THE USE OF AIRPHOTO INTERPRETATION AS AN AID TO PROSPECTING FOR ROAD BUILDING MATERIALS IN SOUTH WEST AFRICA

By

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DECLARATION

In submitting this thesis, I hereby declare that:

(a) this work, with the exception of Chapter 1 and the first part of Chapter 2, where texts from the "Manual of Photographic Interpretation" have been drawn on rather heavily, was done by me personally or under my direct supervision

and

(b) this thesis has not been submitted to any other university for any purpose whatsoever.

Signed: ...J. H. Caiger.....
J. H. CAIGER.

Date : 29th September, 1964.

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The Stereograms and Mosaics were reproduced by Aircraft Operating Company (Aerial Surveys) Limited of Johannesburg. The Author is indebted to this firm for this service, which is not normally one of a routine business nature, as well as for valuable advice in regard to the reproduction.

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PREFACE

Two introductory chapters have been used to give the necessary background to the main subject-matter of the thesis. The first of these chronologizes the significant steps in the development of aerial photographic interpretation from the first recorded aerial photograph to the present day respected position of the art in both military and civilian professional circles. The second introductory chapter deals with the fundamental principles involved in airphoto interpretation and of their specific application to soil engineering mapping for road projects in Southern Africa.

This is followed by the major theme of the thesis, which concerns the direct location by aerial photographic interpretation of the various classes of material used in the construction of a modern day road. Although aerial photographs have been employed in recent years for direct interpretation and interpolation of certain specific road building materials, their use in this manner has been limited to a few special cases. This thesis sets out to show that under certain conditions, which pertain in many regions of the world, airphoto interpretation can be used for the direct location of materials possessing particular engineering characteristics. Further, it sets out to show, that this can be done for the full range of engineering properties required of materials for all the significant layers of construction, despite the fact that the materials involved may be of widely differing composition and geological origin. The actual interpretation is based on the fundamental recognition of the elements of form, tone, and texture making up the total photographic pattern. Similar features reflected on photographs are shown to be comprised of similar materials, not merely geologically speaking, but more especially in respect of their significant engineering characteristics; it is still further demonstrated that this is applicable even when such features are situated some considerable distance apart. Variations of notable engineering importance within one and the same geological occurrence, are also shown to be identifiable on the aerial photographs. For major road projects in areas subjected to certain environmental conditions, these possibilities form the basis of a new prospecting technique, which incorporates the full use of the science or art of interpretation. The basic concept governing the applicability of this technique and the steps necessary to ensure the development of the full potential of aerial photography in its application, are discussed and illustrated by detailed accounts of a number of specific projects. These projects

incorporate both materials appraisals of wide strips of country for route location purposes and intensive prospecting along chosen routes. The techniques thus developed, constitute a new approach to materials investigations for major road projects and in this respect contribute to knowledge in this field.

Finally, conclusions are drawn on the relative merits of materials investigation methods in current use in South West Africa and on how these methods affect the different organisations involved in the planning and construction of major road projects. The use made of airphoto interpretation for similar engineering works in other countries, as well as the possible future scope for the application of the particular method of materials investigation described in this thesis, are also covered.

CHAPTER 1.

THE HISTORY OF AIRPHOTO INTERPRETATION

1.1. 1840 - 1887 : EARLY AERIAL PHOTOGRAPHY FROM BALLOONS

1.1.1. The first known suggestion of aerial photography, taken from a balloon, appeared as a joke in a French lithographed caricature, "Daguerreotypomania", in 1840. This followed closely on the invention of the first practical camera, the "daguerreo-type", on the 19th August, 1839; the co-inventors being Joseph N. Niepce (1765 - 1833) and Louis J.M. Daguerre (1787 - 1851). The invention was immediately bought by the French Government. Photo interpretation as practised today is usually considered to date from this time.

1.1.2. Between 1840 and 1886 various oblique photographs were taken from captive and free balloons, in which houses and other objects could be clearly seen. The first such photo in the United States of America was taken from a height of 1,200 feet over Boston by Samuel A. King and J.W. Black. In 1862 and 1863, the physicists Glaissher, Coxwell and Negretti took aerial photographs over England, while Triboulet and Desmarets took photographs over Paris in 1879 and 1880 respectively. Shadbolt and Dale in England, in 1883, and Sibberer in Vienna, in 1885, made further experiments with aerial photography from balloons.

1.1.3. The first military use of aerial photographs recorded, was during the American Civil War when General McClellan secured the services of balloonists La Montaine and Allon to take aerial photographs of Confederate positions. In June 1862 aerial photographs were also used by the Union Army, to gather intelligence on the defences of Richmond. In 1886 experimental aerial photographs were taken during a free balloon flight for the Russian Army by Kovanka, the commander of an aerostat crew. He took pictures of the fortresses of Kronstadt and Petersburg, which demonstrated the military importance of aerial photography.

1.2. 1887 - 1909 : EXPERIMENTAL PHOTOGRAPHY FROM KITES, ROCKETS AND CARRIER-PIGEONS

1.2.1. Between 1887 and 1909 the development of aerial photography was continued through the medium of kites, rockets and carrier-pigeons, while the technical apparatus was also being improved.

1.2.2. The first recorded kite aerial photographs were taken by A. Batut, a Russian, from a height of 127 metres. This was followed in

1899 by R. Thiele, a Russian government councillor, who connected seven unmanned kites, and produced a "Panoramograph" which proved useful for cartographic recording and interpretation of remote areas.

1.2.3. In 1906 the Saxon engineer Alfred Maul demonstrated a rocket propelled by compressed air, which rose to 2,625 feet, took pictures, and then parachuted the camera to earth.

1.2.4. In 1909, Julius Neubronner published a pamphlet describing carrier-pigeon aerial photography. He also demonstrated a panoramic and stereoscopic camera and urged its use for strategic purposes.

1.3. 1909 - 1918 : ADVENT OF THE AEROPLANE AND SUBSEQUENT ADVANCES DURING WORLD WAR I

1.3.1. The balloon and kite platforms were not navigable in the strict sense of the word, and this prevented the development of aerial photography to embrace a wider range of scientific uses. A piloted aeroplane on the other hand, can carry a camera to any part of the earth. It was the advent of the aeroplane which increased the scope, and advanced the science and art of aerial photography and photo interpretation to what we know it to be today.

1.3.2. The first recorded photographs taken from an aeroplane, were taken by Wilbur Wright on April 24, 1909. These were motion pictures taken over Centocelli, in Italy, but it was not long after this that German aviation students training at English flying schools began to use cameras.

1.3.3. The advent of World War I saw prodigious development in the military use of aerial photography. The first aerial photographs of German-held territory were made by Lieutenant Laws of the R.A.F. He found it difficult to convince the authorities that aerial photographs could be put to practical use, until he brought back photographs of very obvious intelligence value. Almost overnight the importance of aerial photographic reconnaissance was recognized, and proper methods of photography, processing, and photo interpretation, were speedily developed.

1.3.4. Lt. Col. J.T.C. Moore Brabazon in collaboration with Thornton Pickard Ltd., designed and produced the first practical aerial cameras, which were put into use by the end of 1915. Prior to this ordinary ground cameras had been used. This improved the value of aerial reconnaissance and photo interpretation to such an extent that the photographic sections of the British armed forces grew enormously, until the R.A.F. alone was producing an average of one thousand prints a day. The tactics of the war were changed completely, as a vast amount of military information became impossible to conceal from the aerial camera lens. Camouflage materials, dummies, decoys, and other deceptive devices were introduced, but in general, were unable to influence the precise and coldly unbiased record of aerial photography.

1.3.5. It was found that photo interpreters could predict the movements of the enemy by observing the varying amounts of rolling stock and the installations. For example, in 1917 aerial photographs taken by the French Army at Dreslincour disclosed the intentions of the Germans and made it possible to plan countermeasures. In 1918 photo interpreters of the United States First Army detected and identified 90 percent of the German military installations opposite their sector of the front. This interpretation was verified on the ground shortly after the armistice.

1.3.6. Although the value of aerial photography had been amply demonstrated during the war, military interpretation came nearly to a standstill after the armistice in 1918. Few training procedures had been established and few aircraft and aerial cameras were made available.

1.4 1919 - 1939 : CIVILIAN DEVELOPMENTS BETWEEN THE WARS.

1.4.1. Despite the lack of further military development between the wars, commercial uses of photo interpretation made many advances. Photographs were taken and maps produced by several survey companies. which were formed in the United States of America, and some of these companies grew into large organisations. U.S.A. Government Agencies also made extensive use of aerial photography. The Agricultural Adjustment Administration photographed farm and ranch land; the Forest Service photographed timber reserves; the Geological Survey photographed many areas for the production of topographic and geologic maps, and so on. State, country and metropolitan planning agencies followed closely on the government lead.

1.4.2. Several scientific journals began to specialize in photogrammetry and photo interpretation. Carl Troll, professor at Bonn University, published many papers and also translated many others from Russian into German. By 1940, hundreds of papers on photo interpretation had been published in journals of archaeology, ecology, geology, pedology, forestry, engineering, and geography. Books too began to appear; Lee published one of the earliest works on the subject in English in 1922.

1.5. 1939 - 1945 : MILITARY USES DURING WORLD WAR II

1.5.1. Neither the stimulus given to photo interpretation, both military and civil, during World War II, nor its importance in the ultimate outcome of the war itself, can easily be over-emphasized. Perhaps the words of the then Chief of the German General Staff, General Werner von Fritsch, best sum up aerial photography's place in the war effort. In 1938 he is credited with saying : "The nation with the best photo reconnaissance will win the next war". Towards the end of the war in 1944 with the experience of many battles behind him, a Russian front-line commander stated: "Photo reconnaissance is our mainstay, for without it we are virtually blind. Ground observation cannot furnish a commanding officer all the information he needs; only when I have before me aerial photomosaics showing me not only the front line but also the depth of the terrain ahead can I properly make tactical decisions". The above two statements convey to some degree the very extensive use which was made of aerial photography and photo interpretation by all combatant countries during the course of the war. A few examples of this use by each major participant country will be given to illustrate further the tremendous progress which took place in this science during these relatively few years.

1.5.2. In the early part of the war it was Germany which led the world in military photo reconnaissance. From September 1939 to May 1940, they were busy on the Western Front photographing all important military installations from Norway to the South of France. This effective reconnaissance was one reason for the success of their strikes against the Allies during this period. However, after the death of the German Chief of Staff, General von Fritsch, the quality of their photo intelligence declined. In general they were content with second-rate photo intelligence, and there is even some evidence that they failed to make consistent use of stereoscopic pairs.

1.5.3. The Japanese, although they had an efficient programme of aerial mapping patterned on the German methods, did not fully appreciate the value of aerial photography in military intelligence. Their campaigns were carried out without much use of even the photo intelligence available. Towards the end of the war they realised that their neglect of photo reconnaissance was a major defect in their intelligence system, but it was then too late for much improvement.

1.5.4. Among the Allies the British were in the forefront in regard to photo reconnaissance and photo interpretation. In 1941, when the

U.S.A. entered the war they sent officers to Britain for initial training before opening their own photographic interpretation schools. Some notable achievements by British photo interpreters were :

(i) The detection of German invasion barges in canals near the coast of France and the Low Countries in the summer of 1940, which constituted the major evidence that invasion of England was imminent. It impelled the British to launch such an effective air attack that Germany was forced to postpone the invasion and finally abandon it.

(ii) The discovery of German warships, in ports and on the high seas, resulting in several raids which kept German naval power crippled throughout the war.

(iii) The detection of German V-weapons between 1942 and 1945. The V - 1 rocket at Peenemunde was detected twelve months before it was used against England. Ninety-six other steel and concrete launching sites were identified by photo interpreters and subsequently destroyed by bombing.

1.5.5. The American photo intelligence developed rather slowly in the Pacific because most of the early action was defensive. In fact, the landing at Tarawa revealed a major deficiency in American photo intelligence. The depth of water over the fringing coral reef was over-estimated causing many amphibious landing craft to run aground far from shore. When the seriousness of the deficiency was realized the Naval Photo Interpretation centre began a programme of intensive research on water depth determination and devised methods of measuring water depths on aerial photographs which was later proved to be accurate to within 7% for depths up to 30 feet. After this, and the advent of the B-29 photographic aircraft, American photo reconnaissance increased tremendously and highly reliable target information folders were prepared for large areas of continental Asia and its offshore islands, including Japan. At the end of the war in the Pacific, in 1945, Admiral F.G. Turner, who had commanded the American amphibious forces in this theatre since 1943, paid this tribute to photo interpretation: "Photographic reconnaissance has been our main source of intelligence in the Pacific. Its importance cannot be overemphasised."

1.5.6. The Russians had experimented with various methods of photography and photo interpretation during their war with Finland (1939 - 1940), so were reasonably advanced when they entered World War II.

Once their offensive commenced in the fall of 1941, a photo reconnaissance service was established, which distributed annotated maps, photographs, and mosaics in quantity to ground and naval commanders. Two notable achievements of Russian photo interpreters were:

(i) The discovery of the disposition of German defences, airfields, and river crossings during the battle of Stalingrad in 1942.

(ii) The use of aerial photography in planning the counter-attack which lifted the blockade of Leningrad in January of 1944. Urban areas, railway stations, and marshalling yards were photographed at night. Large scale photography was used on German front line defences, and smaller scales for areas some distance from the front.

1.5.7. In the European theatre of the war the Allies worked largely together on photo reconnaissance missions. Just prior to, and after the invasion, their activity in this direction was intense. Detailed aerial photography was undertaken in the following instances:

(i) The invasion of Sicily, for which over 500 photo reconnaissance missions were flown.

(ii) The invasion of the Italian mainland where Allied forces flew more than 1,100 photo reconnaissance missions within a period of three months.

(iii) All enemy-held ports in the western and central Mediterranean were photographed, the largest and most important as much as twice daily.

(iv) Prior to the Normandy invasion, when Allied photo interpreters identified installations, and constructed accurate terrain models which were invaluable in planning amphibious landings. During the assault itself some photo interpreters were attached to group staffs afloat, while others went ashore with the landing forces.

(v) The advance inland towards Germany, when Allied battalions and regiments were issued with annotated, gridded, and enlarged aerial photographs, to plan both small and large offensives alike. One regimental intelligence officer illustrated the extent to which this was done when he remarked :

> "The operation for seizing the town of Wurselen was conducted entirely with aerial photographs."

