be explained by means of a different project organization (efficiency of the management). Besides that, Redd Barna and GTZ were both hindered by ethnical troubles in the project area. The argument that Redd Barna generally drilled deeper wells than GTZ cannot be considered as decisively important; drilling costs, on account of high supplementary costs, depend only partly on exact drilled depths. The indicated expenditures allow the preliminary conclusion that the success rate might have amounted to approximately 30%.

Incidentally, it might not be without interest to think about the reason for the differently chosen average depth of the wells in the two projects to be compared. In the GTZ program one succeeded in systematically locating those points where good wells could be established with a minimum of drilling. Apparently, Redd Barna had no such technique at its disposal and was urged, therefore, to rely on the supposedly increased chances associated with deeper drilling.

The following paragraph is very informative, abstracted from the final report: *"Some of Redd Barna's wells have been given up because in their immediate proximity the GTZ had established wells which provided a better water quality"* (intended to state is also *quantity).* That is a clear statement and there is no hint that the situation has ever been reversed. On the contrary: the unusual success of GTZ did not remain unknown. Several of the other institutions, whose duty was also to supply drinking water, requested GTZ to support them with respect to well point location. In addition, it must be stated that Redd Barna repeatedly (and successfully) drilled on sites, previously located by Schroter, but which had not yet been taken over and carried out by his drilling team. The reality of these remarkable incidences is also reflected in Redd Barna's report.

Limited information referring to a comparable project of the World Bank in Kurunegala District is also available (1982-85). It is reported therein that less than 30% of 848 drillings were successful [9].

Continuation Project in Kurunegala

After 1985, a subsequent project of GTZ was carried out in Sri Lanka under new management, focusing on the dry areas of Kurunegala District. Besides several measures related to the improvement of the infra-structure, the development of rural water supply constituted one of the main tasks. As in the previous project, and apart from a few wells intended for small central water works, it consisted essentially in the construction of individual supplies, that means wells with a yield of 5 l/minute and equipped with hand pumps.

The hydrogeological situation is, in all aspects, comparable with the one in Vavuniya District. The water detection depends on finding fractures in hard rock which are not very pronounced in mostly gneiss and granite formations. A former study of the water supply possibilities only investigated the construction of long distribution pipelines to exploit shallow lying water [10] — by now a no longer acceptable procedure.

Making use of the experiences gathered in phase 1 of the project, dowsers were also appointed in the still ongoing subsequent project. Meanwhile, the following procedure has been found to work well: initially, the target groups (communities) propose well sites to their liking. Then, a hydrogeological team investigates the target area and determines, whenever possible, promising well sites; geo-electrical techniques represents the typical measuring aid. The study of aerial photographs did not play a role due to insufficient resolution and because the aim was to locate well sites of moderate yields in the middle of villages. Finally, two dowsers were appointed to pinpoint the actual drilling sites.

In following this procedure about 1200 boreholes were drilled by the end of 1990. The success rate was 80%, whereby every well with a yield below 5 l/minute was considered as "dry". Although this rate is somewhat lower than in the preceding GTZ project, it is altogether a good result. Both locally involved hydrogeologists, as well as experts who visited the area occasionally, certified that it was extremely difficult and sometimes impossible to find very narrow fractures — like those located in the previous project — by either "intelligent guessing" by means of theoretical trivial methods or pinpointing by means of geo-electrical or other classic measuring techniques.

It must be mentioned that Schroter was not one of the two appointed dowsers; the first was a German and member of the project drilling team, the second was a local person trained for that task by the exploration team since the beginning of the project. Although both dowsers are unable to provide such precise indications as Schroter does, their appointment was very positive. That was also reflected in the following fact: occasionally, when the hydrogeological procedure was out of order, the drilling points, driven by necessity, had to be selected exclusively by the dowsing technique; amazingly, the high success rate was not noticeably reduced. GTZ plans therefore to continue the well-controlled employment of these apparently appropriate dowsers within the described team work of the project.

Final Evaluation of the Sri Lanka Project

The information from previous projects encompasses quite a large framework. In the past, a program of this magnitude had never been performed, in which dowsing played an apparently decisive role, and which led to the accumulation of so many verifiable facts and data. In the following section, these results will be discussed further with regard to the possible significance of the dowsing technique.

The quantitative success of the GTZ program in which Schroter determined all the definitively selected drilling points, is incontestable. Accordingly, the question must be asked if this success would have been also possible without the aid of a dowser. This alternative, however, seems to be improbable on account of the many arguments already described before. Above all, the only two conceivable counter arguments, which could be put forward (and will be treated in more detail in part 3.1) are probably unfounded and cannot be advanced:

- Are there so many fractures in the underground of the project area that there is a 90% chance to find ground water anywhere with a mean yield of about 30 l/minute?
- Can appropriate drilling points be consciously or unconsciously recognized through classic and passive techniques, namely by subtle observation of topography, morphology, flora and fauna?

The first argument can be refuted on both the basis of general as well as practical experiences gathered at the sites and on hydrogeological models which were derived from these data. Small fractures and low permeability have been repeatedly proven to prevail. We must, nevertheless, concede a limited relevance of the second argument; however, in crystalline underground with relatively small and locally very concentrated aquifers, the indications one may possibly gather at the surface are generally not sufficient to enable the location of a well site with the necessary accuracy. The three control tests described above, as well as the comparison with the results from other projects credibly support the rejection of both of these.

It must be suspected that without the incorporation of the dowsing technique the GTZ project would have resulted in a success rate of no more than 30 – 50%. The necessary number of wells would have undoubtedly been reached by means of modern prospecting methods, but cost and time inputs would have been considerably higher than was the case for the actual, effectively carried out GTZ project.

Due to the increasing and credible evidence, one may come to the conclusion that the appointment of appropriate dowsers does notably increase the success rate in a well-planned hydrogeological project. Nevertheless, completeness of argumentation requires the admission that as of now the results described and the derived conclusions cannot represent a final *scientific proof* for the relevance of the dowsing technique. Such a proof can only be established when, independently of the evidence gathered by individual groups, sufficient repetition of the experiments is achieved due to the involvement of independent researchers: only then, and provided that further results confirm the initial observations, a lasting and reliable consensus between competent specialists might be attained.

Comparable Experience from a Pilot Project (Burkina Faso)

The difficulty of water detection in arid areas with a crystalline rock basement can be understood in the light of a more recent study carried out in Burkina Faso, where a maximum of hydrogeological and geophysical investigation techniques has been exemplarily implemented [11]. This research program has been set up in order to investigate whether one could improve the highly unsuccessful drilling results produced by means of the ground water investigation techniques used in the past. The area to be studied was characterized by essentially similar conditions as in Sri Lanka; the yearly precipitation varied between 600 and 1000 mm/yr.; dry seasons are long, and the water reserves are mainly stored in fracture zones in the crystalline bedrock.

The study made use especially of highly sensitive satellite images (MSS and TM) taken at different seasonal periods, and electromagnetic measuring procedures (VLF with movable transmitter and horizontal loop procedure with a penetration depth of up to 40 m), including measurements of the magnetic field and electrical vertical soundings. From the beginning, the combination of the numerous hydrogeological and geophysical procedures was considered to be necessary because otherwise drilling points could not have been located with sufficient reliability. The results were no real surprise to experts and, although obtained in a particular area, are considered as typical also for a variety of other arid zones.

