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GERMAN EXPERIENCES IN DESERT WARFARE DURING WORLD WAR II

-Supplement-

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HISTORICAL DIVISION
HEADQUARTERS UNITED STATES ARMY, EUROPE
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MS # P-129

GERMAN EXPERIENCES IN DESERT WARFARE DURING WORLD WAR II

- Supplement -

by

Fritz Hermann Bayerlein, Generalleutnant a.D.
Dr. Siegismund Kienow

WITH A FOREWORD BY GENERALOBERST A.D. FRANZ HALDER

Topic Leader: Alfred Toppe,
Generalmajor a.D.
Translator : H. Heitman
Editor : H. Heitman
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Historical Division
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UNITED STATES ARMY, EUROPE
1953

Alfred TOPPE
Generalmajor
Date of Birth: 28 June 1904
Place of Birth: Zernin,
Northern Germany

Alfred TOPPE joined the Army in 1923, entering the 14th Cavalry Regiment at Ludwigslust. After training in both Infantry and Cavalry Officer Candidate Schools from 1924-26, he received his commission as second lieutenant in December of the latter year and was assigned to the 1st Cavalry Regiment, being promoted to first lieutenant in 1929. In 1934 he was detached for a two-year term at the Berlin War Academy, where he was promoted captain (Cavalry) in 1935. From 1936-39 TOPPE served as Quartermaster Training Officer of the XI Infantry Corps and then, after participating in General Staff training courses in 1940, was promoted major and assigned to the Paris Headquarters of the Quartermaster General for France as First Assistant to the Chief Supply Officer. In 1942 he was promoted lieutenant colonel and assigned as Chief, Army Supply Department, Army High Command, where he was promoted colonel in 1943.

Following service as Chief of Staff, X Infantry Corps in Northern Russia from early 1944, TOPPE was transferred back to Army High Command as Army Quartermaster General in June of the same year, in which he remained until the war ended, and where he was promoted Generalmajor in October 1944.

Fritz Hermann BAYERLEIN
Generalleutnant
Date of Birth: 14 January 1899
Place of Birth: Wurzburg

After very brief service in the German Army late in World War I, BAYERLEIN was in civilian employment for two years, returning to the post-war army as an officer candidate in 1921. He was commissioned a year later and served for ten years in various infantry units. In 1932-35 he studied at the War College in Berlin, and thereafter was a General Staff officer and had principally staff duties. He was a staff officer of an armored division in the Polish Campaign and became a lieutenant colonel at that time. During the French Campaign and the first year of combat in Russia, he was on the staff of XIX Panzer Corps, and in 1941-43 Chief of Staff of the German Africa Corps. During this assignment he was promoted to colonel. Late in 1943 he was promoted to Generalmajor and appointed commander of the 3d Panzer Division on the Russian front. A year later he was again promoted to Generalleutnant and given command of the Panzer Lehr Division, a demonstration unit that saw a great deal of active service in France and Western Germany. Early in 1945, he became commander of the LIII Corps. BAYERLEIN was finally captured in the Ruhr Pocket in April 1945.

Siegismund KIENOW, Ph.D.
Date of Birth: 29 June 1907
Place of Birth: Potsdam.

Dr. KIENOW studied chemistry at the technical college in Breslau in 1925-26 and geology at the University of Breslau in 1926, the University of Koenigsberg in 1926-27, the University of Bonn in 1927-30 and the University of Goettingen in 1930-34. From July, 1934 to June, 1942 he was employed as an assistant in the University of Muenster. In July, 1939 he was drafted for military service and remained in the army until the end of the war, finally reaching the rank of second lieutenant of the reserve.

While serving in the army, Dr. KIENOW continued his academic work and lectured at the University of Muenster and at the University of Strassburg. During World War II, he served as chief of the geological detachment assigned to the German military forces in Africa, where he gained considerable experience in desert problems, particularly those connected with water supplies. In addition, he served in assignments in Norway and in France. In April 1943, he was awarded the title of Regierungsbaurat, a high title in the building and engineering profession. On 7 May 1945, he was captured at Kresmanes, Northern Norway.

In addition to his military service and his activities as a lecturer in Universities, Dr. KIENOW has had considerable success as a writer on geological subjects. Quite a number of his studies have been published in scientific journals of high repute.

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FOREWORD

by

Generaloberst a. D. Franz Halder

The scope of German experience in desert warfare is restricted to that gained in the campaign against the British in the eastern parts of Northern Africa. The point at which all information on this type of experience was gathered was Field Marshal Rommel's staff. Following the demise of Field Marshal Rommel, Generalleutnant a. D. Fritz Bayerlein, who has maintained contact with the former members of the staff and has access to all military material found in Field Marshal Rommel's estate, has become an important expounder of detailed experience on the subject. For this reason, he was the person from whom expert replies had to be obtained to the supplementary questions asked.

In order to round out the replies, it was necessary, in some parts, to revert to ideas expressed in the original study of the subject, MS # P-129. In spite of certain weaknesses due to the repetitions thus involved and to the broad treatment of the problems discussed in the present manuscript, I nevertheless regard General Bayerlein's work as the best reply that could have been furnished to the questions asked within the time allowed.

If the treatment of the problems raised cannot be considered exhaustive in some parts, this is due to the limitations imposed by time, space and available means on German experience in Northern Africa. In this respect I refer the reader to the remarks in my foreword to the main study, MS # P-129.

I agree fully with the thoughts expressed by the topic leader, Generalmajor a. D. Alfred Toppe, in his introduction to the present study.

GERMAN EXPERIENCE IN DESERT WARFARE
IN WORLD WAR II

CHAPTER 1

INTRODUCTION

by

Generalmajor a.D. Alfred Toppe

The additional questions asked by the Research and Development Board in connection with MS # P-129 are answered in the present manuscript by Generalleutnant a. D. Fritz Bayerlein, who was chief of staff to Field Marshal Rommel during the campaign in Africa. In replying to the more important questions, those relating to the problem of water supplies in the desert, General Bayerlein has made use of two studies by Regierungsbaurat * Dr. Sigismund Kienow, a geologist of high repute who served with the German Africa Corps as military geologist from 1941 to 1943. These two studies are included in this manuscript as Chapter 3.