1.5.8. By the end of the war, intensive military research had developed cameras with fast and nearly distortion-free lenses, fast and dependable shutters and many other technical improvements. The sensitivity of film emulsions had been improved and special types of film had been developed for high sensitivity in certain parts of the spectrum. These improvements, and others which photo interpreters now enjoy, are attributable to the intensive wartime developments described. In addition to this, several thousand men and a few women had received training and practice in military photo interpretation. Many of these were professional people such as geologists, engineers, foresters, geographers, soil scientists and others, who upon their return to civilian life found applications for photo interpretation in their particular professional field.

1.6. 1945 - 1964 : CIVILIAN AND MILITARY DEVELOPMENTS SINCE WORLD WAR II

1.6.1. Due to the impact on civilian life of the many thousands of trained military photo interpreters, the twenty years since the end of the war have seen the use of airphoto interpretation mushroom in many spheres. Most of the developed countries have complete, or near-complete airphoto cover, while many of the underdeveloped countries are at least partially covered. South Africa for example, was photographed towards the end of, and immeidately after the cessation of hostilities. It now has 95% cover to scales of either 1 in 30,000 or 1 in 36,000. Much of South West Africa has been photographed recently to a scale of 1 in 36,000 and aerial photographs covering over 50% of the land surface now exist. Once aerial photography is available, the variety of scientific uses to which it can be put, increases. For example, on many projects which in themselves do not warrant special photography, use is made of aerial photos which happen to be available. The extent to which airphoto interpretation is now being used in civilian life can best be illustrated by the many post-war articles which have been published under one or other of the following sciences: Geology, Soils, Engineering, Vegetation, Forestry, Wildlife Management, Range Management, Hydrology and Watershed Management, Agriculture, Urban Area Analysis, Archaeology, Geography, Ice and Oceanography and Coastal Research. The convenience and versatility of aerial photography has only begun to be exploited in these sciences and many future advances can be expected. Although the principles on which airphoto interpretation is based, are of long standing, the actual methods used in their application to the sciences mentioned, have for the most part originated since the end of World War II. In fact these methods have formed the subject matter of many of the articles and theses which have appeared. This prodigious activity in the application of photo interpretation is also reflected in the tremendous increase in the number and quality of photo interpretation courses offered at Colleges and Universities throughout the world.

1.6.2. Military authorities have by no means been inactive in the sphere of airphoto interpretation, as was the case after World War I. Research establishments such as the Military Engineering Experimental Establishment in Hampshire, England, continue to undertake extensive research and are still playing a leading rôle in this field. Military photo interpretation has also played its part in most of the armed conflicts since the end of World War II. For example, the United Nations forces in Korea used airphoto interpretation extensively from the start of the campaign until the end of hostilities.

1.7. THE PAST, PRESENT, AND POSSIBLE FUTURE RÔLE OF AIRPHOTO INTERPRETATION

1.7.1. In a little more than 120 years, photo interpretation has thus advanced from its infancy through stages of experiment to a respected place in military and civilian professional circles. The advent of the aeroplane and the two World Wars occupying a period of approximately ten years, have in themselves been responsible for much of this phenomenal development. Today the methods of airphoto interpretation are precise, its results reliable, and its value widely recognized. It can be expected to play an even greater rôle in the future space age.

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CHAPTER 2.

THE FUNDAMENTALS OF AIRPHOTO INTERPRETATION AND THEIR APPLICATION TO SOIL ENGINEERING MAPPING FOR ROAD PROJECTS IN SOUTHERN AFRICA.

2.1. INTRODUCTION

2.1.1. Basic principles : The basic principles of airphoto interpretation are relatively simple, but the practical applications thereof can be more complex and require training and practice. The most important principle is that of observation and the technique involved has to be mastered before logical modes of thought can be applied to draw correct conclusions from all the relevant facts presented on any particular airphotos.

2.1.2. Three fundamental facts of aerial photography explain its unique usefulness under many circumstances. First, a large area of the earth's surface is pictured on each photograph. At a scale of 1 in 20,000 this amounts to about 9 square miles. The observer has a birds-eye view and can thus study a wide area at leisure. The relations between objects and their surroundings, as well as significant patterns which might not be readily evident from the ground, can be observed. No detail is sacrificed in obtaining this advantage, as the photos record the minutest particulars. Secondly stereoscopic pairs provide three-dimensional images of the earth's surface and the objects on it, but with the vertical scale exaggerated to about three times its normal size. This enables the measurement of heights and vertical angles to be made and makes it easier to detect and identify objects. In fact, the success of interpretation would be appreciably more difficult, if not impossible, were it not for the vertical dimension. The exaggeration of this dimension is often an additional help, especially where small difference in elevation are important. Thirdly, photographic images are a permanent inventory of an area at the time and on the date on which they were taken. Photographs taken at different periods, therefore, will lend themselves to comparative and historical studies.

21.3. Vertical exaggeration: In stereoscopic pairs of aerial photographs the exaggerated impression of depth mentioned previously, is caused by the larger angle of parallax provided by the air and corresponding photo base, compared with that of the normal eye base. Within limits, at a given viewing distance, the greater the eye base the greater the angle of parallax and, hence, the greater the apparent depth. When viewing stereoscopically each eye looks at the same image but from a slightly different angle corresponding to the relative positions from which each airphoto was taken. The photo base, therefore, becomes a much increased eye base relative to the scale of the photography and the height from which the photos are studied. The essential function of the stereoscope is to bring about this increased eye base by ensuring that each eye looks at only one photograph of the stereoscopic pair. The magnification of the lenses is desirable but not essential. The difference in relative shape between objects and their photographic images caused by this exaggeration, must be taken into consideration in interpretation. During training repeated ground observations should be made of objects studied on the airphotos until allowance for this difference becomes second nature. The ability to obtain stereoscopic vision, that is to appreciate depth through perception of parallax, is however not a skill common to everyone. Those who cannot acquire this with practice are at a distinct disadvantage as photo interpreters.

2.1.4. Advantages and limitations: Photo interpretation, then, has the advantages over direct observation of areal scope, perspective, and time relations. Like direct observation, however, it is dependent on the nature of the scene observed and on the training and aptitude of the observer, for the amount and reliability of the information obtained. For the best results it is essential that the observer be an expert in the particular field for which interpretation is being carried out, as well as being in possession of all the attributes of a good photo interpreter.

2.2. COMMON TYPES OF AERIAL PHOTOGRAPHS

2.2.1. Types and their errors: Airphotos are taken either vertically, where the tilt is negligible, or obliquely. Oblique photographs are classified as either high or low, the former including the horizon while the latter does not. All oblique photos show the earth's surface in a perspective to which the average person is more accustomed, but entail special problems in regard to measurements as well as interpretation. Vertical photos on the other hand approximate most closely to maps and are the easiest to work with once the uninitiated has become accustomed to the vertical view. To those who have trained in interpretation of engineering and other plans this view presents no problems. In flat country, in fact, the difference between a map or plan of an area and the corresponding airphoto to the same scale, is very slight. In hilly terrain the relief displacement (due to radial distortion), which increases from the nadir point outwards, is appreciable towards the edges of the photos and this tends to make horizontal measurements unreliable.

2.2.2. Mosaics: Individual airphotos joined together along match lines to form a vertical picture of a larger area, are called aerial mosaics. These should always be produced along straight match lines as irregular shapes could be confused with soil boundaries. Only alternate flight strip photos are needed on account of the 60% end overlap. Mosaics are normally either uncontrolled, that is made up from unrectified photos; or semi-controlled where uncontrolled blocks of mosaics are rectified and then re-photographed to a reduced scale; or controlled when produced from fully rectified photos. Uncontrolled mosaics, which are mainly subject to the errors of tilt and radial distortion, are satisfactory for most practical purposes.

2.3. INDICATORS.

2.3.1. Size and shape: The size of an object is often one of the most useful clues to its identity. It is thus, an essential first step to familiarize oneself with the relative size of objects on the scale of the photographs being studied. When working with photography of variable scale, however, care will be required and frequent measurements may become necessary to verify the interpretation.

2.3.2. Shadow: Aerial photography for general purposes is usually flown within two hours of local noon so that the shadows present will be small. This is done in order to record as much as possible of the ground surface, for the objects on which shadows fall reflect so little light to the aerial camera as to be visible only dimly or not at all in the aerial photographs.

2.3.3. Tone: In black-and-white photographs, distinctions between hues are lost and objects are observed in tones of grey. Variations in these tones are often major clues to the identity or composition of objects. The film best suited to recording differences for the range of colours of the visible spectrum, is panchromatic, which, with the minus-blue filter to reduce haze interference, is commonly used for general purpose photography. The tones of photographic images are, however, influenced by many other factors apart from colour, but always remain relative for any time of year and under any single condition of photographic processing. For example, (i) a body of water may appear in tones ranging from white to black, depending on the angle of the sun and the number of wave surfaces reflecting light to the camera, (ii) a black asphalt road may appear very light in tone because of its smooth surface and, (iii) a trail may appear white in dry weather but dark after rain. Once the photo interpreter understands these factors tonal variations can be used reliably as indicators and are particularly important in stereoscopic pairs if the objects of interest have little or no height. The soil scientist uses tone differences to classify soils; the forester to distinguish hardwood from coniferous trees; the geologist to map lithology and structure or to prospect for minerals; and so forth.

2.3.4. For specialized jobs definition of tones can be emphasised for particular objects by the use of a different film-filter combination. For instance, infrared or modified infrared photography records conditions of plants, soils, and drainage which are of special interest to the ecologist and agriculturist.

2.3.5. Colour : Colour photography may be economically justified in special cases where natural colours would play a decisive part in identification. It is, however, up to twelve times more expensive than black-and-white photography.

2.3.6. Texture : Texture in aerial photographs is created by tonal repetitions in groups of objects which are too small to be discerned as individuals. In nature differing materials and vegetation can both impart textures to the airphotos distinctive enough to serve as reliable clues to the identification of the objects themselves. The size of object required to produce texture varies with the scale of photography. In large-scale photographs, trees can be seen as individuals; their leaves or needles cannot be discerned separately, but contribute to the texture of the tree crowns. In photographs of smaller scale the crowns contribute to the texture of the whole stand of trees.

2.3.7. Patterns : Appreciation of the significance of aerial photography is chiefly obtained through an understanding of patterns on the earth's surface. These patterns may be either natural or cultural, large or so small that they would probably be overlooked on the ground, but on the airphotos are still detectable. Outcrop patterns provide clues to geologic structure, and drainage patterns are associated with structure, lithology, and soil texture. Vegetation patterns are associated with varying relations between organisms and their environment as well as between varying geological formations and surface deposits. Cultural features are conspicuous in aerial photographs because they consist of straight lines or other regular configurations. Techniques of camouflage attempt to blend this regularity into the natural patterns of the environment. Most of man's activities leave scars on the earth which remain detectable for as long as thousands of years after the activities have ceased. Identification of man-made features on aerial photographs can often be made without resort to field checking. A road and a railway may look much alike in a photograph but can be differentiated from the configurations required by their functions. A road may have fairly steep grades, sharp curves, and many intersections, while a railroad has gentle grades, wide curves and few intersections.

2.3.8. Regional patterns which formerly could be studied only through laborious ground observation can now easily be observed by the use of aerial mosaics.

2.4. SOIL ENGINEERING MAPPING BY AIRPHOTO INTERPRETATION AS APPLIED TO ROAD PROJECTS IN SOUTHERN AFRICA.

2.4.1. Basic concepts: A soil engineering map aims at linking the geology and pedology of an area to engineering properties, and is especially directed towards the projects envisaged. "Soil" used in this sense is defined as both the consolidated and unconsolidated materials to be used in engineering construction, and should not be confused with "soil" as defined in soil mechanics and foundation engineering, or as defined by the agriculturist.

2.4.2. The principles of airphoto interpretation as applied to soil engineering mapping are relatively simple. Basically rocks subjected to weathering and erosion, assume characteristic shapes dependent on their physical and chemical properties. The aerial camera records these characteristic features which, to the trained eye, are then discernible under stereoscopic examination. It is usually possible, therefore, to demarcate accurately on the airphotos themselves, the contact lines between different basic formations and also between variations in the superficial surface deposits. It is stressed, however, that the different types of rock and surface deposits involved, must be established initially by field inspection and correlated with their airphoto indicators, after which they can be inferred by analogy, with a sufficient degree of certainty, in adjoining areas which have been subjected to the same or similar environmental conditions.

2.4.3. The essential differences between mapping with the aid of airphotos and airphoto interpretation, and that of conventional mapping are thus, (i) that the airphotos (which should always be vertical) act as the base map and, (ii) that the stereopairs are used for the direct demarcation of boundary lines. The technique accelerates the production and increases enormously the accuracy of, and amount of detail in, maps.

2.4.4. Contact prints and their handling : Airphoto negatives for general purpose photography are currently 9 inches square in size, and can be printed on either single, or double weight paper, with respectively matte, semi-matte, glossy, or glossy and glazed, surfaces. The single weight paper is thin and weak, while the double weight is thick and stronger. Both tend to curl badly when dry. For soil engineering mapping purposes, double weight paper with matte and semi-matte finishes, have proved to be the most useful combinations.

2.4.5. A set of photographs covering even a limited road project, may number 50 or more individual contact prints. Hence before starting detailed examination of the stereopairs, it is highly desirable to institute an orderly method of handling the prints, so that time is not wasted in selecting the photographs. The following simple method has been found effective in practice :

(i) Give consecutive flight strips letters which follow a corresponding sequence in the alphabet, i.e. A, B, C, D ... etc.

(ii) Number the prints on each flight strip from left to right, beginning with the numeral one.

(iii) Write in the top left hand corner of each print its notation, i.e. letter and number.

(iv) The field and office sets of prints are then distinguished from each other by enclosing the print notations with a circle and a square respectively, or visa-versa (2.4.12).

2.4.6. Indicators : For purposes of conveying information and description of airphoto patterns, it has been recommended that the breakdown of elements forming the total pattern on airphotos, should be as follows :

A. Elements of form:
   1. Topographic form
   2. Drainage form
   3. Erosional form

B. Elements of tone and texture:
   1. Tones and textures of vegetation
   2. Tones and textures of land use
   3. Tones and textures of materials.