Obviously, certain details of structures in the underground may be made visible by geophysical procedures, but not with aerial photographs — and vice versa. The link between EM anomalies and cracks in the rock is not always evident. Investigated fractures and weathered zones may present resistivity anomalies in cases where they are significantly extended, but statements on stored water reserves or waterflow are not possible; deep lying extensions cannot generally be detected through routine measurements, but, if ever possible, only with additional costly supplementary measurements. Fracture zones with narrow weathered spaces do not appear clearly or cannot be located by EM measurements. Besides the resolution limitation of satellite and aerial photographs, non-fracture-tectonic origins of EM anomalies, lithologic and tectonic anisotropies of the rocks and ambivalences of the interpretation of the tectonic structure are methodic weakness of the conventional procedures.

The combination of the numerous applied procedures allowed the location of intersections between tension zones and shear zones which are considered to be particularly promising; here, drillings should be successful because they encounter permeable cracks. The success of that extremely expensive project could be demonstrated in practice. Out of the total of 16 (test-) drillings with depths to 80 m only 2 were dry, whereas the yield of 14 wells was between 10 and 100 l/minute. Nevertheless, it is important to remark that the applied prospecting input of tremendous proportion was only possible within a research project and cannot be considered as a standard for routine investigations. Unfortunately, the possibility of dowsing investigations had not been considered. Excellent tests of this unconventional procedure would have been possible and particularly useful because of the availability of unusually detailed data of the underground conditions.

These findings support the previously mentioned conclusion that the few technical prospecting methods used in Sri Lanka could not warrant a high success rate; the interpretation of aerial photographs and geoelectrical techniques alone has to be considered as being insufficient, as its significance with respect to the ground water flow in the underground is largely undetermined. As the success rate of the first project phase in Sri Lanka was still higher than the one achieved in Burkina Faso, there is a well-grounded argument in favor of the combined technique which, provided that certain conditions are met, makes use of both classical geophysical techniques and dowsing procedures.

1.2 Philippines

According to an agreement between Germany and the Philippines a special energy program had to be set up, which involved the equipment of Verde Island with small solar power systems. In accordance with the desire of the population, GTZ first tried, as a measure to improve the confidence in technical aid programs, to ameliorate the catastrophic water supply. As no comprehensive and financial planning was foreseen for such a small additional action, the GTZ expert Schroter was requested to establish all-season potable water wells in some villages as soon as possible and at a most economical level — feasible only by means of the effective dowsing method.

Verde Island extends over some 17 sq km and, because of its volcanic origin, is only inhabited by about 8000 persons who live in the flat coastal zone. The existence of 7 boreholes could be ascertained after a survey, but only two of them were very deep (about 70 m) and could provide potable water; the one borehole had a former yield of 40 l/minute; by now, however, both wells were out of order. Furthermore, there were 47 dug wells of which 14 could not be used on account of a high salinity; the remaining wells either fell dry in the period from January to May, or exhibited significant deterioration due to salt water intrusion. During that critical season, drinking water had often to be brought by ship to the island.

Modestly extensive geological and hydrogeological information, as well as some data on the existing wells were available from local and national authorities [12]. They indicated a mean precipitation of about 1600 mm/yr, which quickly drains away from the slopes of the 350 m high central mountain range towards the sea. Surface water like perennial rivers or lakes is not present throughout the year.

The volcanic underground lies under a surface layer with thickness of typically a few meters and of a strongly varying formation (porphyry, limestone, sandstone, tuff and diverse conglomerates). The underground is considered as being relatively impermeable with respect to the infiltration of water. Ground water occurs especially in permeable fractures and weathered zones. These consist partly in locally limited fracture zones and partly in greater aggregations often containing sulfur, loose rock and different sediments; a continuous water influx is considered to be weak in these zones,

Thus, one can find most different conditions in close proximity on this island. In summary, peculiar problems arise for water prospecting because of the limited water storage capacity of the underground, the poor permeability, the lack of extended aquifers and the intrusion of salt water from the sea. For the areas lying next to the shore line, the same observations are valid as have been amply described in the Sri Lanka project. The totally different yields and qualities of wells existing on Verde island support these conjectures.

Of the six communities on Verde Island, only San Andres had no water shortage all round the year due to several productive dug wells. Hydro-geological causes could not be found to explain this fortunate situation. More recently, however, it turned out that the good wells had been sited by a local dowser, namely the previous mayor of the place who is still alive. Though this person, after the successful sitings, was still living there, the apparent talent has not been exploited by the neighboring villagers; the reasons remain unknown. Incidentally, of the two deep wells described above, the one having the better yield has also been located by means of the dowsing technique, applied by a foreign clergyman.

In four villages, Schroter found a total of 11 positions for dug wells which ought be equipped with hand pumps. He determined the sites for 10 of the 11 wells on the 10-200 m wide inhabited shore area where he claimed to have found shallow fractured zones by means of the dowsing technique. To support his expectation on hydrogeological grounds, it could be argued that fresh water might be present at these shallow positions: water running down from the mountain along the subterranean fracture zone might exert enough pressure to impede salt water infiltration from the sea. It is quite noteworthy that these sites were sometimes less than 100 m away from existing but unusable (salty) wells.

In 9 of 11 cases, the expected fresh water could be found, although the sites lay only between 20 and 50 m away from the sea and the well bottom was below the sea level. In one instance, a layer of 4 m thick hard rock had to be pierced before water was indeed found in a layer of loose rock at a depth of 5 m below ground level. One of the two dry dug wells was situated at some 1000 m from the sea and remained waterless even up to a depth of 10 m.

At one of the 9 successful wells, Schroter sensed several underground water courses streaming down from the mountain slopes, allegedly exploitable at a depth of about 7.5 m; this prediction, though treated with skepticism, was put down to protocol. In order to attain a maximum water yield the well should be dug at the intersection of the outlined streamlets. After Schroter had left, the well was dug and water was indeed found at a depth of 7.2 m. Unfortunately, it turned out to be too mineralized. The responsible program leader then decided to take the prognostic details established by Schroter more seriously and pumped out the well to check for the possible existence of different inflows. To his surprise, four of these small streamlets could be clearly identified and were separated from each other. One of them was mineralized and could be sealed off by simple means. The remaining 80% of the influx (6 l/min) was potable water. This precise and conventionally unbelievable prognosis will be considered later on again, because it is contrary to what can be expected on the basis of conventional prospecting, and because such a situation is well suited for appropriate scientific test purposes.

Additionally, Schroter localized the sites for another three deep boreholes further away from the coast. The first 24 m deep well provided excellent fresh water; at first, the two other wells produced good water too, but it became slightly saline after completion of the well construction, probably on account of the use of inadequate sea sand as filter material.

On request of the local project management another dowser, a clergyman of German origin, was appointed in 1990 to locate 30 new wells in order to improve the future water supply. Later on, Schroter checked the sites by means of his method and made a detailed prediction referring to the expected depths and yields, as well as to the salinity risk (see the corresponding discussion in part 3). If these locations are drilled later on, the value of the indications of both dowsers could be well checked. The provincial government, impressed by the success of the GTZ procedures, thereafter appointed other dowsers for new successful water investigations.