In order to stress the importance of the several problems treated and maintain coherence within this present work, it has been necessary to repeat some of the information given in MS # P-129, the original study on German experience in desert warfare.

If it is found that certain subjects are not treated exhaustively in the sense of the questions asked, this is due either to the fact that no adequate experience is available in the field in question or to the

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* A title in the engineering profession.

fact that the fighting in Africa took place in areas in which the features of a true desert were not present.

In any theater of operations, success hinges upon the troops being furnished an adequate supply of all means of combat. However, the proper flow of these supplies is influenced decisively by geographical and climatic conditions.

The problem involved in the present study is not so much what influence the supply services at strategic level, that is, the movement of supplies across the Mediterranean Sea, had on the course of operations. The problem to be examined has to do rather with an examination of the methods employed in supplying the troops, whether the flow of supplies had any restrictive effects on operations and, if so, what those effects were, and whether any improvements can be suggested. So far as combat operations are concerned, the replies given by the author are satisfactory.

Assuming that adequate supplies can be moved currently to one or more strategic supply bases, the movement of supplies of combat materiel to the troops is exclusively a matter of organization, the availability of means of transportation and the possibility to carry out transportation. In ground transportation it must be borne in mind that it is far easier to surmount difficulties by a flexible adaptation to existing circumstances than by endeavoring to force nature. Transportation by air makes practically unlimited flexibility possible.

In modern desert warfare it will always be necessary, once the course of a battle takes a favorable turn, to establish advance supply depots in areas not yet reached by the units in combat so that the enemy can be completely defeated in pursuit. These advance bases will have to be established and protected by airborne troops, who might first have to seize the terrain in combat.

The more important items to be moved forward to the troops in action are fuel, food and water, spare parts for armored vehicles.

The place of the responsible supply officer is on the field of battle. There, he will be able, by means of radio communication or liaison planes, to transmit the appropriate orders and instructions without delay. If kept currently informed on the situation, a properly trained supply staff must be able to function smoothly and reliably even if it receives only brief radio instructions.

All available means of transportation on the ground, in the air and on the sea definitely must be controlled by one central agency. A concentration of effort is just as important in the supply service as it is in combat operations.

Transport planes must be constructed for landing in the desert since time, labor and materials usually are not available for the construction of air strips or permanent air fields when advance bases have to be established or supplies moved forward to advancing troops. This is particularly the case during critical situations, when enveloped troops have to be supplied, or when enemy troops have been pocketed.

Until heavier types of planes with a bigger carrying capacity are so constructed that they can land safely under desert conditions it will be necessary to favor lighter types with a lesser carrying capacity. The further development of tracklaying landing gear might do much to improve the situation in this respect. The supply of combat materiel to advance detachments, encircled smaller units or to patrols employed on missions of several days duration by air drop is an important factor.

Whether the development of special types of vehicles for ground transportation is necessary or practicable is a moot point. Usually, specializations in the transportation services harbor dangers; what might be excellent in one theater of operations might be useless in another. If paved or unpaved firm roads are available, wheeled vehicles will be given preference, for economical reasons if for no other. However, if roads have to be constructed, the very necessity to do so may decide the pace of operations. This fact the commander of a theater of operations can and must accept as a constant. He must fight his battle and endeavor to defeat the enemy when the situation seems most favorable for this purpose. The supply service and everything connected therewith must be adapted to this requirement.

A force which has transportation vehicles capable of moving at the same pace as its combat vehicles can operate independently, as far as supplies are concerned. Here, a high rate of speed is not as important as a steady speed and all-terrain mobility.

It is hardly likely that the assignment of a road construction unit to each division, as suggested by General Bayerlein, will prove practicable. Under desert conditions, a division might move hundreds of kilometers in a direction entirely different from that in which its road construction unit has prepared a road. It would appear more advisable to concentrate all road construction units in a pool and employ them in constructing a really good supply route in the main direction of thrust of the army.

If the operations follow the general direction of a coast, coastal ships with a small draft will play an important role in the transportation services. They are less vulnerable to attack by submarines than large ships and their vulnerability to air attack is relatively negligible. They will prove particularly valuable if they are so constructed and equipped that they can discharge their cargoes on open coasts, thus making the establishment of intermediate bases possible. They can also render excellent service in moving supply bases farther forward.

Water supply columns should not differ visibly from fuel supply columns. The standardization of vehicle types facilitates the functioning of the supply services. It is recommended that water and fuel vehicles should be interspersed in columns to lessen fire hazards.

The author's remark on page 48 that water decontamination tablets were not available in the Wehrmacht is not correct. If these tablets were not used by the combat units during the campaign in Africa their use was apparently unnecessary because the army water decontaminating equipment met all requirements.

CHAPTER 2

REPLIES TO QUESTIONS ON GERMAN EXPERIENCE IN DESERT WARFARE

by

Generalleutnant a. D. Fritz Bayerlein

I. WATER REQUIREMENTS UNDER DESERT CONDITIONS COMPARED TO REQUIREMENTS UNDER NORMAL CONDITIONS IN TEMPERATE ZONES

In the German Africa Corps, experience showed that the quantities of water required by the combat troops under desert conditions were not greater than the minimum quantities stipulated by regulations in temperate zones. This may sound unlikely but it is borne out by experience gained in the 1941-43 period. Under civilian conditions, a person will use far more water than he actually needs and is extremely reluctant to forego his usual habits, for instance, his hygienic practices, particularly if he knows that an abundant supply of water is available. Furthermore, the very sight of water or of other potable liquids induces a feeling of thirst. In contrast, a soldier arriving in a desert immediately adapts himself psychologically to the expected lack of water and with surprising speed accustoms himself to managing with the minimum quantity consistent with health.

Explorers place the minimum requirement at two liters per day and person. However, this applies only to trained athletes with extremely high performances and very moderate requirements and should not be applied to the average man.