An idea of the function of indicators in airphoto interpretation has already been given (2.3.1 to 2.3.8). Generalizations on interpretation and the relative importance of the various indicators, are difficult to make, and can be very misleading, due to the wide range of materials and conditions encountered on different projects. Specific cases of the use of many of the above indicators are given throughout Chapter 3, with comments from the experience gained in Chapter 4 (4.5.1 to 4.5.4).

2.4.7. Scale of photography: Overseas it has been found that a scale of photography of from 1 in 20,000 to 1 in 40,000 is usually adequate for general mapping purposes. In Southern Africa experience in the production of soil engineering maps for highway projects, has led to the general observation that the higher the rainfall the larger the scale required to obtain the same degree of accuracy. The following scales have been recommended as a general guide:

Rainfall exceeding 25 inches per annum, scale 1 in 10,000 or larger
" between 10 and 25 " " " , scale 1 in 20,000
" less than 10 inches " " , scale 1 in 30,000.

If the scale of the airphotos is too small an appreciable measure of accuracy of annotation and detail of information given, will have to be sacrificed; and a greater proportion of the annotation will also have to be done under the four magnification stereoscope, thus sacrificing speed of operation as well. The indicators of texture and tone of materials, are cases in point where the minimum scale of photography is sometimes critical (4.4.1). A disadvantage of large scales is the increase in the number of prints that have to be handled in the field for a given area of country. However, these factors are not nearly as important as the clarity of the prints themselves. For this reason reduction or magnification in order to obtain the best scale, is never considered, and only contact prints giving the maximum clarity possible are used. The scale of photography, therefore, has a direct bearing on the convenience of operation, the detail given in, and the accuracy and speed of, any mapping project based on the use of airphotos.

2.4.8. If circumstances warrant special photography for any specific project, then the line of flight should be parallel to the proposed route, thus resulting in a minimum number of photos to handle in the field. If the materials investigation is to be based on a soil engineering map, then the most suitable scale should also be adopted.

2.4.9. Adjustment of stereopairs : Quick adjustment of stereopairs in order to obtain stereoscopic vision, is a necessary accomplishment before attempting detailed annotation work. For correct adjustment, the segment of the flight line on both photos of the stereopair should normally be in straight alignment. To obtain the line of flight, mark in the principal and conjugate principal points on each photo, and then connect these with a straight line. Having once lined the stereopair up in this fashion, the photos are moved parallel to the flight line until a sharp stereoscopic focus is obtained. Usually one adjustment will not serve for examination of all parts of the overlap. This is particularly true in photographs having a short principal distance, where radial displacement towards the edges of the photos may necessitate re-alignment for examination of these areas. In such a case, the flight line segments on the respective photographs will not form a continuous straight line, but must still remain parallel.

2.4.10. With a little experience, stereoscopic vision can be obtained easily without first establishing the direction of flight. To do this, choose a centrally positioned and prominent feature in the stereopair, and then place a finger from each hand on this feature; the fingers are then easily merged under the stereoscope, and on removal, the photos should be in reasonably close adjustment. If the images are not fused perfectly, a slight relative movement, either towards or away from each other, or of rotation, may be required until the image and impression of depth are clear. It is stressed that careful orientation of the stereoscopic pairs in order to minimise eyestrain, is essential for prolonged work on the stereoscopic.

2.4.11. Annotation: For the demarcation of geological boundaries, the coloured or grease pencils often used for general purpose marking of airphotos, are not satisfactory due to their thick traces which can obscure important detail. A pencil of medium hardness and a rapidograph pen with black ink, are the usual annotating mediums. A matte finish can be marked easily by both pencil and black rapidograph ink, whereas glossy, and glossy and glazed, surfaces, which display greater clarity of detail, can only be suitably marked by the latter. Pencil marks are readily removed from the photo finish by either an ordinary pencil rubber, or by a piece of cotton wool dampened with either benzine or water. Black rapidograph ink, on the other hand, can only be erased safely through the medium of a clean piece of water-dampened cotton wool.

2.4.12. It is usual to use two complete sets of airphotos for any major mapping operation. One set, which should be of semi-matte finish for demarcation with both pencil and ink, is used for on the spot stereoscopic examination of the terrain, and for initial detailed annotation. The second set should normally have either a semi-matte or a glossy surface providing maximum clearness, and is for use in the office. This set must be kept unmarked during the field work in order not to obscure any of the detail. In flat terrain it is only necessary to annotate every second photograph in a flight strip. This simplifies the work and helps to avoid unwitting duplication of annotation. In hilly country, however, it may be necessary to use every photo on account of the appreciable relief displacement towards the edges. On completion of the field work and annotation of the field set of photographs, the demarcation lines are copied in ink on the office set of duplicates, from which the map is eventually produced. The advantages provided by the stereoscope are made use of to ensure adequate accuracy in copying. If stereograms are required for publication in an article, then photos with a glossy and glazed finish should preferably be substituted for the semi-matte office set of duplicates, as these retain greater clarity of detail on reproduction.

2.4.13. Where drainage patterns and watersheds are not very obvious, it will sometimes help the later detailed annotation to mark these on the photos before the field work begins. By reversing the stereopairs, the drainage areas become high points which can facilitate their annotation. Watersheds should preferably be marked in a different colour (red) to be distinctive. The initial annotation of drainage patterns and watersheds should only be done, however, if it is likely to be beneficial, and will not obliterate detail which may be important later for demarcation purposes. Overlays are sometimes employed where the possibility of diminishing the clarity of the photos must be avoided, but since the photos themselves are far tougher, it is generally more satisfactory to use a second set of photos in the manner already suggested.

2.4.14. Field equipment: The field equipment necessary for successful soil engineering mapping by airphoto interpretation, is described in paragraph 3.2.9. In addition to these items a heavy duty auger mounted on the back of a 5 ton lorry (or similar vehicle), and capable of boring through considerable depths of sand, gravel, and surface limestone deposits, to the underlying bedrock, is often essential (2.4.16).

2.4.15. Procedure : The field procedure adopted for the mapping, can conveniently be divided into three major operations, which are normally executed in the sequence described below:

(i) First a field inspection is made of the area to be mapped, or portion thereof. The primary objectives are, (a) to distinguish the major morphological units; that is the major landforms such as hills, plateaus, plains etc., (b) to select a key area in each major landform which includes all stages of development and, (c) to establish the predominant geological formation in each landform, from which the lesser formations, or variations thereof, are differentiated, and subsequently demarcated, on the airphotos. The number of trial holes necessary to determine these criteria. should be kept to a minimum.

(ii) The second stage comprises detailed field inspections and airphoto annotation, of all key areas. Trial pits are required to provide sufficient information for full interpretation and annotation.

The selection of the positions of these holes, is therefore important, and should be intelligently determined from field inspections, and from changes in the airphoto patterns. Holes should be sunk to residual soil or bedrock level, and a description of the profiles fully recorded in a field note book. These descriptions are then shortened, symbolized, and recorded on the back of the field-set airphoto adjacent to a pin prick marking the exact position of the hole. In the process of obtaining this information, a preliminary legend is prepared, which should be fairly detailed, including rather too many than too few mapping units. The mapping units may be either composite soil profiles from surface to bedrock, or individual soil or rock types. The selection of the mapping units should take into consideration, (a) the proposed scale of the map, which fixes minimum unit sizes that can conveniently be shown, (b) whether or not the unit is identifiable as such on the stereo model and, (c) the practical requirements of the project. This preliminary legend may have to be altered or modified, as additional information is obtained during the course of the mapping.

(iii) The final step is the annotation of the photos for the whole area by analogy with the correlation obtained in the key areas between airphoto indicator and soil profile. At this stage it should be possible to confine the field work to systematic visual checks on the photo interpretation.

2.4.16. The process just outlined is a simplification of what usually happens in practice. On most mapping projects undertaken by airphoto interpretation, areas are encountered where the indicators are poor, or where the parent rock has no physical expression at all, due to alluvium and/or some other superficial deposit having effectively obliterated all surface signs (3.4.2, 3.5.3, 3.6.2 to 3.6.3, 3.7.2. to 3.7.4, and 3.8.2). The gaps left after direct annotation of the airphotos, have to be filled in by tedious field work and an intimate knowledge of the probable sequence of events which have resulted in the present day conditions. Where thick surface deposits are extensive, lines of demarcation between the underlying parent rock formations, have to be established by boring sufficient holes in a series of sections at right angles to the probable direction of contact. In South West Africa such areas are not uncommon, and surface deposits achieving depths of 20 feet or more, are far from rare. A heavy-duty auger thus becomes a necessary requisite for the application of this procedure, which naturally adds appreciably to the expense of the mapping.

2.4.17. From the foregoing, it will readily be appreciated that the complexity of soil engineering mapping, in common with other allied forms of mapping, necessitates the services of a qualified and skilled geologist, who in addition, must also be an expert photo interpreter if airphoto interpretation is to be applied.

2.4.18. Presentation: The soil engineering map is finally compiled from the annotated photographs, by normal photogrammetric methods. To ensure sufficient accuracy for this purpose, four co-ordinated control points per annotated photo are often necessary. The exact number will depend on the angle of skew of the flight line, and hence the total number of photographs used per flight strip. Apart from the significant geological boundaries, and those of their superficial surface derivatives, the map should also show cadastral boundaries, all classes of roads including farm roads, railways, farm houses, boreholes, dams, the position of all profile holes, drainage channels, areas of slope instability, seepage zones, and any other details that may be of ultimate assistance to the road project.

2.4.19. The scale of the map should be chosen with care for each particular project, bearing in mind, amongst other factors, the following pertinent points; (i) the pattern of the demarcation lines, (ii) the total amount of information to be recorded on the map, and (iii) the number and size of small isolated occurrences which should be shown. In regard to the latter, these can be illustrated larger than true size where only occasional small patches are involved. This will permit a smaller scale to be used than would otherwise have been necessary. However, there is a tendency to choose the scale of the map to comply with a predetermined size and an optimum number of sheets, primarily for the sake of convenience in handling. If the scale thus chosen is too small, it will lead either to the quantity of essential detail obscuring the map and making it difficult to interpret, or alternatively, to essential detail being omitted for the sake of clarity. This should obviously be avoided at all costs, as it detracts from the ultimate value of the map. To date most soil engineering maps produced from airphotos in Southern Africa, have involved a reduction of scale from that of the aerial photography, scales having ranged from

1 in 30,000 to 1 in 50,000.

2.4.20. Basic geological data, such as solid bedrock formations, are depicted in colour on the map. The overlying soil profile is indicated by means of various standard hatchings. In addition the soil profile is given in symbols in each delineated area. For example, the formula P/SiSd/M refers to a soil profile consisting of scattered pebbles on the surface, overlying silty sand, which in its turn overlies mudstone bedrock, probably in a weathered condition on the top.

2.4.21. Each map is accompanied by a report giving details of mapping units and the indications by which they were identified on the airphotos. The quality of the materials available, as judged from the recordings of the detailed soil profiles, possibly substantiated by an occasional test result, are included, together with suggestions for possible use of materials in construction. This information can help with planning the prospecting, and also with any centre line soil survey which may possibly be necessary.

CHAPTER 3.

THE USE OF AIRPHOTO INTERPRETATION AS AN AID TO PROSPECTING FOR ROAD BUILDING MATERIALS IN SOUTH WEST AFRICA.

3.1. CIRCUMSTANCES WHICH LED TO THE INTRODUCTION OF THE USE OF AIRPHOTOS.

3.1.1. Introduction: One of the basic problems in the construction of black top rural roads in South West Africa, is the most economic usage of local materials. In this respect the problem does not differ from that of similar road projects in South Africa. However, our local geological and topographical conditions, often coupled with those of the vegetational cover, pose problems, that if not unique, are not normally encountered in the Republic of South Africa today.

3.1.2. Conditions: Metamorphic processes have resulted in the geology of many parts being variable, and subsequent weathering, transportation and deposition, have in addition, created numerous surface gravel deposits. These deposits vary in quality from totally unsuitable, to suitable for use in the basecourse layer of a bitumen surfaced road. Accurate geological maps, especially those indicating such surface deposits, are not available. Due to this, and to the fact that South West Africa is sparsely populated and is in an early stage of development, these deposits remain virtually untouched, and their existence has largely still to be discovered. To complicate the position still further, large regions of South West Africa are very flat. In the central and northern parts of the territory, where these flat areas are densely covered by trees and bush, and after rain by thick high grass too, visibility is reduced to a minimum (see Photos 1, 2 and 3). In such areas as these,

(Photo by J.H. Caiger)
Photo 1 : Flat terrain with dense tree and bush cover. (Between Sukses and Otjiwarongo)

deposits are sometimes covered by layers of sand of up to 6 feet thick and more, with very little, if any, surface sign to betray the presence of the gravel (see Photo 9, page 44). Prospecting by the normal recognized methods under any of these conditions, becomes largely a question of "by guess and by God". Unfortunately this has often yielded embarassing results in the past.

(Photo by J.H. Caiger)
Photo 2: Limited visibility in flat terrain with dense vegetational cover. (Between Sukses and Otjiwarongo)

(Photo by H. Roth)
Photo 3: Thick high grass after rain. (Between Sukses and Otjiwarongo)

3.1.3. Illustrated cases; (a) Windhoek, (b) Kalkrand: Four cases, three from the Windhoek area and one from South of Kalkrand, are cited to illustrate the nature and seriousness of the problem faced, and the potential of airphoto interpretation in solving this problem.

3.1.4. (a) Windhoek area : The three sections being illustrated are as follows, (refer to Figs. 1, 2 and 3) :

(i) On the 10.5 mile section of road between Windhoek and Brakwater, approximately 6.7 miles of basecourse was stabilized with 5% lime in addition to mechanical stabilization with a fine silty soil in the ratio of 5:1. Subsequent prospecting in the area showed this relatively expensive process to be unnecessary, as gravel of natural basecourse quality is available.

(ii) On the Windhoek - Kapps Farm road, 1.0 miles of base was stabilized with 4% lime. Soon afterwards a 15,000 cu. yard natural gravel basecourse source was located not far from the centre line of the road and close to the stabilized section.

(iii) On the Windhoek - Aris road, a length of 5.9 miles of subbase was stabilized with 4% lime. Some months after this particular road was completed and opened to traffic, an occurrence of gravel was located adjacent to the centre line along which the subbase had been stabilized. This source contained 20,000 cubic yards of basecourse quality gravel.