To conclude, it may be said that decisive indications for appropriate well points cannot be obtained in this area without excessive input of measuring techniques. Useful vegetation indications are lacking. As has been repeatedly mentioned, geo-electrical procedures are not very helpful for a safe identification of small streamlets in inhomogenous underground. Larger fracture formations are certainly detectable, but those show an increased risk for multiple salt infiltration. The successfully dug wells were all fed by small and very narrowly localized streamlets; if these wells had been displaced by only one or two meters, fresh water (from the direction of the mountains) would not have been found. Numerous unproductive dug wells of former times testify that such small fluxes are not very often available and may be hardly found by accident or by intelligent guessing.

1.3 Dominican Republic

In the south-west of the Dominican Republic, an inhospitable arid area extends over some 1000 sq km and until now has been only marginally usable. The institutions of the country developed a model which includes ground water investigation as part of a "project for a rational use of the dry forest." In this way, continued destruction and exploitation by charcoal-burners and goat breeders would come to an end, regeneration of the natural vegetation would become possible while allowing the inhabitants of the island a moderate utilization. For that purpose, both drinking water and irrigating water for young vegetation is necessary.

The project area is situated about 100 km west of Santo Domingo and borders the Caribbean Sea. The very hilly region lies at a mean height of 120 m above sea level and slopes gently to the sea and to the interior. The annual precipitation is generally below 500 mm/yr. The surface layer is rarely thicker than 10 cm and mostly dry, in some areas slightly salty. At numerous places, the rock formation is exposed without any cover. Geological maps do not give any information about this area. In the more densely populated and better investigated areas flysch zones and clay underground with karstified calcareous sandstone intercalations are indicated.

In a joint investigation by the local national water authority and GTZ experts it became apparent after a survey of the area, comprising geo-electrical investigations and smaller-scale ground exploration, that no useful aquifers were available and that the ground water potential was insufficient for irrigation. Deliverable ground water might only — if at all — be found in very limited quantities in small fissures [13]. It is therefore necessary to localize the junction of faults on one hand, and the mostly deep lying fractured limestone banks on the other hand. In the western part of the project area, near Canao and not far from San Antonio, three 300 m deep boreholes are known, all of which were dry.

As a last resort, Schroter was requested to inspect the area referred to. By means of the dowsing technique he tried to locate faults in one part of the area. Very soon he thought he had found one of them and indicated 5 drilling points in 5 km intervals, not far from Galindo. In each case, he predicted not only the precise sites but also the approximate obtainable yield and the required drilling depth.

The first borehole should have been drilled to a depth of 50 m. After having pierced through a thick layer of clay, strong artesian water was surprisingly found at a depth of 48 m. Unfortunately, it was a hot mineral spring with a water temperature of 35° which, due to its high sulfate content, was not appropriate for irrigation purposes. However, electrical conductivity measurements as a function of depth showed a prominent decrease in sulfur content below 40 m, so that possible fresh water might have been also present, but local conditions did not allow a further investigation.

One of the four other drilling points next to Galindo should have been drilled to 70 m. Once more, water was found at 68 m which rose to a depth of 30 m in the borehole. The immediately measured water conductivity showed that it might have been good drinking water quality. The upper layers, however, had revealed the presence of significant amounts of clay; this resulted in a gradual plugging of the borehole which eventually ran dry. The local limited technical facilities were not adequate to solve this problem of mere borehole maintenance and development. Likewise, the next borehole became clogged too, so that the project had to be abandoned for the time being. Unfortunately, the drilling of the two remaining locations was also postponed.

Nevertheless, three borehole drillings had been performed in such an undoubtedly difficult area and in each case unexpectedly large water quantities had been encountered. On account of the available hydro-geologically relevant data and according to the opinion of specialists, it must be viewed as practically impossible to locate such sites by accident or by means of usual classical techniques.

1.4 Congo

In the Congo, the first phase of a pure conventional water investigation program was successfully completed by GTZ. The continuation of this project was to take place in the beginning of 1987 some 100 km further northwest near Loubomo, in an area hardly developed and essentially unexplored. Within the program small water supplies for scattered villages should be installed. Because the wells were to be operated with hand pumps, the required minimum yields were again only 5 l/min.

Success rates of 75% were reported for the first phase. The underground was composed of karst and was so cavernous that no kind of measuring technique was necessary for the location of well sites. As the second area was estimated to show similar conditions, a hydrogeologist decided very roughly locations for 50 possible well sites, solely on account of morphologic indications and purposefulness. In succession to that, Schröter was requested to determine the exact positions of 50 final drilling points by means of the dowsing technique. His duty consisted in indicating the supposed karst water resources as precisely as possible. Along these lines, Schroter indicated before the beginning of the drilling at each location the depth and yield that he expected.

Two years later, results of 51 borehole drillings were available; two of them, however, were not executed at positions determined by Schroter. One borehole collapsed at a depth of 39 m without having a water strike before the anticipated final depth of 50 m had been reached. Another drilling struck semi-artesian water at a depth of 52 m; the water rose in the borehole and clogged it due to an expanding clay underground so that this principally successful drilling had to be abandoned for the time being.

For 47 wells, the actually obtained data may be compared with the predictions. For 42 of them, the expected minimum yield had been accomplished. This represents a success rate of 90%. It should be added, that the actual yields were several times higher than the necessary minimum quantity and the maximum of the deliverable quantities would have been still higher; these maximum values have not been determined (there was no need to know them) and are expected to fluctuate with the season. It is therefore not possible to check the predicted yields in an absolutely meaningful manner. Moreover, since the indicated values vary only slightly from borehole to borehole, their significance may not be too high anyway. It remains to say that for half of the cases, the predicted values were accurate, whereby it should not be forgotten that the predictions had all been made before any drilling results were available in this area. An analogy with the former project is not very helpful because more clay components were found in the present project area.

Some comments are in order with respect to the 5 unsuccessful borehole drillings. Two of these holes had to be drilled up to a depth of 50 and 55 m, but the depths actually reached were only 47 and 50 m, respectively. As the predicted depths may only be interpreted as a guide line, a certain continuation of the drilling would have been advisable. Finally, a satisfactory evaluation of the result would have required answers concerning several other questions such as whether the unsuccessful boreholes had been drilled vertically and technically correct and whether clay intrusions may have impeded the water flow into the borehole.

In any case, the recipe "to drill deeper" is no guarantee for success. The three other unsuccessful drillings of respective depth of 50, 60 and 60 m have been considerably deepened to 78, 72 and 87 m, respectively, without getting any sign of water.

The predicted drilling depths in that partly hilly region with height differences of up to 50 m turned out to be practical and useful values. The distribution of the differences between expected and realized depths for 42 successful borehole drillings are compiled in Table 3, sorted into 4 groups. According to the data, 67% of the predicted depths were better than 10% accurate and 80% were correct within 20%. In the evaluation of the results, however, additional aspects have to be considered.