In the German army, the minimum daily water ration was four liters, of which amount two liters were used for cooking and two for drinking purposes. No allowance was made for washing. However, the water supply situation was never so critical that the troops had to be restricted to this minimum ration for any length of time. If such a situation arose, the troops perforce had to forego hygienic habits and use only one-quarter or one-half of a liter of water for such purposes. One case in which this necessity arose was during the German retreat from the Tobruk area to the Gulf of Sirte in December 1941.

Regardless of temperatures or seasons, the normal daily consumption of water was six to seven liters. Since this ration was already very low, it was not reduced during the winter months. On the other hand, owing to the shortage of transportation vehicles and motor fuel, it was also not possible to increase the ration in exceptionally hot weather, even if adequate supplies of water were available.

In the British army the normal ration was one gallon (4.54 liters) in regions where water was very scarce and 1.5 gallons per man for troops and other men employed at heavy labor in the vicinity of major water supply points. Details on this subject will be found in Chapter 3, in the copy of a report prepared by the Military Geological Detachment of the German Africa Corps on the water supply organization in the British army.

II. TECHNIQUES EMPLOYED TO FIND WATER

Only geological methods were employed in the search for supplies of water. For this purpose the geological unit assigned to the German Africa Corps based its work on the following considerations:

Two subsoil water levels exist in the eastern part of the Sahara Desert, a deep-water level in the limestone or sandstone strata of the tertiary or chalk formation and a near-surface water level in the loose deposits of wadis*, depressions, loose rock hills and dune areas.

The origin of the deep-water level of Lybia and the so-called western desert of western Egypt is in the regions of high rainfall of the Sudan. The water flows northward through the Nubian sandstone strata and the tertiary chalk and marl formations, as can be seen from the geological profile prepared by the 12th Military Geological Detachment, assigned to the German Africa Corps, in October 1942 (sketch 1, page 9). In valleys and other depressions this water level rises almost to the surface and causes the formation of salt marshes and oases. Under elevated terrain, however, it is very far below the surface and can only be tapped by means of deep well drilling. (Photo 1, page 10). The northern limits of this water level are to be found in the belt of oases along the 29th parallel, part of which region is below sea level. The belt includes the Siwa, Giarabub, Gialo, Augila and Marada oases with their strong artesian springs (photo 2, page 10).

The Cyrenaica, with its high rainfall, is a typical barren rock

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* Dry river beds in Northern Africa.

Anlage 2

Sketch 1

Geological Profile

GEOLOGISCHES PROFIL

Matruk - Halfa

Longitudinal Scale 1:2 000 000

(Heights multiplied by 100)

Prepared by 12 Mil.Geol.Det.Panzer Army of Africa, October 1942

Abb. B V 27 **Bir Misaha, auch Mesaha** (22° 12' N, 27° 57' O), **liegt an der Piste** Djebel Uwenat - Wadi Halfa **mitten auf einer Serirfläche, die zum Landen gut** geeignet ist. Als Sichtmarken der **Brunnenstelle** sind ein **kleines Holzhäuschen und ein Holzgerüst** mit Seilwinde zu nennen. Der 67 m tiefe Brunnen (gutes Süßwasser) liegt unter dem Holzgerüst und ist von einem schweren blechbeschlagenen Holzdeckel geschlossen. Ein Seil fehlt am Brunnen und muß mitgeführt werden.

Subsoil Water Obtained by Means of Deep-Well Drilling at Bir Misaha

Artesian Spring in the Marada Oasis

region. The subsurface water is confined to crevices and finds its way to the surface in strong springs (sketch 8, page 70, Water Supply Map, Cyrenaica, 1942).

Circumstances are different in Tripoli, where the high Nefusa mountain stops and condenses the moisture carried by the wind from the Mediterranean Sea. The water thus condensed seeps down to lower levels and collects in impervious strata, so that an adequate supply of water can be found in the deep water level of the Djefara, the coastal plain of Tripoli. In certain parts, the water supply is tapped by artesian wells. This water level extends eastward to the region of Misurata, where strong artesian wells were drilled and made the settlement of the region possible (photo 3, page 12).

As far as the availability of water supplies for the Italo-German forces were concerned the situation therefore was as follows:

1. In Tripoli, the deep water level was tapped by so many civilian boreholes that no new drilling was necessary during the brief period of action there (sketch 9, page 71; Water Supply Map, Interior of Tripoli).

2. In Cyrenaica, sufficient strong springs were available to insure an adequate supply of water for large bodies of troops. Deep well drilling, in contrast, is extremely risky in this region, for which reason no new wells were sunk.

3. In the Gulf of Sirte (El Agheila-Marsa El Brega) and in the Marmarica regions as well as in western Egypt north of the Quattara Depression, deep well drilling held out small prospects of success. Therefore no drilling was done in these areas, and work was restricted

Artesischer Brunnen in der neuen landwirtschaftlichen Siedlung „Crispi“ in Libyen

Artesian well in the Crispi Settlement, Misurata to an exploration and improvement of existing springs along the coast to obtain water for locally assigned troops.

4. If operations had extended to the region of southern Libya and the southern reaches of the western desert, the deep water level there would have become of decisive importance. In this case the available deep well drilling equipment would have been employed. The probable depth at which water could be found would have been determined on the basis of Ball's Map of the Static Subsurface Water Level and local geological surveys (Sketch 3, Ball's Map of the Static Subsurface Water Level in the Eastern Libyan Desert, 1927).

The above-surface and near-surface water levels were far more important factors. Immediately after rain commenced, measures should have been taken to catch and conserve the water and to follow it up through all stages of its downward flow in order to store as much of it as possible.

In foggy coastal areas it is possible to obtain water from the air by means of corrugated iron plates, gravel pits and so forth. The quantities are extremely small but often quite useful. House and tent roofs should be constructed to catch rain water.

Troops who are to fight in deserts need appropriate training and instruction in this subject. Every man must realize that every quart of water that he can obtain for himself relieves the burden on the supply services. His resourcefulness must be developed and he must be taught to help himself and not to depend on others. This type of training would have saved us many difficulties on the El Alamein front, but, unfortunately, it was neglected in the German desert army.