3.1.5. Examination of the respective airphotos shows that the unsatisfactory results obtained by normal methods of prospecting, could have been avoided, with a consequent saving to the Administration of thousands of Rand, had the technique described in section 3.2 of this thesis been applied. The exact localities of the gravel sources referred to, together with some other pertinent sources, have been marked on the appropriate airphotos, so that these areas can be examined stereoscopically in relation to the surrounding terrain.

(Photo by H. Roth)

Photo 4: A ground view within area A in Stereogram 1. A depth of up to 4 feet of gravel overlies the mica-schist formation (see Test Result Sheet 1).

3.1.6. Within area A in Stereogram 1, which shows the road near Brakwater, a good natural basecourse gravel has recently been located (see Test Result Sheet 1 and Photo 4). Area B contains similar gravel, as yet untested due to the present lack of demand. In fact, suitable natural gravel is plentiful in the vicinity of area B, and extending downstream.

3.1.7. Areas A in Stereogram 2 show where the 15,000 cubic yards of basecourse quality quartz gravel was obtained for the road to Kapps Farm (see Test Result Sheet 2). The centre line of the new bitumen surfaced road over this section, is close to that of the old road which can be seen in this Stereogram. In Stereogram 3, A shows yet another place where subbase quality gravel was located by normal prospecting methods at such a late stage of the construction, that it was not possible to plan the most economic usage of the source (see Test Result Sheet 3).

3.1.8. In Stereogram 4, A is the site where 20,000 cubic yards of basecourse quality gravel was located after this particular section of the road between Windhoek and Aris, had already been opened to traffic (see Test Result Sheets 4 and 4 A). B is another similar area, which fortunately was located in time to be used in the basecourse. A and B in Stereogram 5, are the localities from which most of the lime-stabilized subbase gravel was derived. The test results of the natural gravel were similar to those recorded on Test Result Sheet 5. These are the test results of a workable depth of plastic gravel, from a locality indicated by the arrow B in Stereogram 3 (3.1.10).

3.1.9. A brief geological description of the Windhoek region is necessary to indicate the basis for airphoto interpretation of good quality road building quartz gravels. The region, which enjoys an average annual rainfall of about 14.5 inches (370 mm.), consists mainly of mica-schists and quartzites from the Khomas Series of the Damara System. Within these formations, veins and lenses of quartz occur. It is generally accepted that this quartz was developed during the metamorphic processes which resulted in the formation of the mica-schists and quartzites, and was not an igneous intrusion. This quartz, being more durable than either the mica-schists or the quartzites, has weathered at a considerably slower rate, thus forming residual and transported quartz gravel sources, which, in varying thicknesses, cover practically the whole surface area. The soil fines portion of these gravel occurrences, fluctuates considerably in plasticity. Most of the soil fines, whether plastic or not, are derivatives of the predominant mica-schist formations. The fluctuation in their plasticity is caused primarily by variations which were established in the parent material during the formative metamorphic period, and to a lesser degree by the present state of weathering and decomposition. Soil fines produced from the occasional quartzitic formations are all of low plasticity.

3.1.10. The general requirements for a good quality gravel source, apart from the more specific specifications, are that it be of relatively low plasticity and not too finely graded. Further, practical considerations dictate that a minimum average depth of 12 inches and a guaranteed minimum quantity of 3,000 cubic yards, is required under the prevailing topographical conditions, before the source can be satisfactorily and economically worked. Over much of the surface area, the gravel layer is far too thin to be workable, and in many places where it is sufficiently thick, it contains soil fines which are too plastic. So, despite the fact that practically the whole surface area is covered with quartz gravel, the vital occurrences of such economic importance to the construction of rural roads in the area, are relatively few in number and are often difficult to locate by normal methods.

3.1.11. However, the requirements for good gravel sources, also provide superior water absorption and retention qualities to those generally pertaining in the surrounding terrain. This fosters the growth of vegetation, resulting in a greater size and intensity of growth, of both trees and scrub bush. To the trained observer, such areas are readily discernible on the airphotos, from their distinctive surface textural appearance (2.3.6). A close stereoscopic study of the areas embracing good gravel occurrences, in relation to the surrounding terrain, and more specifically, in relation to area B in Stereogram 3 and areas A and B in Stereogram 5, all of which contained inferior gravel of workable depth,

(Photo by H. Roth)

Photo 5: A ground view at the point of arrow C in Stereogram 1. Despite the surface signs the gravel is no more than a few inches thick at this site.

will illustrate the degree of difference which can be expected in texture of vegetation (see Stereograms1 to 5 and Test Result Sheets 1 to 5). It is stressed that the vegetation is not of a different type, but varies only slightly in size and intensity of growth. Such variations are sometimes difficult to distinguish from the ground, where the view may be limited (compare Photos 4 and 5). They can thus easily be missed by normal prospecting methods, even when the terrain has been adequately covered.

3.1.12. The transported material in flood plain areas of drainage channels, often provides more favourable conditions for growth, than even those of the good quality gravel occurrences described above. Such areas also contain larger trees and more intensive growth than that of the surrounding terrain. The material in these flood plains, however, is usually too finely graded to too great a depth, to make the working of a possible coarser gravel layer underneath, an economic proposition. Due to their topographical location, such areas can easily be spotted on the airphotos, and immediately discarded as possible sources of high quality natural gravel.

3.1.13. Other areas which result in a similar textural appearance on the airphotos, cannot be discarded without a field check. The dotted areas B in Stereogram 2, are a case in point. These areas are actually densely covered with a small scrub bush, and contain no large acacia trees as do the adjacent areas A, which demarcate good sources of gravel. The thick scrub bush cover has formed over the surface contact between mica-schist and quartzite formations.

3.1.14. <u>(b) South of Kalkrand: (refer to Figs. 1, 2 and 4)</u>: On the contract between Kalkrand and Mariental, preliminary investigations indicated that it would be necessary to crush calcrete, or calcrete conglomerate, for an appreciable length of the basecourse layer. The contract was based on this information and only a nominal quantity of natural gravel for basecourse was added to the bill of quantities, in order to obtain a price. The contractors priced without giving serious consideration to this latter item, which was naturally assumed to be relatively unimportant. Some months after the contract began, and after the first calcrete had already been crushed, the Resident Engineer's staff located extensive quartz gravel deposits, which occur from Kalkrand southwards for a distance of approximately 14 miles, but only on the western side of the dotted line X - Y (see Figure 4). This gravel was found to be suitable for use in the basecourse layer, either as stock-piled, or after the addition of a small percentage of non-plastic dune sand. It was eventually used in the base for approximately 27 miles, which was more than half the contract distance. It was also used for many miles in the subbase layer.

3.1.15. Had the contract documents reflected the true significance of this gravel, then the pricing of the bill of quantities would in all probability have been affected appreciably and might even have led to the contract being awarded to a different firm. As it was, the successful tenderer had underpriced the small quantity shown against this item. The much larger amount of approximately 40,000 cubic yards, eventually used in the basecourse, was instrumental in putting this firm under judicial management, and consequently causing both the Consultant and the Administration anxiety, as to whether or not the contract would be completed. The completion date was in any case delayed, due, amongst other things, to the dislocation of construction activities caused by the late discovery of these deposits.

3.1.16. The lack of full information in the planning phase, probably affected the location of the road as well. At this stage a route running West of Kalkrand was seriously considered, and would almost certainly have been adopted, had the full facts been available (see Stereogram 6). The route could then have continued along the eastern boundary of the quartz gravel deposits, thus resulting in an appreciable saving on haul distance, especially over a six mile length of road, where the dead haul, which varied between 1 and $1\frac{3}{4}$ miles, could have been reduced to practically zero. The difference in length between the two routes is negligible.

3.1.17. The basis on which airphoto interpretation could have been used to advantage in this case, will be more readily followed after consideration of the general geology of the area. Contemporarily this region receives an average annual rainfall of about 8.5 inches. It is a marginal area of the Tertiary Kalahari System, from which the sand has been removed by erosion, exposing surface limestones and quartz pebble gravels. The quartz pebbles are rounded, and were obviously deposited during an earlier wet period. Percolating calcium carbonate solutions have subsequently coated these pebbles at many localities, to form calcrete conglomerates. Where quartz gravel deposits of three foot or more in thickness occur, these have tended to protect the underlying Stormberg basalts or lava (Karroo System) from erosion, and weathering has been most severe where the pebble covering was either thin or non-existent. The good deposits of low plasticity are, therefore, generally to be found on high ground or capping ridges. Quartz gravel has naturally also collected in the low "swallow-hole" areas, which form the typical internal drainage pattern of this type of surface limestone occurrence (see Stereogram 7). However, the gravel in these "swallow-holes" tends to be variable in layer thickness and contains plastic fines often in relatively high percentages, which have accumulated in the low spots through a process of downward leaching.

3.1.18. In Stereogram 6, the position of a large quartz gravel deposit due West of Kalkrand is indicated by arrow A. The approximate boundaries of this deposit can be demarcated on the airphotos from a slight change of tone, caused by the preponderance of surface quartz pebbles within the borrow pit area. The indicator is not very well defined; and it is stressed that the marked boundaries are approximate **rather** than exact. The tonal change can possibly be noticed best under a small magnification stereoscope which provides a reasonably wide areal view. In Stereogram 7, the locality of a long quartz gravel deposit, in which four separate borrow pits were established, is indicated by a dotted line, following the watershed of a prominent ridge, from which a distinctive local parallel drainage pattern has developed. This pattern is in marked contrast to the general calcrete swallow-hole pattern of internal drainage, and is also in marked contrast to an adjacent local sub-dentritic drainage pattern, which has formed in the basalt underlying a relatively thin layer of calcrete. Once the exact position of a portion of this deposit had been fixed in the airphotos, it was possible to indicate the northern and southern extremities of the source from the watershed of the parallel drainage pattern. Indicators for exact eastern and western boundary demarcation of the relatively narrow deposit, are not definitely distinguishable. It is possible that a larger scale of photography might have shown some change of tone and/or texture, making more exact demarcation possible (4.4.1).

3.1.19. Since most of the quartz gravel deposits are, to a greater or lesser extent, impregnated with calcrete, they have tended to lose their individuality, and, as far as airphoto indications are concerned, have in effect become part and parcel of the surface limestone formation. In general, such surface limestones have proved to be the most difficult of formations, in which to achieve results of the high degree of dependability, which can normally be expected from the use of photo interpretation as a direct aid to prospecting (4.5.2). Despite this difficulty, there are still sufficient airphoto clues, as illustrated above, to have ensured the discovery of the true materials position in the planning phase of the project, had the technique described in section 3.2 been applied. As it was, the preliminary investigations did bring to light small deposits of quartz gravel, but, without the aid of airphotos, these were thought to be only isolated pockets of no practical importance, and their true significance was missed, with the unsatisfactory consequences already described.

3.1.20 Airphoto interpretation introduced: Incidents such as those recorded above, must obviously be avoided. If this is to be achieved using conventional methods of prospecting, then large teams headed by trained technical personnel, will be necessary for most projects, so as to ensure that the field work is completed within a reasonable time. Technical personnel, however, generally in short supply, are at a premium in South West Africa, and are certainly not available in the numbers that would be required for the more difficult projects. Airphoto interpretation, using two distinctly different approaches, was introduced as an aid to materials investigations for road projects, in an attempt to solve these difficulties (4.1.1 to 4.1.2).

3.2. THE TECHNIQUE OF USING AIRPHOTO INTERPRETATION AS AN AID TO ROUTE LOCATION AND DETAILED PROSPECTING.

3.2.1. Basic concept: The technique of using airphoto interpretation as an aid to route location and detailed prospecting, has been developed in South West Africa to overcome the difficulties caused by the environmental conditions and to fulfill the needs of the following basic concept, which concept holds true for conditions over much of South West Africa (3.1.2) :

> As a road is built entirely out of materials, it follows that the theoretical minimum possible cost of construction is governed by the most economic usage of the materials supplied by nature, whether these be processed or not. The primary objective of the materials investigation should always be to establish this criterium as closely as possible, and not merely to arrive at a satisfactory solution. The cheapest materials solution is often governed in its turn by the availability of low-cost subbase and basecourse sources. This question is of much more importance, than attempting to estimate the cover required by the in situ material throughout the length of the road (i.e. centre line soil surveys). This is especially true in flat terrain, where drainage conditions in any case often dictate an imported cover of 18 inches or more, and a centre line soil survey for design

purposes becomes unnecessary. In other cases, an increase of a few inches in the cover requirements supplied from cheap sources, would not influence the total cost of the work as much as the use of expensive subbase and basecourse materials, with perhaps a slightly smaller overall cover (texts of sections 3.3 to 3.8 inclusive).

3.2.2. Adaptability : Before describing the general operational technique of using airphotos and airphoto interpretation, as an aid to extablishing the most economic route and also as an aid to detailed prospecting along the chosen location, it is stressed that the best sequence of operations may often vary from job to job, depending on local conditions and special requirements. Thus, the technique must remain adaptable if full benefit is to be derived from airphoto interpretation.

3.2.3. Route location : Where topographical, drainage, military, or other local considerations do not dictate a particular location between two fixed points, the distribution of low-cost subbase and basecourse materials will be the deciding factor in the final location of the route (3.2.1). This is by no means an uncommon occurrence in South West Africa; and such conditions necessitate a preliminary materials appraisal of a wide strip of country effectively covering the area of possible location (3.3.1, 3.5.6 to 3.5.10, 3.7.15, 3.8.4 to 3.8.7). Speed is often essential, as detailed work on the project must be delayed until a decision on the location has been reached. It is here that the airphotos are of inestimable value. The technique in this case, is to note all prominent features on the airphotos, and then field check at least two or three different localities for each similar type of feature. Any likely sources of base or subbase material should be noted, and if time allows, sampled for laboratory testing. With practice and the application of ones local knowledge, the potential of large areas of country can be appraised quickly and fairly reliably, thus enabling a decision on the most economic location to be made with a reasonable amount of confidence.

3.2.4. Detailed prospecting : After the location has been determined the detailed prospecting is undertaken. A 6 mile wide strip of country, that is approximately 3 miles on each side of the centre line, is investigated initially. Detailed stereoscopic study of the airphotos should now become a daily routine. From these studies the long term and the day-to-day work of the prospecting operations, can be systematically planned. Experience has shown that the airphotos can be studied to the best advantage under good artificial lighting in the evenings, when the following day's work can also be planned. If this practice is followed, a surprisingly short time is required to gain a really intimate knowledge of the area being investigated.