TABLE 3

Deviation	Number	Percentage
0 - 10 %	28	67 %
10 - 20 %	5	12 %
20 - 40 %	7	16 %
> 40 %	2	5 %

Results referring to drilling depths of 42 wells in a karst area in the Congo. The drilled depths varied between 70 meters with a mean value of 48 m, the predictions varied between 40 and 60 meters with a mean value of 47 m. Listed are the absolute and proportional number of depths predicted by the GTZ expert, Hans Schroter, in different accuracy intervals. For example, 67% of the data were more accurate than 10%.

First, the mean value of the actual depths amounted to 48 m and about 80% of the drilling depths ranged from 40 to 60 m. Thus, a very rough and rather unspecific "prediction" of, say, 50 m depth for each drilling would automatically have resulted in a success rate of 80%, when an accuracy of ± 20% was aimed at. Indeed, the drilling depths advised by Schroter did range from 40 to 60 m with an average close to 47 m. They showed, however, a significant correlation with the actually required depths. Besides that, by resorting to "intelligent guessing" a mean drilling depth of 70 m should have been chosen; that number resulted from the experience obtained during the first project phase and the hydrogeologist in charge recommended it also as the basis for the new project planning regarding the expected total depth to be drilled. The quite different prediction for a mean depth of only 47 m could therefore (before the first drillings had taken place in the actual project area) not be well founded. Hints due to landmarks in conjunction with topographic features cannot be fully excluded, but must be regarded as highly improbable.

In general, boreholes were drilled only as deep as necessary in order to reach the required, relatively low minimum yield. Therefore, it cannot be argued that, after having found water, the boreholes had been drilled still deeper up to the initially advised depth. This was unnecessary for a further reason: in most cases, the relatively small yields aimed at were immediately found in karst water channels and thus, it was not necessary to carry on the drilling in order to improve the yield. However, a less significant trend in this direction can not be completely excluded because of self-interest of the drilling company which is usually paid for drilled meters irrespective of the results.

Finally, it must be stated that, for the moment, no simple classical measuring procedures are available which permit detailed depth predictions for relatively small water channels in deep lying karst.

In the meantime, 40 drilling spots were located by means of the hydrogeological method and, in part, by dowsing techniques during the third phase of the project in the geologically different Kiwongo District. No kind of drilling had been formerly carried out in this area. Up to now, 33 of the 40 points have been drilled, 19 of which are successful. It turned out that clay layers of some 40 m thickness cover a series of fractured calcareous sandstones. The water found in the fracture zones was semi-artesian and rose up to 10 – 15 m below the ground level. With 10 l/min per meter lowered level of the water table, the yields were clearly above the expected minimum values. The uniformity of the drilling profile indicated that a regionally extended aquifer exists. Since drilling points were not systematically divided according to their origins, i.e. whether determined by hydrogeological means or dowsing techniques, and as some boreholes are still to be drilled, the respective success rates cannot be ascertained.

1.5 Niger

Near the town of Gotheye, conventional investigations have been performed and, based on the information obtained until then, 7 boreholes had been drilled to a depth of 150 m. The total obtained yield was about 150 l/min which was only a third of the 450 l/min, required for the supply of this town. As the necessary water quantity could not, in the opinion of the responsible hydrogeologists, be reached, an alternative had to be searched for. It was planned to take the water of the Niger river flowing close to the area and to treat it appropriately for public use. That implied high expenditure as well as operational and maintenance costs for the water treatment, which might be avoided if sufficient and suitable ground water was available. Before this time-consuming and expensive solution was adopted, an opportunity came up to conduct an investigation of the area by means of the dowsing technique.

The GTZ expert Schroter was asked to visit the area where he inspected the available boreholes and their environment by means of the already described method and tried to determine to what extent water bearing fractures might already have been hit. According to his subjective assessment, he found that this had only occurred in two of the seven borehole sites. But even these 2 sites he considered being badly positioned as other, neighboring points along the supposed fracture would provide a higher yield.

The best of the seven original locations provided 80 l/min at a depth of 144 m, but just missed a better developed fracture situated in a relatively permeable zone. After a short investigation, Schroter located a point barely 40 m from that site which he considered to be much better and which would hit the fracture zone more accurately. Furthermore, he predicted that the new location had to be drilled to a maximum depth of only 90 m to obtain a yield of 300 l/min. A little later, drilling took place at this point and water was actually already found at a depth of 54 m. Provisional pump tests verified the high expected yield of 250 l/min at a depth of 60 m. Later long term pump tests, though, revealed a decline of the water table so that this well cannot yet be considered as being definitely successful. In particular, the well could not yet be considered as completed, because the borehole was not drilled down to the proposed depth of 90 m. A perfect technical construction of this borehole up to the depth advised by Schroter may well provide the initially predicted and necessary yield. Nevertheless, the participation of the dowser brought about an unexpected and remarkably good result from the start.

1.6 Yemen

This time the aim was to establish a water supply scheme for approximately 17,000 inhabitants of the Yemenit town of Al Wasitah and its neighboring desert communities. Two hydrogeological studies from 1985 and 1988 formed the basis of the investigations [14, 15]. At this time, a single well in Al Hamidah yielding 3 l/sec and several shallow dug wells were known in this area. The latter ones are situated in the Wadi Ayyan and produce water for approximately four months, especially in the monsoon season. The mean annual precipitation is about 300 mm, of which more than 60% evaporates and 30% flows away, so that only 10% is available for ground water recharge.

Lime and sandstone, as well as rock of volcanic origin characterize the region. The Wadi apparently lies on an extended fault with strike angles of 20-30° and is covered by 100 m thick layers of sediments of limited permeability. The surrounding formations are practically impermeable, so that the water catchment area of the Wadi is limited by its own extension.

Hydrogeological studies considered drillings into the rock basement to be unpromising and recommended the establishment of three deep wells in the Wadi area where the sediment layer exhibited maximum thickness. Detailed geo-electrical soundings indicated drilling depths up to 100 m, down to the hard and impermeable rock basement, in order to most efficiently exploit the aquifer which was believed to lie in the lower sediment layers. On account of the limited permeability, a distance of 200 m between drilling points was considered to be sufficient. As the actual water demand amounted to 12 l/sec, a target yield of 15 l/sec was envisaged. To provide the demanded quantity it was estimated without further model calculations that two wells would certainly be necessary. A third well should be built to serve as a standby.

The location of the drilling points followed the above mentioned combined procedure. Initially, topographic features had been utilized to roughly define an area in which geo-electrical investigations were conducted at 11 sites by means of the Schlumberger/Wenner method. Schroter then located some promising points by means of the dowsing technique. His three finally selected points were incontestable according to the interpretation of geo-electrical measurements.

Schroter recommended drilling to a depth of 65 - 70 m and expected the principal inflow with a yield of more than 10 l/sec between the depths of 25 and 55 m. In all cases, water influx was indeed observed, actually in the ranges 22 – 29 m and 51 – 57 m for borehole 1, up to 60 m for borehole 2, and 12 – 35 m and up to 57 m for borehole 3. The yields amounted to 8, 13 and 25 l/sec, respectively, however with varying strong drawdowns. Especially for borehole 1 a comparatively small specific influx occurred for a drawdown of as much as 51 m. Unfortunately, in this case the major water bearing zone had not been utilized at the beginning of the drilling procedure since appropriate filter casings were not employed. Water was observed only after some modifications of the plain casing had been performed, so that it is possible that the quoted yield is not the available optimum. It must be appreciated, though, that already well number 3, which was drilled and developed first, delivered by itself more than the totally required water quantity.