Similarly to roofs, flat rock surfaces can be employed to catch water and the water thus obtained can be stored in cisterns. Natural models for the type of installation suggested here can be found in many arid regions; a few examples are the rock bank waterholes of Southwest Africa, the Ugurungas of East Africa, the Gnamma holes of Australia, the rock tanks of Arizona and the Galts of Egypt, all of which are the result of the chemical disintegration of rock, the effects of which are particularly concentrated in small hollows because of the water collecting there. The hollows are enlarged by the action of water during the rain seasons and by the action of the wind during dry seasons, and, if the circumstances are favorable -- in the shade, for instance -- can contain an appreciable amount of water well into the dry season. They can be enlarged, provided with mud catching devices and protected against animals, and can prove useful in the establishment of strong points in the desert or as water supply points for patrols, small detachments and so forth.

Large cisterns were constructed in ancient times by the Romans (photos 4-7, pages 15-16). However, most of these old cisterns are no longer of any use today, in some cases because their catchment areas have been destroyed in the course of time owing to the natural disintegration of rock. Modern large cistern installations were constructed by the Italians in Libya long before the campaign in northern Africa began (photos 8-10, page 17 and 30-31, pages 48a, 48b).

One important mission of the agency responsible for the supply of water is to ascertain the site of all cisterns existing within the zone

Roman Cisterns in the Zem Zem Wadi

Abb. G 22 Wadi Hammamat auf halbem Wege zwischen dem Nil und Kosser. Auf dem ebenen, breiten Wadiboden, über den heute eine befestigte Straße führt, eine Brunnenanlage mit altem Römerbrunnen links.

Roman Cisterns in the Hamamat Wadi

Cistern Ruins at Ain el Gazala

Bir el Kenayis in the Western Egyptian Desert
Ancient Cistern on the Matruh - Siwa Road

South Cyrenaica
Large Modern Cistern in
Shallow Valley

Bir el Harmat
Cisterns on the
Acroma - Bir Hacheim
trail, showing
catchment walls and
water furrows

Bir Zebeda Cistern,
near Gheddahia,
showing Well

of operations and in the communications zone, to examine them in order to determine their usefulness and, if necessary and practicable, to take steps to repair or improve them.

The surface water rapidly finds its way into sand-filled dry river beds called wadis, and from there to pans called deirs or shigfeds and rain lakes called sebkhas, vleys and so forth. Here, it evaporates or becomes brackish. Rain lakes of this type can prove extremely useful in the supply of water for larger bodies of troops for temporary periods.

Some of the water will sink to lower levels through the loose deposits in the lake bottoms. The coarser the deposits are, the greater the amount of water which will sink in this way, but very little of it finds its way to the permanent subterranean water which forms a uniform subsoil water level. The balance of it is retained nearer the surface by capillary action and forms what is called ground moisture, which is gradually drawn upward again into the evaporation areas.

Generally speaking, ground moisture cannot be recovered, although methods are known by which, under certain circumstances, small quantities of water can be recovered which might suffice for patrols or advanced outposts. The indigenous population are masters at recovering water from the ground moisture. They will dig a hole nine to twelve feet deep in the evening and wait a few hours until water has collected in the bottom (photos 11-13, pages 19, 19a). The next caravan to arrive will dig a similar hole a few yards away for the same purpose. These water sites can always be recognized by the large number of holes that have been dug in the bed of a wadi. An inexperienced person is liable to think that they are a

Abb. B II 3 **An der Wasserstelle von Maghara** (30° 14' N, 28° 53' O), am Südende des Salzsees von Maghara, der ungefähr das Ostende der unter dem Meeresspiegel liegenden Kattara-Senke kennzeichnet (vgl. Übersichtskarte). Es ist nur wenig Pflanzenwuchs in der Umgebung vorhanden, das Wasser muß erst aufgegraben werden.

Natives Digging a Well Near Maghara

Bir Kassaba
Water Site,
South Libya

Abb. B V 29 **Bir Kassaba** 22° 11' N, 29° 55' O) liegt an der Darb el Arbain (Weg der 40 Tage), 45 km N der Piste Bir Misaha- -Wadi Halfa. Es befindet sich hier in einer von Steilstufen im W und N umgebenen Senke eine verhältnismäßig dichte Vegetation mit Palmen, die auf Grundwasser schließen lassen. Die zwei Männer im Vordergrund suchen eine geeignete Stelle zum Aufgraben.

Digging Well
to Recover
Ground Moisture
at Bir Kassaba

Abb. B V 30 **Bir Kassaba.** Mit den Händen ist der lose Sand aufgegraben worden und in ½ m Tiefe sammelt sich bereits Süßwasser. Längs der Darb el Arbain finden sich mehrere derartige Brunnenstellen (vgl. Karte 1:500000).

sign of permanent subsoil water and is disappointed when, upon digging a hole, he finds no water in it. It is necessary for him to know that his labor will only be rewarded if he digs after sunset and that he must wait until the water raised by capillary action finds its way into the hole he has dug.

At times, small mounds form over moist ground, the sand firming down because of the moisture so that it is not blown away by the wind. Areas with a heavy growth of vegetation are also often an indication of plentiful ground moisture (photo 12, page 19a)so that the presence of vegetation can not always be taken as a sign of subsoil water.

True subsoil water is rarely found in the loose deposits of the real desert. It is only where such deposits are thick or where they cover the entire floor of a valley for a long distance and are protected against evaporation that they occasionally carry water in isolated arteries in certain rubble and gravel strata, the course of which does not always follow the general direction of the valley. The point of confluence of two dry river beds is usually a favorable spot for drilling. If the bed of a dry river is impermeable for some distance, a close inspection might reveal sand or gravel filled potholes which might contain water for a long time after rain. If the river bed contains coarse gravel, an effort should be made to find the deepest points of the rock bottom.