3.2.5. Prospecting for subbase borrow pits at economic haulage distances is normally the first step. This usually amounts to sampling all likely sources close to the centre line and at approximately 5 to 6 mile intervals, and to locating the exact sampling points in the airphotos. Provided the sources sampled display distinctive physical characteristics, their boundaries can be demarcated accurately on the airphotos (2.4.2). After the test results become available, the road building potential of these sources and, by interpolation, of similar sources within the full area embraced by the 6 mile wide strip, can be gauged with a reasonable degree of reliability. This has been put to the test by sampling gravel from the same general feature but at different localities and also by sampling gravel from a similar feature but in a different area. Test results generally have been surprisingly consistent (3.5.9, 3.5.14, 3.5.16, as well as other examples in the texts of Chapter 3). Formations which obviously hold out no prospects, can now be completely avoided, and the prospecting effort concentrated in the more likely areas. In other words, it is now possible to plan the prospecting operations with a good degree of certainty that the borrow pits sampled will give the most economic usage of the local materials.

3.2.6. In the next stage the prospecting operations develop largely into a routine process of borrow pit sampling, which can be speeded up considerably by increasing the field party, provided the laboratory facilities are available for handling and storing large numbers of samples. The exact positions of all base, subbase, and shoulder borrow pits sampled, should still be marked on the airphotos. This information is needed for the annotation of the mosaics and later, for the detailed planning of the use of borrow pits, and for the preparation of locality diagrams for those borrow pits situated at some distance from the centre line. On projects where this latter number is appreciable, the airphotos can be very useful, as accurate locality diagrams can be traced from them in a matter of minutes. If this technique is followed, the chance of missing any significant deposit within the 6 mile wide strip is considerably reduced and, after practice, becomes negligible.

3.2.7. The use of mosaics: Mosaics of the whole region to be investigated, should be prepared at the outset and should then be used in conjunction with the stereopairs. In flat terrain unrectified mosaics will serve adequately for this purpose. General information, such as the position of farm boundaries, camp fences, and water points etc., can conveniently be added to the mosaics which can then serve as a base map for the planning of the overall field operations. The exact position of sampled borrow pits must be copied on the mosaics from the stereopairs, and the deposits which these represent, should then be delineated. Significant occurrences will be readily apparent from the test results, and by analogy with their airphoto indicators, it will be possible to demarcate other similar likely sources. On completion of the annotation in this fashion, the materials position will be available in a form which can be seen and appreciated at a glance; and if a centre line soil survey is necessary, this can be intelligently and economically planned from these annotated mosaics.

3.2.8. Personnel : No additional personnel over and above those normally used in materials investigations, are required for the application of this technique. However, either the person in charge of the field operations, or the engineer directing the work in general, but preferably both, should possess the following attributes :

(i) be observant and inquisitive;

(ii) have undergone training in airphoto interpretation;

(iii) have had many hours of practice in the use of stereoscopes;

(iv) have a basic knowledge of geology; and,

(v) be an expert in the materials field of rural road engineering. In this regard familiarity with materials specifications and the ability to relate construction practices to the workability of prospective sources, is particularly important.

3.2.9. Equipment : Items (i) and (ii) below, are essential additions to the equipment normally used for prospecting, while item (iii) may be very useful under certain circumstances:

(i) A large stereoscope is required for detailed study and annotation of the airphotos in the office. While annotating a stereopair, movement of the stereoscope itself is obviously undesirable. The stereoscope should therefore, either be capable of scanning the full overlap, or the table on which the airphotos are placed for examination, should be fitted with some mechanism, such as runners, to allow free movement along directions both parallel and vertical to the line of flight, thus enabling all parts of the overlap to be studied and annotated under one set-up. A further essential requirement of the stereoscope is that it should incorporate magnifications of the order of 1½ and 4, so that wide coverage on a small scale and small coverage but on a larger scale, are both readily available. The relative use made of the respective magnifications for any particular job, will depend on a variety of factors, but especially on the scale of the photos and the nature of the significant road building materials.

(ii) A field stereo-set is also necessary and should consist of a pocket stereoscope with magnetic feet, and a light metal table capable of taking one stereopair of photos. The photos are kept in position on the metal table by 6 small magnets. The set can easily be handled in a vehicle, and is required for stereoscopic studying of the terrain on the spot, and for ensuring that the exact location of each relevant sampling point or borrow pit site is correctly marked on the airphotos.

A pair of stereo-spectacles can be substituted for the pocket stereoscope. However, experience has shown that these have one or two serious disadvantages for this type of work. One's head is inclined to move out of focus very easily when scanning the stereopair. This results in an undue strain being placed on the operator's eyes. As long hours of stereoscopic work are necessary, this is regarded as a serious disadvantage. Sufficient practice in the use of the spectacles might however, go a long way to eliminating this complaint. In flat bushveld country another disadvantage of the particular pair used, was the small vertical exaggeration. This made it more difficult to distinguish slight depressions and rises, which are often significant from a materials point of view. In hilly country, of course, the small vertical exaggeration would not necessarily be detrimental, and might even prove to be an advantage in certain cases.

(iii) Various hand augers are often useful, especially where sand of variable thickness covers suitable gravel. The augers can be used to establish quickly areas of minimum sand cover, as well as those where the sand layer is uneconomically thick. The digging of unnecessary holes can thus be avoided, resulting in an appreciable saving of time and labour. Under extremely dry conditions, such as those prevailing in most parts of South West Africa, successful augering in sand, silts, or clays, requires the regular addition of small quantities of water. These augers have other limitations as well, and local experience is the best guide as to whether or not benefit will accrue from their use on any particular project.

3.3. SEEIS - OMITARA

3.3.1. Terms of reference : The location of the Trunk Road over a distance of approximately 27 miles between Seeis and Omitara, revolved round the selection of one of two main possiblities, designated respectively as the Northern and Southern Routes. The Northern possibility follows more or less the existing road, while the Southern Route runs along the boundary fences between the farms Bodenhausen 191 and Excelsior 286, Okatumba Süd B and A (192 and 197 respectively) and Muambo 130, to a point on the boundary fence between Silversands and Safari.129. From this point the route runs approximately north-east, traversing the farms Silversands and Orumbo 198, and then running immediately South of the mountains on Otjivero 202, finally to cut across Omitara West 203, and join the existing road and Northern Route on the farm De Hoop 110 (see Figs. 1 and 5). This location is about $1\frac{1}{2}$ miles shorter than that of the Northern possibility. This fact, in conjunction with the drainage and other considerations, made the selection of the latter Route an uneconomic proposition, unless the cost of the road building materials was to be appreciably less than that of the Southern Route. A materials appraisal of a strip of country effectively covering the significant area along both Routes, was therefore undertaken. The area of country involved was of the order of 150 to 200 square miles extent.

3.3.2. Geology : The region under consideration forms part of the Damara System. The annual average rainfall and significant geological occurrences are similar to those described for the Windhoek area (refer to 3.1.9 and Fig. 2). In this region however, sand deposited during flood periods often blankets both gravel sources and basic geological formations. This is especially true of the area adjacent to the Southern Route.

3.3.3. Topography and vegetational cover : The terrain is mainly flat, but does contain occasional hills and undulations (see Stereograms 8, 9 and 10). In the eastern section, the Southern Route skirts a quartzitic mountain range, which then runs in a general north-easterly direction out of region investigated (see Fig. 5). The whole area is covered by stunted acacia trees and, in certain localities by scrub bush as well. In places where thick sand occurs, yellow wood (Terminalia Sericea) and larger acacia trees may be found. After rain the grass forms a thick carpet on the otherwise bare ground between the trees and bushes.

3.3.4. Appraisal, both Routes: The general technique adopted for this type of appraisal has been described in paragraph 3.2.3. Using this approach, an abundance of good quality road building material was found to exist along both Routes (see Test Result Sheet 6 and Fig. 5). The most significant deposits usually occur on high ground and straddle many, but not all, of the hills. They consist of quartz gravels, which occur in large quantities in layers from 18 inches to 3 feet thick, and are often exposed, or found under a thin layer of sand only. Deposits lower down the slopes and on the flats, generally underlie a thicker sand cover, and tend to occur in relatively thin layers containing markedly more-plastic fines, due to the process of downward leaching. On account of the abundance of readily available high quality gravel along the Southern Route, this location became the obvious financial selection, and was hence recommended for final approval (3.3.1).

3.3.5. Photo interpretation: Stereogram 8 (stereotriplet actually) shows where gravel samples were taken from holes A, B, C, D, and E along the Southern Route (see Test Result Sheet 6 and Fig. 5). The boundaries of the sources sampled were demarcated from their topographic position, texture of vegetation, and lighter tone generally but not always, exhibited by the less plastic gravels (3.1.11). This change in tone is illustrated by the respective positions of the holes B, C, and D and the corresponding sample test results, which show the tendency of the plasticity to increase on the lower reaches. The dotted areas were marked by analogy with those actually sampled, and a few of the former, which were field checked, were found to contain visually similar quartz gravel. No attempt has been made to demarcate all likely sources, due to the wide-spread nature of the gravel occurrences. Holes F and G in Stereogram 9 (stereotriplet) are two further localities sampled along the Southern Route. The deposit represented by F, is primarily identifiable in the airphotos from its relief and texture of vegetation, while that represented by G is similar to some of the sources demarcated in Stereogram 8, although it is not quite so well defined. Test results of samples from hole G illustrate again the tendency to downward leaching of plastic fines, resulting in an increase in the Plasticity Index with depth. A few areas where similar gravel deposits can be expected, have been demarcated with dotted lines. Stereogram 10 (stereotriplet) shows a section of the proposed Northern Route along the existing road and adjacent to the Nossob River. Test results of samples from hole K and the airphoto indicators of the encompassing demarcated source, illustrate the similarity of the gravel occurrences along both Routes. Dotted areas again indicate some of the other possible gravel sources.

3.3.6. <u>Time factor</u>: Using the technique developed and the experience gained under similar environmental conditions in the Windhoek area, a period of two days was all that was required for the field identification of significant airphoto variations, and for the sampling of typical potential road building gravels (3.2.3, and 3.1.4 to 3.1.13). After the test results became available, it was possible to annotate a mosaic showing both Routes, with detailed materials information similar to that shown in Stereograms 8, 9 and 10. This information was available within a relatively short time, to those responsible for the final decision on the location of the route. Had conventional methods been used, a much longer period of field work would have been necessary to accumulate the same amount of information with an equivalent degree of reliability.

3.4. KLEIN OMATAKOS - SUKSES

3.4.1. <u>Introduction</u>: The initial investigations and planning of the road from Okahandja to Sukses, a distance of 66.5 miles, was undertaken by a firm of consulting engineers (see Fig. 1). For the last 15.5 miles, that is from the Klein Omatako Mountains to Sukses, the Consultants recommended, (a) that shoulder material be transported for a distance of up to 13.5 miles and, (b) that the basecourse be either constructed from crushed natural gravel for the full distance, which recommendation would have involved leads of up to 15.5 miles; or alternatively, that the crushed natural gravel be used for approximately 9 miles, followed by 6.5 miles of experimental base constructed from lime- and/or bitumen-stabilized sands (see Fig. 6). These proposals would have resulted in an expensive road and were not immediately acceptable to the Administration. The Consultants were not prepared to carry out any further work, being convinced that they had already recommended the best financial solution under the circumstances. The Roads Branch of the Administration thus undertook a materials appraisal of the area, using the method of prospecting developed from the aid of airphoto interpretation (3.2.4 to 3.2.6).

3.4.2. Environmental conditions (refer to Fig. 6) : The Omatako and Klein Omatako Mountains, situated in the extreme South of the area under consideration, are formed of shales and sandstones from the Stormberg Series of the Karroo System, and of intrusive dolerite, usually in sheet form. They owe their present day existence as mountains to a concentration of this dolerite, which has proved more weather resistant than either the shales or the sandstones, and has tended to protect these latter formations. The foothills are littered with boulders and pebbles of quartzitic and sandstone origin, deposited around the same period. To the North, the sandstones and shales have weathered considerably faster, and have subsequently been covered by thick sand to form a very flat topography. Auger holes were sunk to 20 feet and more at various places over a wide area in this plain, without encountering rock formations. Immediately South of Sukses the basic geology changes to that of the Damara System, but there is no corresponding change in the flat nature of the topography (3.5.2. to 3.5.5.). The depth of the sand cover, however, is considerably reduced, and is often as little as 5 to 6 feet. Surface limestones have formed in this area, as well as in the vicinity of the Klein Omatako Mountains; but in the intermediate area no such deposits occur, due in part no doubt, to the extremely thick sand cover which is not so conducive to the development of calcretes. The area is traversed by three rivers, the Omurambo Omatako, the Ebuameno River, and the Sukses Omurambo, which flow in a general easterly direction. The annual average rainfall is of the order of 360 mm. (14.1 inches), and after rain, the whole area is covered by thick grass in addition to the permanently established acacia trees (see Fig. 2). Scrub bush is encountered in isolated localities and is often associated with surface limestone occurrences.

3.4.3. Shoulder material: Specifications for shoulder material are not particularly exacting, and can usually be met from reasonably spaced local sources. Hence as a first step, it was considered essential to reduce to reasonable proportions, if possible, the maximum lead resulting from the Consultants' proposals. Test results of the surface limestones immediately South and West of Sukses, quickly confirmed the Consultants' statement regarding its general high plasticity and inferior quality. Prospecting effort was thus concentrated on the eastern side of the new centre line, where the limestones appeared to be of better quality. A suitable surface limestone deposited, designated borrow pit 64.5, was located in the position indicated in Stereogram 11 (see Test Result Sheet 7). A close stereoscopic study of the airphotos, shows that the boundaries of the deposit can be delineated easily from a marked difference in the texture of vegetation. Small scrub bushes cover the area of the limestone occurrence, while the encompassing terrain is covered by the usual acacia trees. This difference is readily detectable on the ground as well, but under the conditions prevailing, the chances of locating so small a deposit at such a distance from the centre line by normal ground prospecting methods, are remote. A second limestone deposit of similar quality was located about 6 miles further South, and 1½ miles West of the centre line (see Test Result Sheet 8). This deposit and adjacent likely sources were demarcated on the airphotos by direct analogy with a calcrete deposit already located by the Consultants. The airphoto indicators are a slightly raised topography and a lighter grey tone (see Stereograms 12 and 13). Airphoto interpretation was further used in assessing that no suitable deposit within 3 miles of the centre line, existed between these two borrow pits; and due to the success previously achieved by this method, this assessment was accepted as reflecting the true position (3.2.4 to 3.2.6).