In this project area, as in many others, the dowsing technique proved itself practically useful and sufficiently reliable. The impression should be avoided, though, that in the present case the unconventional technique, combined here with classical procedures, would be indispensable for a project success. On account of the estimated considerable spatial extension of the aquifer, conventionally located drilling spots might have been successful with high probability. For example, due to some practical considerations, drilling site 2 was slightly relocated from the initially determined point and was nevertheless a success. However, the drillings revealed quite different underground conditions and the observed two higher yields could not have been attained anywhere in the area; the limited ground water recharge and permeability renders successful drillings difficult, in principle.

In view of later discussions to explain the dowsing effect, a test is relevant which was carried out near Al Bayda. Within a program put into effect by KFW (Kreditanstalt für Wiederaufbau, Germany) regarding urban water supply, geo-electrical investigations were conducted in a wide, extremely arid area at an altitude of 3000 m. A few sites were also investigated by means of the dowsing technique. Water was not to be expected. Schroter determined two sites where he predicted a fracture zone extending down to 150 m. The subsequent geo-electrical measurements at this site allowed a resolution up to only 35 m and were interpreted as follows: the feature represented not a pronounced fracture zone, but only a slightly weathered one with loose materials.

Later, a drilling was carried out at one of these two points: from the drilled material it became clear that there was indeed a fractured zone up to the final depth of 150 m; as expected, no water was present. This result strengthens the supposition that dowsers do perceive geological fault zones, but in fact, not actually the accumulation of water (as a chemical substance). This important conclusion will be discussed in part III and should be examined more thoroughly in further experiments.

1.7 Cape Verde Islands (Fogo)

One of the Cape Verde Islands in the Atlantic Ocean west of Senegal, Fogo has been investigated and intensively examined since 1979 for water resource development, first by the Bundesanstalt fiir Geowissenschaften and Rohstoffe (BGR, Germany), as well as by the Kreditanstalt fiir Wiederaufbau (KFW) [16, 17], and finally by GTZ and partners [18]. The island extends over an area of some 25 km in diameter and consists mainly of a volcano (last eruption in 1951) rising to 2829 m above sea level; the island has 40,000 inhabitants living on the steep slopes and on the coastal zone. The mean annual precipitation varies from 1100 mm in the northern part to less than 300 mm in the southern part of the island. In the last decade, a strong decline in precipitation could be noticed.

Without supplementary artificial irrigation, agriculture can only be practiced during the 4 months of the rainy season when surface water is available. At other times, people get their water from three springs which have a total yield of 20 l/sec and lie at sea level. Besides that, there are some other small springs and wells of less significance. On account of the difficult geological conditions, traditional dug wells are generally not possible. In the higher lying regions of the island the supply situation is absolutely unsatisfactory for private and agricultural needs; because of economic considerations, the required large water quantities cannot be pumped up to all the prospective users.

The availability of all-year productive springs proves the existence of permanent ground water; however, there are only seven springs on higher sites whose total yield does not exceed 70 l/min. The ground water recharge is estimated to be relatively high and is estimated to be several times the yield of the known springs. Permeable volcanic ashes and scoriae, as well as the bottom of the volcano crater which lacks of an outlet, promote significant infiltration. It may be supposed that the major part of the ground water (more than 90%) flows through a subterranean channel system and predominantly emerges undetected below sea level.

The underground consists of a complex layer structure of basalt, scoriae, volcanic breccia, tuffaceous rock and ashes, varying abruptly in order and locality. For that reason, one has to take into consideration significant anisotropies in the ground water body, as well as frequent occurrence of galleries. Due to the uncertain ground water situation, an investigation program involving 50 – 300 m deep boreholes was proposed. The rocks are considered to be more or less impermeable and one assumes that dry boreholes are not only possible, but probable.

Because of the strongly varying rock formations geophysical measurements were not conducted to site drilling spots — they would not have provided supplementary useful information for the area. Accordingly, the proposed final drilling points were dictated by considering topographic-morphologic features and appropriate access possibilities.

In the scope of GTZ activities, Schröter was requested at the end of 1988 to undertake dowsing investigations on Fogo. He located seven drilling sites on the highlands (about 1000 m above sea level), where useful yields of several liter/sec were expected at depths of 45, 70, 80, 90, 130, 150 and 250 m below the ground level of the respective site. Particularly remarkable is the fact that he located shallow fracture zones at seven other sites on the highlands: there, the possibility for dug wells was given which could be built without excessive effort and would deliver (predicted) mean yields of 30 l/min in depths between 8 and 25 m.

More than 10 years after the beginning of the original investigations, the first exploration drillings were carried out, though only at sites conventionally determined. At a location some 500 m above sea level, the first drilling was conducted to a depth of 150 m without finding a single sign of ground water. With this, the early hypothesis supposing that a ground water surface lies in a large front not too deep below ground level had to be abandoned. Consequently, no further drillings were carried out on the higher lying slopes. Instead, the next drilling was carried out at a spot 100 m above sea level on the shore and struck a rich fresh water lens at a depth of 100 m, quite close to sea level. With this, a fourth spring was provided to solve the problem for the coastal zone, but the shortage in the higher lying regions still remains.

After concluding of the still ongoing investigation by the KFW/BGR group, GTZ plans to drill some of the dug wells proposed by Schroter on the higher lying sites. Although results are not yet available, the existing quite interesting situation which evolved until 1990 is well documented and partly mentioned here. If only a fraction of the dowsing predictions could be verified in this extremely difficult area, it would contribute towards a better understanding of the unconventional water detection technique.

1.8 Kenya

In Kenya's Lamu District, a thinly populated area of 100 sq km, a settlement program has been put into effect for some future 10,000 inhabitants. For this reason, a new water supply system had to be provided with high priority. One of the main problems consisted in the well-known circumstance that a ground water horizon can be reached by means of usual dug wells, but the water exhibits generally a high content of salt and, thus, does not satisfy the needs. Near the neighboring village Witu, however, there were four old wells with depths of 13 and 28 m, of which two could still deliver fresh water.

At the beginning of 1990, GTZ tried to implement also the unconventional method to locate appropriate sites for dug wells. The prospecting based on dowsing was quite specific, as Schroter predicted the presence of fresh water in shallow layers in spite of the risk of sea water intrusion.

At once, provisional test drillings of limited scale were undertaken by means of hand drills at several of the points specified by Schroter. The overburden was only a few meters thick with underlying coral-calcareous deposits. Relatively close to the surface saline water was found between 5 and 10 m, which was of no help. Nevertheless, Schroter insisted that the fracture zone he had sensed by means of his dowsing reaction was not yet reached and that fresh water could only be found below the encountered salt water table. As this prediction seemed to be unlikely from a hydrogeological point of view, one first hesitated to continue with further drilling. Finally, it was decided to deepen seven of the boreholes. It turned out that Schroter's unbelievable prediction was indeed correct: a thin clay layer underlay the saline water stratum and immediately beneath, the expected fresh and good drinking water showed up at depths between 12 and 15 m. At several other points located by means of the dowsing technique, hard rock was reached which could not be pierced by the simple hand drill employed. In these cases, one must wait for the results until more suitable technical measures can be implemented into the project.