The chances of finding water are better in broad, open valleys than in narrow steep gorges, but it would be wrong to dig or drill at spots where the flow of the water has been so slight that it has deposited only a fine sedimentary substance.

Water is often found on the upstream side of rock banks in dry river beds; on the downstream side of such banks there is also a possibility that water may have collected in small quantities in the sand-filled pot-holes formed by the water spilling over the banks. Where a river bed bends sharply, it is always best to concentrate first on the outer bank at the bend, where deep holes may sometimes be found that have been formed by the swirling action of the water.

The closer one gets to the coast, the more subsoil water will be found in dry valleys. Within any sector of the coast extending over several kilometers, water can be found with certainty in the sand or in dune areas, often in sufficient quantities to supply fairly large bodies of troops. However, the quality of the water is variable.

In the vicinity of the coast even the rainwater contains salt in varying degrees, although the chlorine content of 1420 milligrams found by Kaiser in Southwest Africa in 1919 will rarely be found. At Luederitzbucht, Southwest Africa, Kaiser found 244 milligrams of chlorine per liter of water obtained from the heavy fog and this content is likely to be closer to the average chlorine content of water thus obtained. In the ground, the water becomes more salty, since a great part of the rainwater soaking into the ground subsequently rises again to the surface and evaporates, leaving behind the salt it contained. The result is that the ground and the subsoil water become more and more salty with the passage of time.

Where the subsoil water appears above the surface, evaporation leads to such a strong concentration of salts in the residue of water that salt marshes develop. Relatively close to these salt marshes, water may often be found underground with a far lower salt content since less evaporation takes place. This may surprise the uninitiated but it serves to prove that, in subsoil water, the high salt content of one body of water percolates only slowly to water of a lower salt content. Experience shows, in fact, that the salt content varies both horizontally and vertically.

In the vicinity of the coast, potable water will often be found in thin layers or in small patches floating on top of the salty subsoil water, where it has collected during the last rain without as yet having absorbed salt from the water below it (sketch 2, page 23; Section II, Chapter 3, Operations of the 12th Military Geological Detachment at Sollum). Section II of Chapter 3 contains a report on the finding of a potable water patch of this type in a wadi at Sollum. This report may be taken as a model for the methods to be employed in similar circumstances. Usually, the potable water in such patches is rapidly exhausted and if pumped out too rapidly, salty water will flow into the well. Nevertheless, the supplies obtained thus proved highly valuable and helped to relieve the strain on the supply services.

On the whole, the demands made in respect to the quality of potable water in desert areas should not be as high as in more temperate climates. In the Marmarica region the troops at no time received water with a chlorine content lower than 1 gram per liter, which is usually sufficient to give the water an unpleasant taste. Owing to the large amounts of water used, the salt content of the water obtained from wells increased on the average to 1.2 grams per liter in the late autumn of 1941.

Both humans and animals can adapt themselves to water with a relatively high salt content, and water that cannot be used for drinking purposes often is suitable for baking or for preparing soups and even when it is very brackish it still can be used for making cocoa.

Owing to the sparsity of vegetation and population, water in arid areas rarely contains impurities of an organic nature unless the ground in the vicinity is polluted, against which very strict precautions must be taken. Very severe penalties must be imposed on the pollution of the ground in all areas where wells are situated.

If water tastes and smells dank, the quality can be improved by stirring in some clean sand. When it is allowed to settle to the bottom, the clean sand will have absorbed some of the impurities. A small quantity of alum may be used to accelerate the precipitation of impurities and a few drops of iodine or permanganate of potash can be added to purify the water and improve its quality.

The table on page 25 shows the types of water supply points likely to be found in desert areas, the sites at which they may be found, and further particulars.

Water Supplies in the Deserts of Libya and Egypt

Type	Nature	Sites	Quality	Quantities	How obtained
1	Rainwater	Chiefly in the coastal region	Good	Variable	The rain water is caught and stored in cisterns
2	Dew water	As above	Good	Small	Gravel pits
3	Rain lakes	Desert proper and coastal region	Good	Sometimes large supplies	By pumping
4	Ground moisture	In wadis in the desert proper	Poor to fair	Very small quantities	Holes are dug as required after sunset
5	Near-surface subsoil water level	In wadis, rubble hills, dunes	Variable	Small in the desert proper, ample near the coast	Wells and trenches
6	Deep subsoil water level	Tripolitania and south of the 29th parallel; oases areas	Usually good, frequently warm and with a sulphur content	Ample	Deep wells, frequently artesian
7	Springs	Cyrenaica, Kefusa Mountain	Good	Ample	Development of the springs
		Marmarica, western desert	Fair	Very small	Development of the springs

The main source of supply for the German troops in the Sirte region and in the western desert of Egypt was found in the near-surface water level in dunes (sketch 3, page 27; sketch 4, page 28). In the Marmarica region in the near-surface water level in wadis, in the Cyrenaica region in springs (map 2, page 81). Rainwater lakes also played a major role, particularly when the front was at El Alamein. The German forces at no time had to depend on the meager water supplies to be found in the desert proper. It is nevertheless imperatively necessary that the responsible water supply officers inform themselves thoroughly on the water conditions in the desert and instruct their troops currently, so that the troops will be able to help themselves in the case of an emergency. A knowledge of the experience related here has saved the life of many a soldier.

The water present in the deep subsurface water level is recovered by means of deep drilling. For civilian purposes most of the water is pumped by means of windmills (photos 14 and 15, pages 29 and 29a) which have proved extremely satisfactory because of the steady winds which prevail, but which necessitate the above surface storage of an adequate supply.

Springs must be properly developed. At times, the flow of water can be increased by clearing mud and other deposits from the opening of the spring and by removing the sinters. Great care must be exercised to avoid changing the established hydrological conditions in spring areas. Blasting is a hazard in spring areas as it might lead to a complete loss of the water supply.