3.4.4. <u>Basecourse</u>: The basecourse investigation was started at the Klein Omatakos, where the Consultants had recommended the use of crushed natural quartzite gravels. Prospecting was aimed at trying to locate some source which would lend itself to lime stabilization, and so provide an alternative to crushing. Intensive work in the area confirmed that nothing of significance had been missed. However, a dolerite dyke, or sheet, of which the Consultants were unaware, was located with the aid of the airphotos within 0.4 miles of the centre line. The main and subsidiary exposures, are a mere 12 to 15 feet, and 3 feet wide, respectively. Their individual positions are indicated in Stereogram 14 by the tips of arrows A and B (see Photos 6 and 7). The chief airphoto indicator is undoubtedly the linear form of the exposure, which, on account of its extreme narrowness, is only readily discernible when viewed through a stereoscope or lens of at least a four magnification. A difference in tone of materials along bare sections, and a lack of growth where the adjoining country is heavily vegetated, is also apparent (4.5.1 and 4.5.4). The dolerite gravel is of sufficiently good quality to have been used as a lime-stabilized base, but unfortunately the material along the contacts is of such inferior quality, that the admixing of even a small percentage thereof, would render the source useless. The narrowness of the outcrop therefore, precluded the practical possibility of its use as a basecourse material. The exposure does serve to illustrate, however, the size of source which can be located by this method (3.2.4 to 3.2.6).

(Photo by H. Roth)

Photo 6: A dolerite outcrop of barely 12 to 15 feet in surface width, which was located from airphotos. In the background the Omatako Mountains can be seen.

(Photo by H. Roth)

Photo 7: A subsidiary to the exposure of dolerite shown in Photo 6. The dolerite is the centrally placed, dark coloured, formation bordered by reddish material. The width of the occurrence is 3 foot.

3.4.5. North of the precincts of the Omatako and Klein Omatako Mountains, and up to the change in basic geology close to Sukses, conventional basecourse material does not exist within economic depths of the surface (3.4.2). A few auger holes in features selected from the airphotos to cover this region effectively, were sunk for confirmation purposes before proceeding with detailed prospecting in the vicinity of Sukses. Systematic checking of all features observed on the airphotos in this latter area, led to the discovery of a number of quartzose lateritic gravel deposits, which had formed over granitic rocks in layers of approximately two foot in thickness. Five to seven feet of sand usually cover these gravels, and in consequence surface sign is neglibible. The deposits are situated well East of Sukses, the closest to the centre line, and fortunately the best in quality and quantity, being just under 4 miles away (see Fig.6).

(Photo by H. Roth)
Photo 8: Quartzose lateritic gravel near Sukses being stock-piled for use in the basecourse. Note standing water due to poor drainage conditions.

The position of borrow pit 68.2, located in this particular source, is indicated by an arrow in Stereogram 11 (see Test Result Sheet 9). Its approximate boundaries were delineated on the airphotos from, (i) a slight depression in the topography, (ii) the texture and height of the trees and, (iii) a darker grey tone, due to the relatively poor surface and sub-surface drainage conditions, despite the non-plastic nature of the soil fines (see Photo 8). The depression is actually so slight that it is difficult to observe on the ground, but is definitely revealed by the vertical exaggeration and wider field of vision provided by a stereoscope. The trees are of the yellow wood variety, and grew taller but more sparsely than the acacia trees of the encompassing terrain. The effect is noticeable in the airphotos from the relatively open textural appearance of the yellow wood trees. The deposit is not very well defined, and includes ordinary granitic pockets within its area (see borrow pit diagram on Test Result Sheet 9). These pockets can be noticed under close stereoscopic examination, but the intricacy of their boundaries, together with the scale of the photos (1 in 36,000), makes exact demarcation difficult. The locality indicated by arrow A in Stereogram 11, also contained a small amount of lateritic gravel of similar quality.

3.4.6. The test results of these two deposits meet basecourse specifications in every respect except grading (see Test Result Sheet 9). This shortcoming could easily have been rectified by screening, but in view of its otherwise good results and the exceptionally low traffic counts

(50 to 150 v.p.d), it was decided to construct the basecourse from the natural gravel, but to a sub-standard grading specification, and in so doing, keep costs to a minimum. The final basecourse plan accepted and subsequently followed during construction, was to use the crushed natural gravel from the Klein Omatakos for approximately half the distance recommended by the Consultants, followed by natural lateritic gravel for the remaining 7½ miles. Photo 8 shows some of this lateritic gravel being stock-piled in borrow pit 68.2, in preparation for removal to the road.

3.4.7. Conclusions: In an area previously prospected intensively by normal methods, airphoto interpretation was instrumental in achieving the following major cost reductions (see Fig. 6) :

(i) The maximum haul distance for shoulder material was reduced from 13.5 to 7.0 miles.

(ii) The possible need to construct 6.5 miles of experimental lime- and/or bitumen-stabilized sand base was eliminated.

(iii) The maximum lead for basecourse gravel was reduced from 16.5 to approximately 9.0 miles.

(iv) The difference in cost between the construction of approximately 7.5 miles of basecourse with natural lateritic gravel instead of with crushed natural quartzite gravel, was saved.

3.5 SUKSES - OTJIWARONGO

3.5.1. Introduction: This project embraced a full materials investigation from an initial appraisal of the road building potential along a possible western route, to detailed prospecting along the route eventually selected (see Figs. 1 and 7). Due in general to the geology, topography, and natural vegetation, the location of suitable road building materials posed most of the problems referred to in section 3.1, and it was in finding the most economic solutions to these difficult conditions set by nature, that the technique of using airphoto interpretation as an aid to prospecting was developed (section 3.2).

3.5.2. Geology (refer to Fig. 7) : The basic, or solid, geology of this region is formed from rocks of the Post-Damara Complex. These rocks were formed by pressure and heat metamorphism from mica-schists, quartzites, and limestones, from the Damara System. The mica-schists and quartzites were altered into granites by the process known as "granitization", and are folded in many places into the older crystalline limestone formations, which also underwent re-crystallization during the metamorphic process. Granite is the predominant formation with bands of crystalline limestone, often interbedded with quartzites and granites, traversing the area in approximately a north-easterly direction (see Stereogram 20). The hills are formed by one or other of these rock types, or by a mixture of them all (see Photos 13 and 14 on page 52). However, on the farms Omusema-Uarei and Kahlenberg on the extreme westerly fringe of the region investigated, a prominent mountain range formed of beds of sandstones, sandstone conglomerates, and shales, from the Stormberg Series of the Karroo System, also occurs. These mountains played no direct part in the road project, their closest point being well over 4 miles West of the new centre line.

3.5.3. From Sukses northwards to the Okateitei River, Tertiary deposits of sand and gravel, generally from 6 to 8 feet thick, cover the basic granite and limestone formations. North of the Okateitei River these deposits tend to disappear, leaving the granite and limestone either exposed, or covered by only a thin layer of residual soil. Surface limestone, or calcrete as it is often termed, occurs throughout the whole area, and often attains some considerable depth. Its most common occurrences are in sheet, nodular, or powdery forms.

3.5.4. West of the Sukses Omuramba old raised river beds are a prominent feature. These show that the earlier drainage pattern was in the opposite direction to that of the present drainage system. This reversal in direction was caused by upheavals in the vicinity, which generally altered the relative levels of the topography (see Stereogram 15, and Photo 12 on page 50).

3.5.5. <u>Topography and vegetational cover (refer to Fig. 7)</u>: The topography from Sukses to the Okateitei River is exceptionally flat. North of the Okateitei River the country undulates and occasional hills form conspicuous features. The annual average rainfall in this region is of the order of 450 mm. (18 inches), which has resulted in a dense vegetational coverage of either acacia or yellow wood (Terminalia Sericea) trees, or of scrub bush (see Fig. 2; and Photos 1, 2 and 11 on pages 21, 22 , 48 respectively). After rain the grass forms a thick carpet to the otherwise bare ground between the trees and bushes (see Photo 3 on page 22).

3.5.6. <u>Route location (refer to Fig. 7)</u> : From Sukses to the farm Slagveld, a distance of approximately 9 miles, the location of the new road was determined mainly by drainage considerations and conveniently situated farm boundaries. However, from Slagveld northwards to about the Waterberg turn out, a distance of nearly 28 miles, there were three possible routes, which became known as the Western, the Existing and the Eastern Routes. The Western Route was the most direct and made maximum use of watersheds. However, it cut directly across farms creating water problems in many of the farmers' camps. The Route could only be justified if a large financial saving would result, and this depended to a great extent on whether or not the materials position offered a sufficient advantage. The Existing Route generally followed the location of the old road, around which all the farms had been developed. It had the added advantage of utilizing the bridge over the Okateitei River. This did not result in a particularly desirable geometric location at this point, but the Route was favoured as being the most economic solution under the circumstances. The Eastern Route on the other hand, would necessitate the construction of a new bridge over the Okateitei River, and would also involve the sub-division of farm camps for approximately 10 miles between Slagveld and the Ohakaua boundary fence. For these reasons, this Route was not considered seriously at this stage, but was merely regarded as a possibility.

3.5.7. Before a choice between the Western and Existing Routes could be made, a preliminary materials survey was necessary along the Western Route, especially where this Route was an appreciable distance West of the old road. The critical distance involved, was about 18 miles. With the aid of the airphotos, it was quickly established that no natural high quality gravels are available along this section, and crushing of crystalline limestones or quartzites would have been necessary. These rock formations are equally available along the Existing Route, which in consequence became the obvious selection.

3.5.8. Re-location, Eastern Route: Prospecting now started along the Existing Route. One of the first borrow pits sampled (B.P. 75.5) is about three-quarters of a mile East of the centre line and on the farms Somerkoms and Apostle. The gravel layer, consisting essentially of quartz pebbles and decomposed granite, is approximately 2 feet thick, and occurs under a 3 to 4 ft. layer of sand. Test results showed the gravel to be of good subbase quality, a portion of the borrow pit even being suitable for use in the base (see Test Result Sheets 10 and 10 A). There is very little surface sign to betray the presence of the gravel, but the feature in which the borrow pit is located, is easily recognisible on the airphotos. It forms a slight depression and is free of tree and bush vegetation (see Stereogram 16 and Photo 9).

(Photo by H. Roth)
Photo 9: Site of proposed base and subbase borrow pit 75.5 on the farms Somerkoms and Apostle. Note the lack of surface sign, and of tree and bush vegetation.

3.5.9. Immediately after the potential importance of such features was realized, the airphotos were studied in detail, and all likely looking features were noted. One of those in the same vicinity, but much closer to the centre line, was an obvious choice for further investigation. It was found to contain gravel only slightly inferior to that of borrow pit 75.5, but still sufficiently good to be used as a lime-stabilized base, or as a subbase in its natural state. The deposit (B.P. 75.6) is limited in quantity, but constitutes a useful supplementary source of base and subbase material at this point (see Stereogram 16 and Test Result Sheets 11 and 11 A). The airphotos further revealed similar features occuring to the North, practically as far as the Okateitei River (see Mosaic 1). To ascertain whether or not the soil profiles in these features bore any resemblance to those already sampled, a similar site (B.P. 83.3) was investigated 7.8 miles to the North, and close to the Okateitei River (see Stereogram 17). The soil profile and gravel test results were found to be surprisingly consistent (see Test Result Sheet 12). As a final check, a few inspection holes were dug in various features between these borrow pits. The same general profile was encountered East of the dotted line X - Y indicated in Mosaic 1. Similar looking features to the West of this line however, were found to contain either gravel with highly plastic fines, or depths of sand in excess of 10 feet. In most of the features the amount of surface sign is negligible.

3.5.10. By the use of the technique of airphoto interpretation in conjunction with a minimum amount of field investigation and laboratory testing, it was now possible to predict with a high degree of certainty, that good quality road building material in virtually unlimited quantities, was available East of the line X - Y, and North of the Apostle - Somerkoms boundary fence for a distance of about 8 miles to the proximity of the Okateitei River (refer to Mosaic 1). Over much of this length the centre line adopted coincided with that of the old road, and ran practically parallel to, but 1 to 2 miles West of, the X - Y line. This represented a large amount of dead haul, and hence considerable unproductive expense, whereas the discarded Eastern Route lay within the area of good material over the whole length involved. In view of this, the question of re-location along the Eastern Route received serious consideration, and without calling for further field checking, the decision was made to adopt this Route in its entirety. It was estimated that the saving in transport costs would more than pay for the new bridge over the Okateitei River, and that this in its turn would result in a much improved geometric location (see Stereogram 19).

3.5.11. Prospecting, base and subbase: Subsequent intensive prospecting along this section confirmed the original assessment. Prospective natural base, lime-stabilized base, and natural subbase gravels were tested and proved in large quantities. The position of specific borrow pits established are indicated in Mosaic 1 (see also Fig. 7). Stereogram 18 is included for detailed stereoscopic examination of further typical examples of the mode of occurrence of these deposits. It shows in particular a source of quartzose lateritic gravel (B.P. 79.0) situated about half way between the original features tested (see Test Result Sheet 13). It will be noted from the borrow pit spacings that the maximum lead for subbase material is under 3 miles, and that the amount of dead haul is negligible. These leads could have been decreased still further if so desired.

3.5.12. Due to the vegetation and the geological and topographical nature of the country, weeks of arduous investigation would have been required by established prospecting methods, in order to trace this gravel and to arrive at the true facts (3.5.2 to 3.5.5). It is also not unlikely that the areal extent of the deposits would not have been appreciated, as under comparable circumstances South of Kalkrand (3.1.14 to 3.1.19).