An appropriate construction and development of the already successful boreholes could lead to useful fresh water wells by correctly sealing off salt water inflow from the upper layers. This situation is interesting and informative as it is impossible or very difficult to make quick and reliable predictions of small fresh water resources situated below an extended thicker salt water stratum without exploration drillings. The continuation of the project will reveal the significance of the dowsing technique within this kind of soil formation.

1.9 Sinai

In most parts of the country, Egypt suffers from an ongoing water scarcity. This applies especially to the Sinai peninsula, whose desert character is even known to non-experts. Within the scope of a cooperation between Egyptian authorities and GTZ, especially focusing on rural areas in central and north Sinai, called RDNS (Rural Development North-Sinai) and SHF (Self Help Fund El Arish), the usefulness of the dowsing technique could once more be demonstrated.

A high degree of drought characterizes this project area; precipitation is generally less than 30 mm/yr, of which the major part evaporates. Accordingly, the regeneration rate of ground water is exceedingly low. Only in the northern coastal zone, are somewhat higher quantities recorded, e.g. about 100 mm/yr in El Arish. In central Sinai folded rock formations and flat regions with Tertiary, shallow weathered karst can be found. Under certain conditions, it may be possible that limited amounts of water accumulate at moderate depth.

In the past, numerous attempts have been undertaken to find both deep and shallow lying aquifers. More recently, renewed efforts were made by Israeli authorities (during the occupation from 1967 to 1982), and three projects were implemented after 1985, initiated by UNICEF, EC (European Market Community) and a cooperation with Japan, especially in order to investigate deep aquifers (down to 1000 m). Achieved success was moderate and did not match expectations. For example, 87 drillings were executed up to 500 m within the EC project, but only 8 of these resulted in the finding of water. It should be added, that the extraction from a great depth is both less economic and not very advisable since the water found there is mostly of fossil origin, that means it hardly regenerates.

In central Sinai, there are only a few production wells and the additional use of tank-trucks is necessary to ensure a minimum water supply for the scattered population. Hitherto, investigations for the detection of supposed shallow and very small subterranean water bearing structures remained practically without success. Therefore, the Egyptian authorities welcomed the GTZ proposal to try the dowsing technique in this most intricate area.

Under the control of experts from the Desert Institute of Cairo, Schroter determined within a few days 15 drilling points in 8 different areas, separated some 150 km from each other. Besides the exact location, he also predicted the supposed drilling depth and the expected yield. The suggested depths ranged from 8 to 60 m, with an average of 25 m, whereas the indicated yields varied between 15 and 60 l/min.

Meanwhile, 12 of the 15 sites have been explored. In view of the difficult conditions the provisionally available results are very impressive and had not been expected at all: right away, in 10 cases the attained yield amounted to 30 l/min, without exceeding the predicted drilling depth. It might be hoped that the ongoing well construction increases the initial yield numbers. Only two holes were dry; for given reasons, it has yet to be checked whether exceedingly large quantities of bentonite, used in conjunction with the applied drilling method, might have clogged the small water influx from narrow weathered fissures.

In any case, the available results have been classified as highly positive so that the Egyptian authorities requested the GTZ dowser for a survey of two other arid areas elsewhere in the country where conventional water prospecting programs had produced so many series of expensive and unsuccessful dry drillings that their continuation was at stake. The results due to dowsing are not yet available.

TABLE 4

	Site	Rate (m^3/day) th	Rate (m^3/day) exp	Depth th	Depth exp	Remark
1	Quseima	50	>50	30	25	
2	Quseima	50	>50	5-15	5	
3	Quseima	75	-	60	?	displaced 1m
4	Bir Guraid	30	50	17	7	
5	Bir Guraid	40	35	17	14	displaced 5m
6	Bir Guraid	50	45	25	21	displaced 1m
7	Bir Guraid	60	50	30	20	
8	El Tamad	100	25	17	7	(a)
9	Kuntilla	50		30		not drilled
10	Naqab	75		35	?	displaced 1m (b)
11	Naqab	30		18		not drilled
12	Ghofga	75	40	35	19	(b)
13	Ghofga	25	27	25	17	
14	Ghabiya	25	-	18		bentonite (c)
15	Natila	25	20	18	<18	

New wells in Central Sinai Desert. The data stated includes delivery capacities in cubic meters per day and well depths in meters, once according to the dowser's prognosis (th) and once according to preliminary results of drilling (exp). All wells still have to be conditioned and washed out, which should yield even higher delivery capacities — particularly for the well in El Tamad (a). Since some of the wells were not drilled at the designated points, a number of very narrow water-bearing fissures may have been missed. One borehole near Naqab (b) has not yet been completed, because the rock proved extremely hard. In some cases, especially in Ghabiya (c), so much bentonite was poured into the boreholes that small influxes at the entrance into the hole may have been plugged off.

For further investigations of the dowsing phenomenon, which yet remains to be understood, the following observation from the prospecting in central Sinai is very important: some of the drilling points determined initially and solely by the dowsing technique could be verified thereafter by a simple technical measuring procedure. Operating a receiver working in the lower UKW band, anomalies of the field strength appeared, which were quite sharply localized (to less than about 1 m) and harmonized very well with the points, respective lines, formerly pinpointed by means of the dowsing technique. It must also be made clear, though, that the investigated fracture zones appeared as being so weak and narrowly confined that their purely technical localization is still totally impractical without combination with dowsing. By the way, this finding must be viewed as another indication for the validity of the statement that dowsing reactions are not only occurring merely by chance, but are linked with a deeper origin, which may also relate to the electromagnetic sensitivity of biological organisms (part 3.3).

Finally, it remains to be added that the localization of successful wells could not be explained by resorting to known effects. Most of the wells lie in a flat area where no anomalies due to vegetation or topography can be spotted. If such subtle indications had been available here, indigenous local experts would surely have recognized and exploited them long ago (see part 3.1).

1.10 Namibia

Since the beginning of 1992, extensive efforts have been invested in the further practical testing of the integrative model described in part 4.2 within the scope of technical cooperation between GTZ and the Department of Water Affairs (DWA) in Namibia. In the interest of pertinent progress, project-relevant dowsing data is being checked and verified as systematically as possible according to two different measurement techniques (VLF, SF). The VLF long-wave measurements are being conducted with the set of equipment known as "WADI." An expanded version (variable transmitter with receiver) of the SF short-wave method was made available by the Munich-based group of researchers in cooperation with the GTZ following encouraging experience in the Sinai (part 1.9).

The project proved successful, and the authorities in Namibia asked GTZ to extend Schroter's assignment to beyond the previously agreed year 1992. At the time of printing, prospecting is still under way, so that no final report is yet available. However, in addition to ample information on results to date, three interim reports *[23-25]* are at hand which justify preliminary reporting within the framework of the intended phenomenon profiles. Final evaluation of the results, however, will be contingent upon the forthcoming final report from the DWA, which will include the geotechnical measurements and their correlation with the dowsing data.