It was found advisable to direct the flow of water from a number of

Sketch 2


Simple Type
Well in Dunes
Sand Dune
Water Trench
Salt Marsh
Fresh Water Level
Salt Water Level
Sand Dune
Coast

MS # P-129
Sketch 3

MATRUH WATER SUPPLY SITUATION (EW/S PLAN No. 37)

Tripoli.
Settlers Cottage
with Windmill

Abb. A IV 10 Matar, Brunnen und Pistenkreuzung rund 60 km OSO von Adjedabia, liegt in einem völlig ebenen, einige Kilometer großen Becken, das allseitig 10 bis 30 m ansteigt, der runde weiße Wasserbehälter und das Windrad sind gut zu sehen, letzteres besonders bei Tiefflug. Am Brunnen liegt ein Hilfslandeplatz, an seinem Lande-T und der Eckbezeichnung kenntlich. Der Boden wird von einer festen Sandtenne gebildet, deren Bewachsung äußerst spärlich ist.

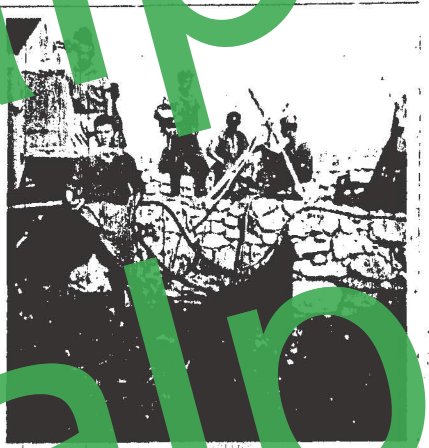
Matar, near Agedabia.. Well with Windmill springs into one central pipeline. Filters must be of a type which can be removed and replaced if necessary, since the water frequently contains lime and iron which are precipitated in the presence of air and might decompose the filters. The diameter of the pipes used should be so wide that the pipes will not be filled to capacity even when the springs are at their highest flow. Illustrations of developed springs will be found in photos 16 and 17, page 21.

Water from the near-surface water level is recovered in pit type wells or trenches. The wells are usually one to three meters in diameter. In most cases the wells have to be lined at least part of the way. The best method is by means of concrete rings, but rings made of corrugated iron and angle iron are also useful for this purpose. If metal is used, it is recommended that the sections be joined telescopically. The use of timber is not recommended, but frequently cannot be avoided. The timber requirements for a well 1.5 meters square are given by appropriate experts as twenty-four 1½" x 1" boards.

If there is any danger that salt water from a lower level might enter the well, it is advisable to seal off the bottom with concrete and to provide holes in the lower sections of well lining which will permit the entry of water from the sides. Another expedient which proved useful was to use a movable intake attached to a float, so that water was always pumped only from just below the surface, where the salt content was lowest.

A serious difficulty which is often encountered is the sand which filters into the well from below and from the sides. This not only

A Built Up Spring at Um er Zem, Cyrenaica



Drawing Water from a Built Up
Spring at Ain Mara, Cyrenaica

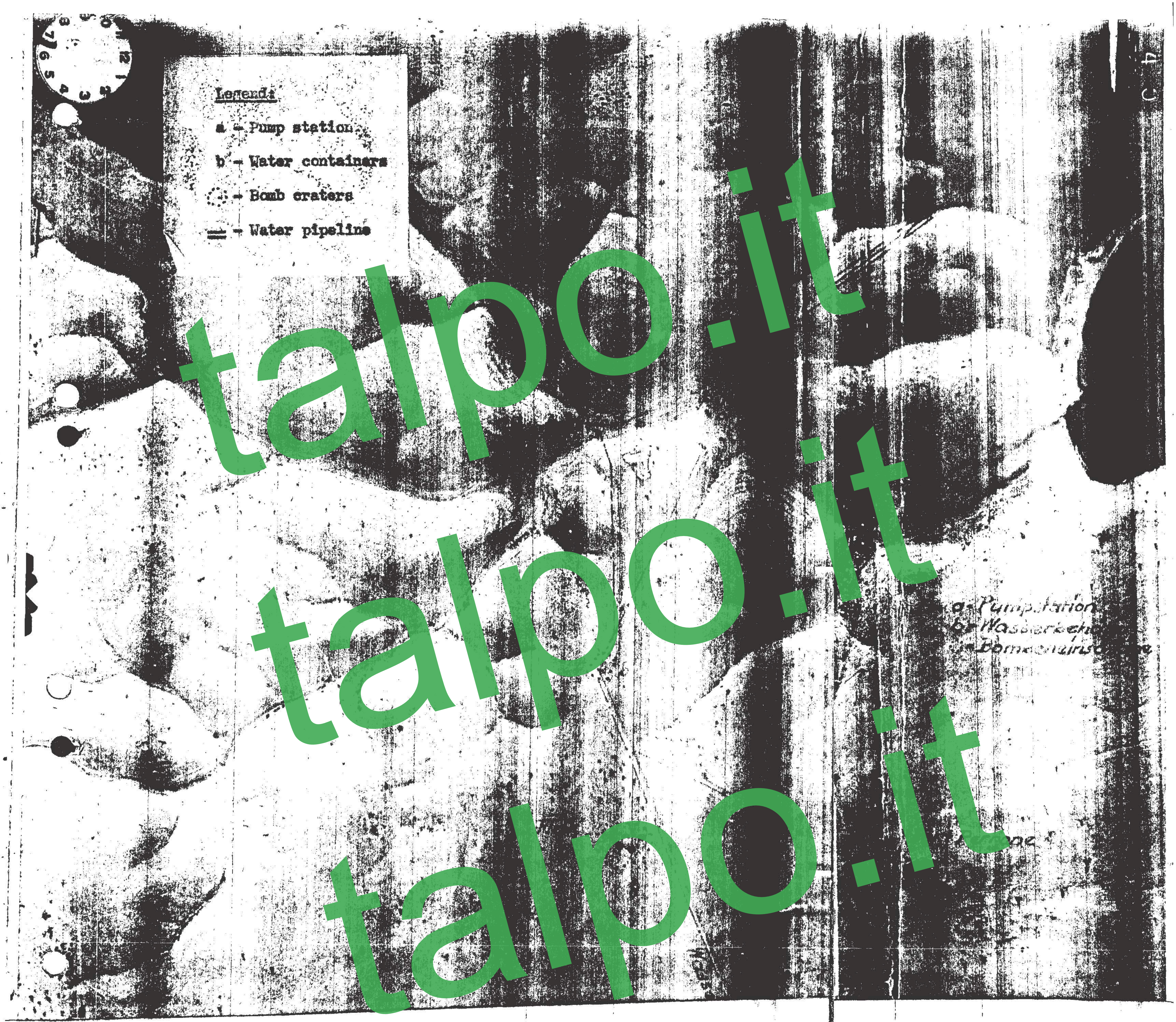
MS # P-12
ANLAGE 1

Sketch 4

WATER SUPPLY MAP

WESTERN DESERT-KEY MAP OF DRINKING WATER SITUATION

W/S. PLAN Nº 29.