3.5.13. South of the Apostle - Somerkoms borrow pit first sampled and West of the centre line, numerous similar looking features also occur (see Stereogram 16). Strategically placed auger holes showed the sand cover in these to be invariable over 10 foot in thickness. Some isolated features East of, or straddling, the centre line however, were found to contain gravel at economic depths which is of subbase quality (see area of B.P. 72.4 in Stereogram 16; and Test Result Sheets 14 and 14 A). These latter features were all pin-pointed on the airphotos, systematically field checked, and then the most economically situated of them, selected for further laboratory testing. In this way, adequate quantities of suitable gravel were found for building the road from Sukses to within economic reach of borrow pits 75.5 and 75.6 (refer to Fig. 7).

3.5.14. In the country along both sides of the centre line, and stretching North of the Okateitei River for a distance of 5 to 6 miles, another useful source of subbase material was found, the significance of which could easily have been missed without the aid of airphotos used in the way described previously (section 3.2). The gravel consists of decomposed granite of low plasticity, usually underlying a thin layer of pebble-marker quartz gravel, or of sand. The low plasticity areas occur in irregular shapes of varying sizes within the main granite mass, whose general Plasticity Index is in excess of 10, rendering this material unsuitable for use as natural subbase. The marked difference in Plasticity Index of adjacent occurrences within the same granite mass, is primarily due to variations which were established during the process of "granitization", and to a lesser extent to the subsequent degree of weathering and decomposition. Despite the irregularity in

(Photo by H. Roth)

Photo 10: A view in area A of borrow pit 86.2. In the foreground is the beaconed hole number 1 (see Test Result Sheet 15). The positions of further holes can be seen in the background from the small heaps of gravel. The larger acacia trees on the extreme left and right of the photograph and also in the background, mark the boundaries of the suitable material. Centrally placed stunted acacia trees grow within the approved area. No definite depression can be detected in the photograph.

shape, some of the low plasticity areas are sufficiently large to be workable in practice. The boundaries of three such areas in which subbase borrow pits 86.2, 87.2, and 87.9 were established, are demarcated in Stereogram 19 (see Test Result Sheets 15, 15 A, 15 B, 16 and 17). The tips of arrows A and B indicate yet other unsampled but prospective subbase sources, which have been left undelineated so as to allow maximum clarity for the recognition of the airphoto indicators. One of the most obvious of these, is the concentration of large thorn trees around the borders of the suitable areas. A slight depression relative to the adjacent terrain, accentuated by stereoscopic exaggeration, is also easily discernible. These depressions tend to impede local surface drainage, and this probably accounts for their distinctly darker grey tone. From the ground the depression is not readily noticeable. On account of this, and perhaps even more due to the irregular shapes of these occurrences, the difference in the pattern of the terrain is extremely difficult to detect by ground observation alone. Photo 10 illustrates this as well as possible under the circumstances.

3.5.15. If conventional methods had been used, and the possibility of a variation in the materials had not been recognized, the normal approach would have been to grid a typical area with trial pits. Either visual examination of such holes, or visual examination confirmed by test results, would have indicated a wide variability in quality, which could in all likelihood have led to the erroneous conclusion that workable subbase gravel was not available. The fact that two distinctly different materials, from a road building point of view, were the primary cause of the apparent variation, might not have been appreciated. Had the project been one of the few in which a soil engineering map had been produced from airphotos, the whole area would correctly have been delineated as "granite", and the areas of low plasticity would have remained undifferentiated with the probable ultimate result being the same as that of normal prospecting (section 2.4).

3.5.16. Closer to Otjiwarongo the predominant granite formation was comprehensively tested during the materials appraisal along the Western Route. It was found to be generally of poor quality with the exception of that occuring in contact with the bands of crystalline limestone, which was often of subbase standard. When detailed prospecting activities along the Eastern Route reached this area, the crystalline limestone formations in the proximity of the centre line were marked up on the airphotos, and without further loss of time in prospecting, granite borrow pits were sampled at the most economic localities along these contacts (see subbase borrow pit spacings on Fig.7). This is illustrated in Stereogram 20 where two bands of crystalline limestone have been delineated. The position of an area tested during the initial investigation along the Western Route is indicated by arrow A (see Test Result Sheet 18). This source is too far away to serve the Eastern Route. In consequence borrow pit 99.6 was established along the same band of crystalline limestone, but adjacent to the new centre line (see Test Result Sheets 19 and 19 A). The quality of this gravel was found to be similar, and if anything more consistent, than that previously test. Thus the time which would normally have been required for further prospecting, was saved. These granitic sources of possible subbase gravel, are not directly distinguishable in the airphotos as are most other occurrences of road building material described in this thesis; but have to be established by prospecting for suitable areas along the contacts with the bands of crystalline limestone. Potential areas are therefore recognized from the airphoto indicators responsible for showing up the bands of crystalline limestone. These are, (i) the linear form of the bands themselves (4.5.1 and 4.5.4), (ii) their darker grey tone, probably due to the relatively poorer drainage conditions and, (iii) their texture of vegetation due to the predominance of scrub bush and to the sparsity and small size of the acacia trees. Solid crystalline limestone exposures are common in these bands, and soil cover, where it does exist, is often shallow. The bands thus tend to support more scrub bush and less thorn trees, especially those of comparable size, than the bordering granite formation (see Photo 11).

(Photo by H. Roth)

Photo 11: Scrub bush and stunted acacia trees growing over a band of crystalline limestone near Otjiwarongo. Note the larger trees in the background which grow on granitic formation.

3.5.17. Immediately South of Otjiwarongo no natural, or lime-stabilized, basecourse quality gravels are available. The crystalline limestone which is plentiful, is an easy material to crush, and would normally have been the most suitable proposition in this area. However, during the materials investigation between Otjiwarongo and Otjikango, a large calcrete deposit, which proved suitable for use as either a screened or lime-stabilized basecourse, was located just North of Otjiwarongo (3.6.11). It was considered cheaper to use this material to fill the gap South of Otjiwarongo, despite the long hauls of up to 13 miles which would be required, than to develop a crusher site in the crystalline limestone for only a small quantity of gravel. This point illustrates the importance of a wide coverage where natural, or cheaply processed, basecourse materials may be available.

3.5.18. Prospecting, shoulders: The surface limestones are wide-spread throughout the whole region, and hence were thoroughly tested in the early stages of the investigation. They are generally of very inferior quality, the best proving suitable for shoulders only. For this reason they were of little importance except near Sukses, where shoulder material was hard to come by, due to the general high plasticity of the surface limestones in this particular vicinity. The airphotos were studied with a view to locating possible better class deposits. Two slightly raised reef-type features in an otherwise exceptionally flat landscape, were noticed, the nearest being about 1.3 miles due East of the centre line, and 3 miles from Sukses (see Stereogram 21). These features proved to consist of calcrete of better quality, and suitable for use in the shoulders (see Test Result Sheets 20 and 21). The chief airphoto indicators are, (i) the raised topography mentioned previously and, (ii) a markedly lighter grey tone. The terrain encompassing these features also consists primarily of calcrete, but of the inferior quality generally found in this area. These two deposits solved the shoulder-material problem along this section.

3.5.19. Prospecting, surfacing materials: If suitable low-cost sand proved to be available, a sand surface dressing was to be specified for the surface treatment. The grading of the sand necessary for this type of surfacing, limits the quantity of material passing the 100 mesh screen to not more than 2%, which requirement often makes suitable deposits hard to find. Fortunately in this region many of the river and stream bed sands are of granite origin, and it was possible to select deposits with suitable grading characteristics, without too much difficulty. In the southern and central areas, the rivers most likely to yield satisfactory results were the Sukses Omuramba and the Okateitei River. These were obvious selections even without the aid of airphotos, and suitable deposits were sampled in both river beds (see Stereograms 15 and 17, and Test Results Sheets 22 and 23). Closer to Otjiwarongo suitable sand is not so plentiful, and localities for prospecting are not so obvious. Recourse was again made to the airphotos, and all likely-looking stream beds were chartered and systematically checked, until a suitable deposit was located (see Stereogram 20 and Test Result Sheet 24).

3.5.20. If prospecting with the aid of airphotos, the old raised river beds West of the Sukses Omuramba also become obvious potential sources of suitable sand. From the ground however, the limited areal view precludes the possibility of observing the drainage pattern, and makes recognition of the true nature of the deposits much more difficult. This is assuming of course, that at least a portion of the river beds would be found if prospecting entirely by normal methods (see Stereogram 15 and Photo 12). The old river bed adjacent to the sand surface dressing deposit (68.5) established in the Sukses Omuramba, was sampled at the same time as the latter, and to a depth of about 6 feet. The top 3 to 4 feet of sand at this locality, is too finely graded for sand surface dressing, but it becomes progressively coarser with depth and would probably have met specifications below a depth of 6 foot. On account of the suitable sand nearer to the centre line in the bed of the Sukses Omuramba, further testing of the old river deposits was not pursued.

(Photo by H. Roth)

Photo 12: A downstream view along a section of the old raised river bed West of the Sukses Omuramba. River sand from a hole can be seen in the foreground. Note the slightly raised topography and the concentration of vegetation towards the boundaries of the river bed.

3.5.21. At a later date sand was urgently required for slurry sealing a section of single surface treatment just South of the Klein Omatakos, where the whip-off had become excessive. The grading limits specified for the sand are critical, and must be met if the slurry seal is to be successfully laid. The top 3 to 4 feet of sand in these old river beds, screened through a $\frac{1}{8}$ inch mesh, meets these specifications, and proved very useful in this particular case (see Fig. 8). This source may prove of still greater importance if slurry seals are to be used for future maintenance of the bitumen surface in the area.

3.5.22. The existence of these old river beds was first discovered during stereoscopic examination of the airphotos, and was later confirmed by field inspection, and finally by the prospecting holes referred to. The most important airphoto clue to the true nature of the occurrence, is the drainage pattern, which is obviously that of a river and accompanying tributary system. The boundaries of the beds themselves can be delineated from their raised topography, and often from a concentration of vegetation as well (see Stereogram 15 and Photo 12).

3.5.23. Airphoto indicators, summary: The chief indicators used for the recognition of the different formations and deposits, are summarized below for easy reference:

(i) Surface limestone (calcrete): Generally the main indicator is the relatively darker grey tone, which is often caused by the indifferent drainage conditions provided by the material itself. A notable exception is that of the relatively better quality calcrete near Sukses (3.5.18). Another important indicator is often the texture of vegetation imparted by a predominant scrub bush growth, which is usually found in areas of shallow soil covering sheet or similar types of calcrete occurrences (3.4.3).

(ii) Old river beds: See paragraph 3.5.22.

(iii) Tertiary gravel occurrences: See paragraph 3.5.8.

(iv) Granite: Being the primary formation, granite was not normally differentiated. Its indicators in regard to relief, natural vegetation, and grey tone, are naturally complementary to those of the surface and crystalline limestones. However, the granite hills or portion of hills, are distinguishable in the airphotos from those formed by crystalline limestone, from the indicators of slope and texture of material. Granite hills, or portions thereof, have a steep slope and a rough surface texture caused by the numerous large granite blocks, or boulders, scattered over the surface. On the other hand, the crystalline limestone hills, or portions thereof, have a relatively flatter slope and a smooth surface texture. This is illustrated in Stereogram 20 and also by Photos 13 and 14. The indicators used for distinguishing the low from the high plasticity granite immediately North of the Okateitei River, have already been discussed (3.5.14).

(v) Crystalline limestone: See (iv) above and paragraph 3.5.16.

3.5.24. Forms of drainage, which are often of primary importance as indicators, have played only a small rôle in this area due, in large measure, to the extremely flat topography, to the absorbtion characteristics of the Tertiary deposits, and to the vegetational cover.

(Photo by H. Roth)
Photo 13: One of the two granite hills known as Tweekoppies (see Stereogram 20). Note the rough texture caused by the granite boulders.

(Photo by H. Roth)
Photo 14: A crystalline limestone hill near Otjiwarongo. Note the smooth texture and flat side slopes compared with those of the granite hill shown in Photo 13.

3.6. OTJIWARONGO - OTJIKANGO

3.6.1. Introduction: The location of the road between Otjiwarongo and Otjikango, a distance of approximately 24 miles, was fixed to within narrow limits by the presence of the railway line, which follows farm boundaries close to the shortest possible route (see Figs. 1 and 9). The question did arise however, as to whether to retain the existing location West of the railway line, or to re-locate on the eastern side. In considering this problem, the desirability of minimizing the number of railway crossings required for the transport of basecourse and subbase material, was an important factor. The project therefore, initially necessitated a full materials appraisal of a six mile wide strip of country with the railway line as the approximate centre. After a decision on the exact location had been reached, the problem resolved itself into establishing the most economic sources of material for the construction of the road to bitumen surface standards, and to a 7,000 lb. design wheel load.

3.6.2. Geology: The general geological description of the country between Sukses and Otjiwarongo, is also applicable to this area (3.5.2 and 3.5.3). However, North of Otjiwarongo crystalline limestone forms all the hills and mountains of any significance, and is also the predominant geological formation. Occurrences of granite are occasional, and are limited in areal extent. Exposures of quartzites are also rare, only two having been found, one just North of Otjiwarongo, and the other a little over a mile West of Otjikango.

3.6.3. The surface limestones, or calcretes, are spread much wider than in the region between Sukses and Otjiwarongo, and obliterate the basic geological formations over large tracts of country. This is undoubtedly due to the predominance of the crystalline limestone formations, from which calcium carbonate has been carried in solution by rain water, to be precipitated later into surface limestone. Two principal forms have developed, and are referred to respectively as sheet and nodular calcrete. The sheet calcrete usually occurs in the plains in a massive form underlying 2 to 3 feet of soil, and is exceedingly difficult to pick. The nodular calcrete, which often contains lime-coated rock fragments, is found in both sloping ground and relatively flat terrain. Surface limestones in boulder and in fine powdery forms, are also present, but are a relative rarity.

3.6.4. Topography and vegetational cover (refer to Fig. 9): North of Otjiwarongo, and for a distance of approximately 10 miles, the country undulates gently with isolated crystalline limestone hills forming prominent features on the eastern side. The direction of the main drainage naturally follows the slope of this topography from East to West. After this, and up to about four miles from the end of the section, the terrain traversed by the road is exceptionally flat, but over the last 4 miles the country begins to undulate again. Crystalline limestone hills and mountains appear two to three miles West of the centre line, and from about mile 15 northwards; but despite these mountains no main drainage system has developed in this region, and any drainage there might be, is purely local.