The prospecting was done in regions where conventional methods have proved difficult and extensively disappointing. As regards the geological setup in the subject areas, the water is confined to fissured zones of the crystalline solid rock. Covered by 60 to 120 meters of unconsolidated rock (sand, gravel), those zones begin at relatively large depths. The bushy terrain makes it extremely difficult to find superficial features with which to pinpoint the borehole locations. Nevertheless, the first hole Schroter had arranged to be drilled in the village of Tsumis was successful, yielding 80 l/min at a depth of 150 m.

An initial prospecting series was conducted in the areas surrounding Kamanjab, which was characterized by granite and gneiss. Of the 28 boreholes with an average depth of 74 m drilled there in 1987, as many as *25* were completely dry, and the remaining 3 yielded only very small amounts of water. Schroter located three new drilling points at which boreholes were sunk to about 80 m: they yielded 170, *35* and roughly 15 l/min, respectively. Considering the circumstances involved, the first result was quite good. A verticality check of the other two boreholes showed that they ran at an inclination and may not have properly intercepted the fissured zone (see below). All **3** locations were surveyed with the aid of the WADI unit, and the results showed striking coincidence between Schroter's points and salient maxima in the real part of the measuring curves.

Between 1968 and 1990, some 17 deep wells were sunk in the vicinity of Kalkfeld. Only one of them proved useful, while the others were all either

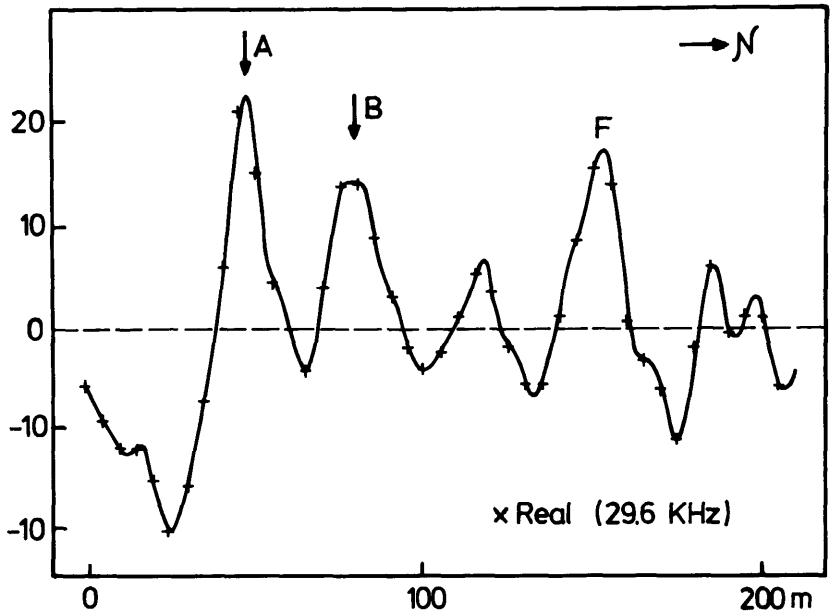

Fig. 3. Examples of VLF data obtained with the 'WADI'-instrument at sites with fissured bedrock in Namibia: in an area near Namutoni Schroter indicated the presence of two intersecting water-carrying subsoil structures. He determined a survey line which covered the two structures; his dowsing-reaction points are labeled **A** and B. The 'WADI'-profile measured at a later time exhibits prominent maxima in the real part of the data. F signifies the influence of a fence.

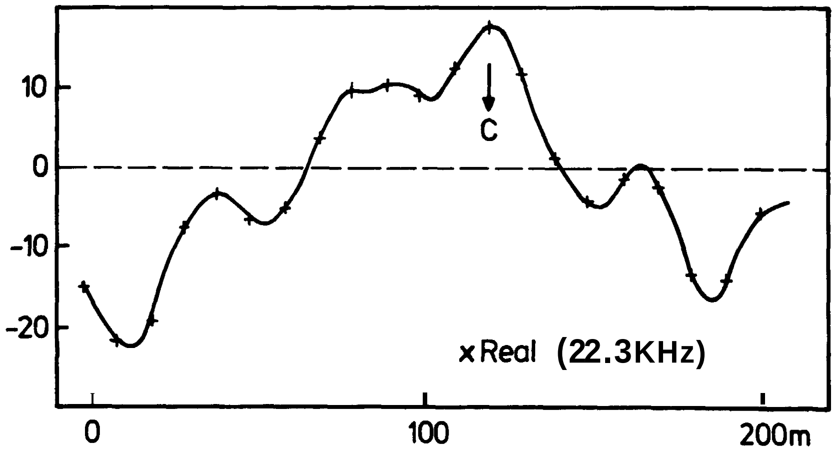

Fig. 4. Similar data obtained at the well site where the drilling point was initially displaced by 1.6 m with respect to Schroter's point C, resulting in a low yield. A second strictly vertical drilling at the precise point C turned out to be successful (see text). Obviously, VLF data does not suffice to guarantee a successful drilling. However, dowsing reaction points and locations of maxima in VLF data do not always coincide as well as is the case in the examples shown here.

totally dry or extremely weak. Consequently, the town remained without a safe supply of water. Within half a day, Schroter located two promising drilling points and suggested a depth of 140 m for each. The first hole immediately yielded a spectacular 250 l/min, thus solving the community's most urgent problem. The second well produced only about 15 l/min, but a subsequent verticality check showed a 1.5 deviation from perpendicular, which can be of significance, as explained below.

In Grünau, the drilling team sunk a hole 1.6 m away from the point indicated by Schroter. The resultant yield at the final depth of 120 m amounted to only 10 l/min. A subsequent verticality check indicated again a deviation of about 2°, meaning that the well face was actually shifted by several meters away from the target point. Since Schroter had assumed very narrow zones of fissuring, this time a new well was sunk at exactly the originally indicated point 1.6 m away from the first hole. Of course, more appropriate measures were taken to guarantee vertical drilling. The results justified the work, i.e., the new yield was high enough to warrant completion of a service well (although the final numerical results of the pumping test are not yet available).

This test is most significant in that it provides experimental verification of two frequently articulated suppositions: water-bearing fissure zones can be (1) very narrow and (2) located with surprising accuracy by dowsing. Moreover, the result proves that it is not at all an excuse when Schroter attributes poor results to the non-verticality of a drilled well.

Those remarkable findings led to measures aimed at making all further wells in that area as vertical as possible. In Owambo, Kokoland and West Hereroland, where the ground water situation is by no means better than in the areas discussed above, 17 new boreholes were drilled according to the modified and improved method. Even though some of them had to reach as deep as 200 m, *all* were successful.

The project experience gained with the type-WADI long-wave measuring instrument is especially noteworthy. As already mentioned, numerous signal patterns that could be interpreted as indicative of good prospects were obtained in the latter-mentioned prospecting area. As widely known and accepted among experts, such patterns can be quite helpful. On the other hand, such measurements normally would not suffice as a sole indicator of suitable drilling points. Notably the most productive well near Owambo, with more than 3000 l/min — did not betray its presence via a conspicuous VLF signal. If those responsible had relied more on the WADI readings, they might not have even drilled that well. Consequently, it would most probably be worthwhile using the latest technology to look for other types of physical signals at that particular location.