Legend:
a - Pump station
b - Water containers
- Bomb craters
- Water pipeline
a- Pumpstation
b- Wasserbehä
c- Bombeneinsch
C 4

EASTERN LIBYAN DESERT

STATIC SUBSOIL WATER LEVEL MAP SHOWING LEVEL TO WHICH WATER WILL RISE IN BOREHOLES, BASED ON J. BALL 1927

Legend

—— Elevations in meters

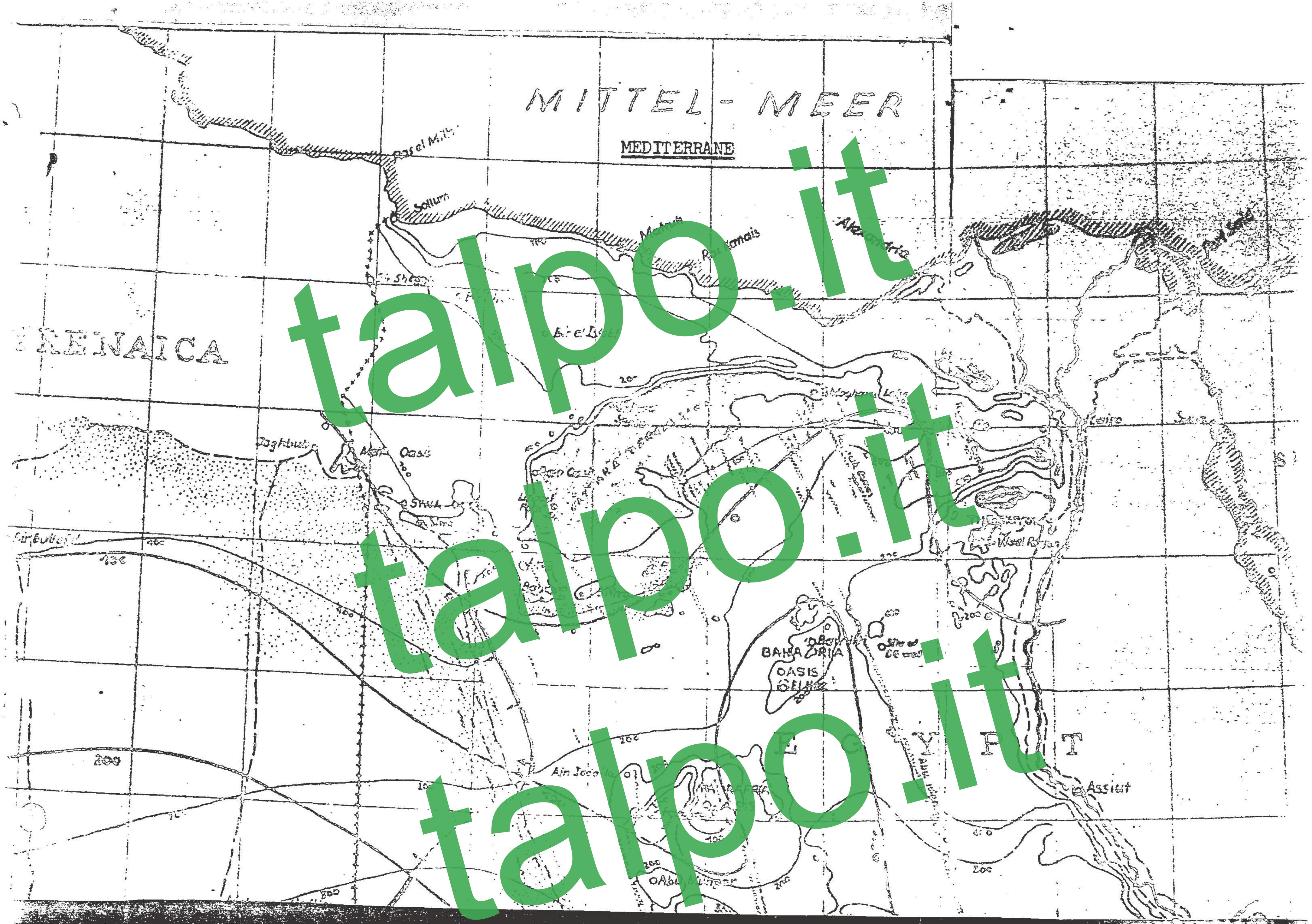
━━ Static subsoil water level

▬ Areas with a static subsoil water level less than 100 meters below top surface

- - - - Caravan routes

⁘ Dune areas

☐ Below sea level


MITTEL-MEER
MEDITERRANE
ras el Milh
Sollum
Matruh
Alexandria
Port Said
ENAICA
Giarabub
Siwa Oasis
Cairo
Suez
BAHARIA
OASIS
EGYPT
Assiut
Ain Dalla
Abu Mingar
200
400

Salt Content of Water in the Hasseyat Wadi

Salzgehalt des Grundwassers
im Wadi Hasseyat.