(Part 2 to appear in the following issue of JSE.)

Acknowledgments

The list of colleagues and supporters is far too extensive to delineate in full, but specific mention must be made, for a broad range of reasons, of a number of persons. For suggestions and information referring to the subject studied here, as well as for a critical examination and correction of essential parts of the manuscript, I thank **A.** Apostol (New York), Prof. Dr. H. Berckhemer (Institute of Geophysics at the University of Frankfurt), Dr. A. Berktold (Institute of Geophysics at the University of Munich), Prof. Dr. E. Bockh (BGR Hannover), Dr. Eisenburger (BGR Hannover), Prof. Dr. H. Gebrande (Institute of Geophysics at the University of Munich), Prof. Dr. A. Hahn (Niedersachsisches Landesamt fur Bodenforschung), R. Koschel (GTZ), P. Krause (GTZ), P. Menche (GTZ), R. Rammner, Dr. U. Schreiber (Geological Institute of the University of Bonn), and Dr. W. Stengel-Rutkowski (Hessisches Landesamt fur Bodenforschung). I am particularly indebted to Tom Williamson (Preston, England) for enlightening discussions and his support to edit the English translation. A generous grant by the Schweisfurth-Stiftung, which contributed to produce the present edition, is highly appreciated.

References

[1] E. Schleberger. *Wasser fur Alle.* Schriftenreihe der Deutschen Gesellschaft fiir Technische Zusammenarbeit (GTZ), Eschborn, No. 183 (1986); ISBN 3-88085-287-1.

[2] H. L. Konig und H. D. Betz. *Der Wunschelruten-Report.* Wissenschaftlicher Untersuchungsbericht, Herold Druck & Verlag, München (1989); ISBN 3-923819-05-6.

[3] H. D. Betz. *Geheimnis Wunschelrute — Aberglaube und Wahrheit Über Rutenganger und Erdstrahlen.* Umschau Verlag Frankfurt (1990); ISBN 3-524-69086-6.

[4] R. Buchholz. *Trinkwasserversorgung und Sanitärmaßnahmen im Bezirk Vavuniya/Mullaitivu Sri Lanka.* GTZ-Projektbericht (1983).

[6] M. W. Wijesinghe. *Hydrogeological Study of Aquifer Systems in Mullaitivu District.* Cooperation project National Water Supply and Drainage Board (Sri Lanka) and GTZ (1984); see also the associated reports on well data.

[6] M. W. Wijesinghe. *Hydrogeology and Development of Waterfrom Fractured Aquifers in Vavuniya District.* Cooperation project National Water Supply and Drainage Board (Sri Lanka) and GTZ (1985); see also the associated reports on well data.

[7] M. W. Wijesinghe. *Location and Development of a Well System in Hard Rocks for Water Supplies to Vavuniya Town.* Cooperation project National Water Supply and Drainage Board (Sri Lanka) and GTZ (1985); see also the associated reports on well data.

[8] S. Sothirajah. *Water Supply Project in Vavuniya District.* Final Report, Project P603, Redd Barna (1986).

[9] B. K. Singh and H. A. Jayasena. *Ground Water Exploration.* Cooperation project between the World Bank and the National Water Supply and Drainage Board Sri Lanka (1984).

[10] N. N. (Hydroplan Ingenieur-Gesellschaft mbH Herdecke). *Expertise on Water Supply Projects in Sri Lanka.* Cooperation project National Water Supply and Drainage Board (Sri Lanka) and GTZ (1978).

[11] E. Bockh, C. Grissemann, M. Siebenhiiner, A. Kolodziey. *Pilotprojekt Hydrogeologische Untersuchungen fur Landliche Wasserversorgung — Beitrag zu den Methoden der Grundwasser-Prospektion im Kristallinen Grundgebirge Westafrikas (Untersuchungen in Burkina Faso).* Cooperation project between the Bundesanstalt fiir Geowissenschaften und Rohstoffe and the Comité Interafricaine d'Etudes Hydrauliques (1989).

[12] F. P. de Torres. *Water Resources Study Verde Island.* Special Report of the Project-Administration, Batangas City (1987).

[13] Y. Gilboa. *Informe Preliminer de la Hidrogeologia del Valle de Azua, Republica Dominicans.* Report of the Dominican Institute for Agricultural Sciences (1965); see also associated hydrogeological special reports and GTZ project reports, issued by P. Luhmann and H. Koschel (1988).

[14] N. N. (Dorsch Consult). *Al Wasitah Water Supply Project.* Project report (1988).

[15] N. N. (Dorsch Consult). *Final Design Al Wasitah Water Supply Project.* Final Project Report (1990).

[16] E. Bockh, R. Reichelt. *Wassererschließung auf Fogo/Kap Verde (Integrierte Entwicklungsmanahmen).* Bundesanstalt fiir Geowissenschaften und Rohstoffe, Hannover (1980).

[17] N. N. *Kap Verde. Wasserversorgung Fogo.* Project Control Report of the Kreditanstalt fiir Wiederaufbau (KFW, 1985)

[18] N. N. (Geotechnik Dr. Kunert). *Erweiterung der Wasserversorgung der Insel Fogo/Republik Kap Verde.* Expert report on hydrogeological conditions and drilling program (Cooperation with the KFW, 1987).

[19] R. Rammner und B. Wenzel. *Bericht uber eine Geowissenschaftliche Untersuchung fur CO_2 Erschließung bei Burgsinn.* Institute for Geo-science, Angelburg (1988).

[20] H. Gebrande. *Bericht Über Bodenunruhe-Messungen bei Burgsinn.* Institute for Geophysics, University of Munich (1989).

[21] L. Engh. *Detektering av Underjordiska Vattendrag — Test av Tre Geofysiska Metoder (Slingram, VLF, Georadar) Samt Biofysisk Metod (Slagruta).* Lunds Universitets Naturgeografiska Institution, Raporter Nr. 55, ISSN 0438-3339 (1983). See also the German translation (46 p., 21 fig.; available from the author): Nachweis Unterirdischer Wasserleiter —Vergleichende Untersuchungen mit Drei Geophysikalischen Techniken (Slingram, VLF, Bodenradar) und der Rutenganger-Methodik.

[22] M. E. Ghazawi and A. Hildenbrand. *Interim Report on the Drilling Results of the Shallow Water Investigation in Selected Areas in North-Sinai.* Desert Research Center and Research Institute for Water Resources, Cairo (1991192); private communication by Dr. M. E. Ghazawi.

[23] J. H. Nieuwoudt und J. Nawrowski. *Memorandum on Field Investigation at Kamanjab, Namutoni and Kalkfeld.* Department of Water Affairs (DWA), Geohydrology Division, Windhoek, Namibia (May 1992).

[24] N. N. *Memorandum on Field Investigations for GTZ.* Geohydrology Division, Windhoek, Namibia (August 1992).

[25] N. N. *Further Results on Field Investigations by Using the Combined Method of Dowsing and Geophysics.* DWA, Geohydrology Division, Windhoek, Namibia (Marz 1993).