Sketch 10

Scale: 1:2000
M. = 1:2000

Old Well (in use)
alter Brunnen in Betrieb

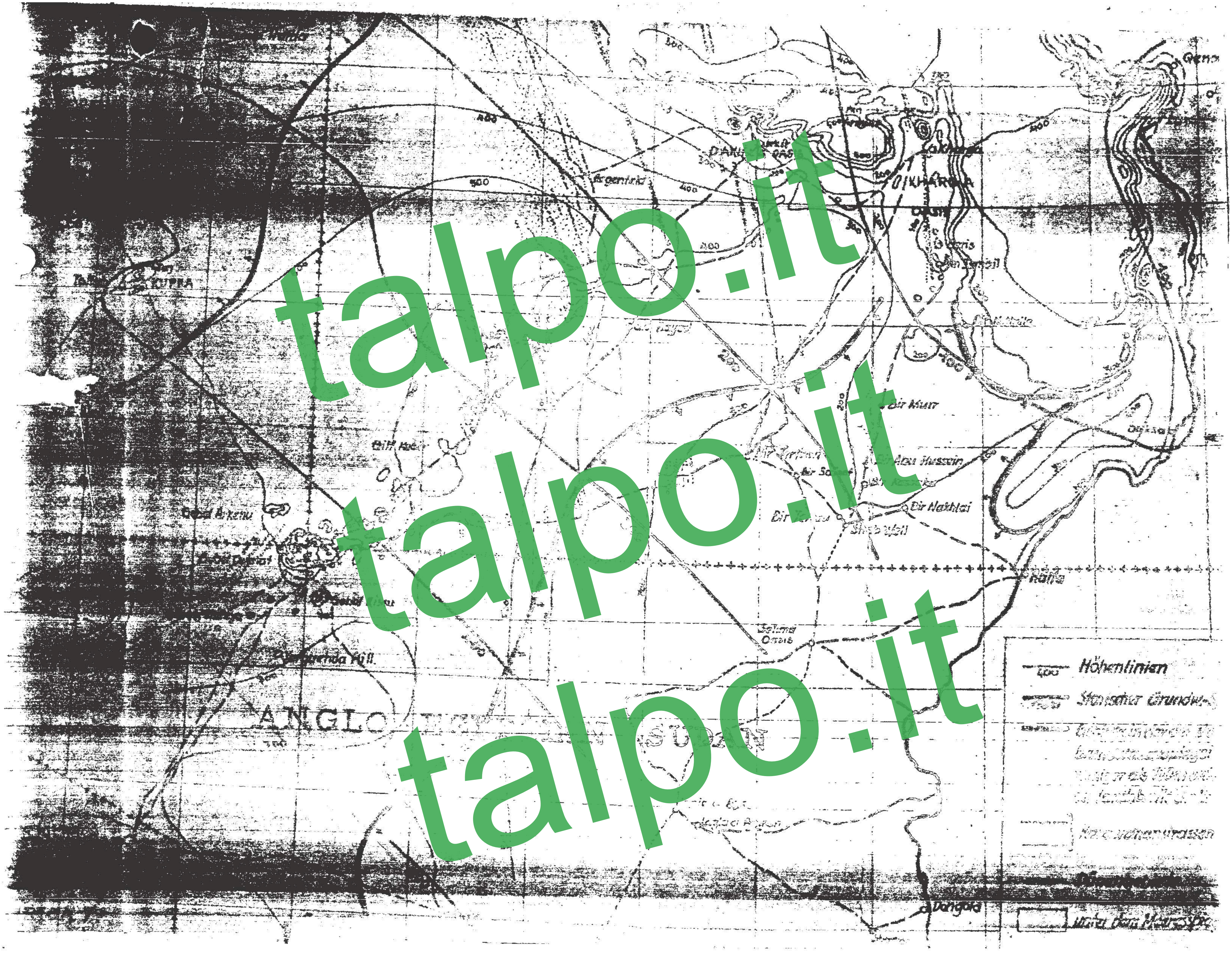
Destroyed Well
zerstörte Brunnen

New Boreholes. Upper Figure: No of Borehole, Lower Figure: Chlorine Content in Milligrams per Liter
neue Bohrlöcher
obere Zahl = Nr. des Bohrloches
untere Zahl = Chlorgehalt in mg/l

Lines of Equivalent Salt Content
Linien gleichen Salzgehaltes

Feigenbäume Fig Trees

Waldrand Bank of Wadi


Gena
400
300
200
DAKHLA OASIS
Argentinid
KHARGA
Kharga
Baris
Kufra
Bir Murr
Bir Abu Hussein
Bir Sahara
Bir Nakhlai
Shab Well
Gebel Arkenu
Gebel Uweinat
Halfa
Selima Oasis
ANGLO
SUDAN
Dongola
Höhenlinien
Staatliche Grundw...
...unter dem Meeresspiegel

Army Engineer Commander
12th Military Geological Detachment

fills up the well but, because of the sand settling down around the sides of the well, might make it difficult to keep the lining straight. In such cases it is helpful to place coarse gravel around the well; this gravel will settle with the sinking sand and finally will prevent any further sand from entering the well. It also proved helpful to place gravel and boulders, the finer gravel at the lower levels, in the bottom of the well before pumping commenced. In the case of wells with a very large diameter, the danger of sand filtering in is somewhat reduced.

If wells are sunk in the beds of dry rivers, everything possible must be done to prevent the influx of above-surface water when the river is in flow. The sides of the well must be walled with concrete. The walls must either be raised well above the level of the river bed or must be flush with the bed and so built that they can be securely covered. The best place for the pumps is on the river bank and the pipes must be buried so that pumping can continue even if the river is in full flow.

The well system at Tobruk is the biggest to be found in a dry river bed in the Marmarica region. It was constructed by the Italians during peace and has two pumping stations which force the water into elevated reservoirs from which it flows into the water mains of the town (photo 18, page 33). During the siege of Tobruk, all attempts of the German air force to destroy these installations failed.

Photo 19, page 34, illustrates a well dug in a wadi near Bardia during the war. Photo 20, page 35, shows a well dug by the Italians at Ain el Gazala, also during the war, and the very serviceable hand pu

Dordia. Water Site in the Cezuma Wadi

Italian Well at Ain el Gazala

Sollum. Well with Abessinier * Field Type Pump

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* Trade name