3.6.5. The annual average rainfall does not differ appreciably from that quoted for the Sukses - Otjiwarongo region (see 3.5.5 and Fig. 2). The tree vegetation is likewise similarly dense, except in portions of the flat terrain where sheet calcrete prevents all but a few acacia trees from taking root. The predominant types of trees encountered are acacia and apple. In one locality only are yellow wood trees to be found (3.6.14 and 3.6.15). Scrub bush occurs in various places, and a thick grass carpet covers the whole area after rain.

3.6.6. Exact road location: There was no decisive pointer as to the side of the railway line on which to locate the new road. A detailed analysis, including a materials assessment, was therefore instituted. By normal prospecting methods and in the time available, it would have been difficult to hazard an opinion with any degree of certainty, as to which, if any of either, is the more favourable side from the materials point of view; especially bearing in mind previous South West African experience of isolated high quality deposits which, if they occurred, could quite easily establish a definite preference with far reaching financial implications (paragraphs 3.1.14 to 3.1.19 and sections 3.5, 3.7, and 3.8). However, employing airphotos as an aid, a relatively short time sufficed to arrive at the conclusion that neither side held any appreciable advantage over the other (3.2.3). Thus the final decision to locate along the existing road on the western side of the railway line, was not influenced one way or the other by the materials position.

3.6.7. The results of subsequent detailed prospecting, admittedly mainly West of the railway line so as to obviate the necessity for a level crossing wherever possible, brought to light no additional information which could have influenced the original assessment. A similar materials plan could equally well have been achieved on the eastern side, had the necessity arisen. Sufficient borrow pits were established on this side during the preliminary work to substantiate this claim (see Fig. 9). In other words, the accumulation of the detailed information necessary for formulating a materials plan on such a project, showed that nothing of significance had been missed in the initial assessment. In South West Africa, even after a detailed materials investigation by normal methods of prospecting has already been completed, additional work will often uncover information which completely changes the material picture, even to the extent that far-reaching re-planning becomes a necessity at a late stage in the project. Sections 3.1 and 3.4 cite specific cases in point.

3.6.8. Preliminary prospecting: Testing done prior to the decision on the exact location of the road, indicated that both the granites and the calcretes are generally of a better quality than those encountered between Sukses and Otjiwarongo (3.5.16 and 3.5.18). The granites were found to be consistently of subbase quality, while deposits of nodular calcrete to meet both mechanically processed basecourse and shoulder specifications, were obtainable without too much difficulty (see Test Result Sheets 27, 27 A, 29 and 29 A). However, calcrete deposits of natural subbase and lime-stabilized basecourse quality, proved much more difficult to locate, due to the fact that calcrete of a sufficiently low plasticity to allow for the normal variation of Plasticity Indices within a borrow pit area, is not readily discernible in the airphotos.

3.6.9. The marked improvement in the general quality of the granites North of Otjiwarongo, is probably due to differences in the metamorphic processes, and to the relatively small areal extent, and in consequence proportionately greater contact zone, of these occurrences (see Stereograms 22 to 25, and refer to paragraph 3.5.23 (iv)). The superior road building quality of the calcretes North of Otjiwarongo, cannot easily be accounted for by a difference in climatic conditions, if present day conditions, which vary very little between Sukses and Otjikango and are favourable to the formation of calcretes, are any guide (see Fig. 2 and paragraph 3.7.4). The improvement is much more likely to be ascribable to some other cause. It is possible that the predominance of the crystalline limestone formations North of Otjiwarongo, not only gave rise to a wider distribution of surface limestones, but to a more rapid development as well.

3.6.10. Prospecting, base: Apart from the screened nodular calcrete already mentioned, other standard basecourse materials available are, (i) crushed sheet calcrete, (ii) crushed crystalline limestone and, (iii) one deposit only of screened quartzose lateritic gravel situated over 2 miles from the road and on the eastern side of the railway line. From economic considerations, it was decided to concentrate on trying to locate sufficient sources of nodular calcrete close to the centre line, which, after screening and recombining with a binder, would be suitable for use in the basecourse. On account of the anticipated processing, and of the fact that to expose the calcrete normally requires the removal of 3 feet or more of sand, a haul distance of about 5 to 6 miles was calculated to give the ideal borrow pit spacing.

3.6.11. A borrow pit to meet the above requirements was actually tested during the preliminary work. It is situated 1.3 miles North of Otjiwarongo, and about 0.4 miles East of the road (see Fig. 9, Stereogram 26, and Test Result Sheets 25, and 25 A to 25 D). Prospecting, if successful, was therefore only required in the vicinity of miles 11.0 and 21.0. With the aid of the airphotos, it was possible to concentrate further the prospecting to areas in the calcrete itself, which were likely to produce satisfactory results. In such areas the acacia trees grow larger and more profusely than in terrain where only sheet calcrete occurs (3.6.5). The forms of calcrete which encourage a more luxuriant growth, are the honeycombed structures of boulder and nodular calcrete, and powdery limestone with its high percentage of voids. These forms provide an easier access for both roots and rain water than the compact nature of the massive sheet calcrete. This difference in vegetation, accompanied by a lighter grey tone for the more densely wooded areas, is easily discernible in the airphotos (see Stereograms 23, 24, and 26).

3.6.12. The terrain to the West of mile 11.0, contains a number of likely areas **interspersed** in a large region of sheet calcrete. These areas were marked up on the airphotos, and given a priority order for investigation, based on both haul distance and their positioning relative to the centre line. In the first area prospected, soft powdery limestone was encountered, but the second area produced a good nodular calcrete gravel containing an appreciable amount of lime-coated quartz aggregate, in which a borrow pit to meet the requirements was later established (see Stereogram 23 and Test Result Sheets 26 and 26 A). Immediately West of the centre line, and in the vicinity of mile 21.0, most of the country apart from the band of crystalline limestone and adjoining granitic areas, can be considered as a potential source of suitable calcrete (see Stereogram 24). In this region, a little more prospecting effort was needed before a suitable deposit was discovered, due mainly to the increased occurrence of unsuitable powdery, or boulder, calcrete. A very good deposit of nodular calcrete, with typical honeycombed structure, was eventually located and sampled, 0.3 miles due West of mileage 22.6 (see Stereogram 24 and Test Result Sheets 27 and 27 A).

3.6.13. Thus by the use of the airphotos in the manner illustrated, it was possible to plan the basecourse prospecting to achieve the best practical solution with a minimum amount of wasted field and laboratory effort.

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3.6.13. Thus by the use of the airphotos in the manner illustrated, it was possible to plan the basecourse prospecting to achieve the best practical solution with a minimum amount of wasted field and laboratory effort.

(Photo by H. Roth)
Photo 15: Yellow wood trees growing over the lateritic gravel deposit in which borrow pit 21.1 is established (see Stereogram 25 and Test Result Sheets 28 and 28A). Note the boundary of the deposit towards the left of the picture. This is marked by the appearance of the acacia tree in front of which a figure is standing.

3.6.14. During the preliminary materials appraisal for road location purposes, a feature in the northern region was immediately recognised from the airphotos and from previous experience, as a possible source of lateritic or quartz gravel (3.4.5 and 3.5.8). The feature occurs in a granitic area, and is situated 2.1 miles East of mileage 21.1. It forms a slight depression which is easily discernible in the airphotos, but much more difficult to detect from the ground. A slight difference in the texture of the vegetation caused by the growth of yellow wood trees, can also be observed (refer to paragraph 3.6.5, Stereogram 25 and Photo 15). For easy comparison, acacia and apple tree stands in adjacent areas are also indicated on Stereogram 25 (see Photo 16).

(Photo by H. Roth)
Photo 16: A stand of apple trees in the area indicated by arrow B in Stereogram 25.

3.6.15. Two trial holes, made on the initial field inspection, confirmed the existence of a quartzose lateritic gravel deposit. Later the area was comprehensively sampled and tested, proving the deposit to be similar in quality to those located in the same types of feature, but much further South (3.4.5). The gravel meets basecourse specifications after the removal of excess fines, but despite this, the occurrence, which is the only one of its kind in the region, did not influence the location of the road, due to the more economic calcrete sources already described; and for this same reason, its use has not been planned (see Test Result Sheets 28 and 28 A). On account of its distance from the centre line, it is doubtful whether the existence of this deposit would have been discovered without the aid of airphotos.

3.6.16. Prospecting, subbase: In view of the consistent test results of subbase standard obtained from the granites, it was decided to locate subbase borrow pits in these formations wherever economically possible. After delineating the few granite possibilities on the airphotos, it was seen that only three of these occur sufficiently close to the road on the western side to have warranted further attention. Fortunately these occurrences are well situated at approximately mileages 6.9, 11.6 and 21.3, to serve most of the section economically. Borrow pits virtually adjacent to the road, and sufficiently large to meet the anticipated requirements, were sampled within these three sources. As was expected, the subsequent test results proved the granite to be suitable for use in the subbase. (see Fig. 9, and Test Result Sheets 29, 29A, 30, 30A, 31 and 31A).

3.6.17. The granite occurrences at mileages 6.9 and 11.6, are chiefly differentiable in the airphotos from their surface textural appearance caused by the predominant growth of apple trees, which is in contrast to that caused by the acacia trees covering the adjacent calcrete deposits (see Photo 16). Both occurrences also form a slight rise in an otherwise very flat terrain (see Stereograms 22 and 23). At mileage 21.3 the granite occurs in small irregular shaped areas in contact with a band of crystalline limestone. Another such area (B.P. 21.0B) adjacent to the same band of crystalline limestone, but just East of the railway line, was also sampled and proved to be of similar subbase quality. These areas would be extremely difficult to locate under the existing conditions by normal ground prospecting methods. However, the wider, and vertical view provided by the airphotos, makes it possible for such prospective sources to be readily detected. They can be differentiated from their surface textural appearance, produced as before by the natural vegetation, and also from a much lighter grey tone than either that of the band of crystalline limestone, or, that of the surrounding surface limestone (see Stereogram 24).

3.6.18. Apart from these granite borrow pits, gravel from calcrete borrow pit 1.3, and from a weathered quartzite borrow pit 1½ miles West of mileage 23.9, will also be utilized in the construction of the subbase (see paragraph 3.6.2, Test Result Sheets 25, 25A to 25D, 32, and Fig. 9). The quartzite outcrops, forming minor rises in the terrain, were first noticed in the airphotos from their difference in topographic relief (see Stereogram 24 and Photo 17).

(Photo by H. Roth)

Photo 17: A weathered quartzite outcrop near Otjikango, in which subbase borrow pit 23.9 is established (see Stereogram 24).

3.6.19. Prospecting, shoulders: The location of shoulder material did not present any particular problem, as most workable calcretes, apart from powdery limestone, meet specification requirements. Where possible, material is planned from established base and subbase sources. In gap sections, however, favourably placed sites which appeared likely to produce suitable gravel, were delineated on the airphotos for further investigation. In this way economically situated deposits were proved with a minimum amount of wasted effort.

3.6.20. Prospecting, surfacing sand: From an examination of the airphotos, it was definitely established that the only possible sources of sand for surface dressing are the stream beds in the precincts of Otjiwarongo (see Stereogram 26). Drainage over the rest of the region is too localized to have possibly produced a suitable deposit (3.6.4). However, due to the relatively small quantities involved, sands from this area could be used economically right up to Otjikango. A decision has still to be made on the type of surface treatment to be used, but suitable sand, similar to that located South of Otjiwarongo, was found on the Kalkveld road (see Stereogram 26 and Test Result Sheet 24).

There are undoubtedly other suitable deposits available as well, some of which may possible be more conveniently placed, and could be used if a sand surface dressing is specified. Here again, the airphotos were instrumental in directing the effort to the only area likely to yield satisfactory material, and thus also, in preventing fruitless searching over large tracts of country.

3.6.21. Airphoto indicators, summary: The primary indicators used for the recognition of the different formations, or of significant variations within the same formation, are summarized below for easy reference:

(i) Surface Limestone, which is the most wide-spread formation by virtue of the fact that it blankets the basic geology over large areas, was not normally differentiated. Essentially, its indicators are complementary to those of any geological formation of differing composition, or origin, with which it is in contact. However, within the surface limestone itself, powdery, boulder, and/or nodular forms, were distinguished from the massive form, by texture of vegetation and by grey tone of material (3.6.11).

(ii) Lateritic gravel: Texture of vegetation and relief (3.6.14).

(iii) Granite: Texture of vegetation, relief, and grey tone of material (3.6.17).

(iv) Quartzite: Relief (3.6.18).

(v) Crystalline Limestone, although the principal basic geological formation in the area, played only a small part in the investigations. As all the hills and mountains of any significance consist entirely of crystalline limestone, they are recognizable as such from their topographic form. However, the more subdued bands of crystalline limestone are initially detectable from their general "sweep" across the adjacent formations. A closer examination will also reveal a darker tone of material, and a difference in surface texture caused by the growth and distribution of scrub bush and tree vegetation (see Stereogram 24).

3.6.22. Drainage patterns, apart from indicating the only possible sources of sand for surface dressing, again played no part in either the recognition of geological formations, or in the location of road building material.

3.7. GAZA LINE TOWARDS RUNTU

3.7.1. Introduction: Instructions were received to construct a new all-weather gravel road link between Grootfontein and Runtu, which would meet the anticipated needs of proposed development in the Okavango Territory. From approximately latitude 19° northwards to Runtu, the country is completely uninhabited and of relatively flat topography. For these reasons, the route was located virtually along a straight line from a point about 40 miles from Grootfontein on the existing road to Karakuwisa, across this virgin country, to Runtu (see Fig. 1). A narrow trace to provide access to, and confirm suitability of, the terrain, was pushed open along this route; after which a superficial materials investigation was conducted without the aid of airphotos. This led to the belief that sufficient gravel of a suitable quality was available to produce a satisfactory wearing course. At a critical stage in the construction, it was discovered that this was in fact not the case, and that the quality of the materials located, was completely unsuitable. A serious situation had arisen, and it was decided to have a strip of airphotos taken at a scale of about 1 in 36,000, with the trace as the approximate centre line, and then to prospect seriously for suitable wearing course materials in the problem area.

(Photo by J.H. Caiger)

Photo 18: The road South of the Gaza Line showing the regular pattern of streets and dunes. The dunes are the darker-green wooded sections, while the streets support essentially scrub bush and grass, and are lighter-green in colour.

3.7.2. Geology and topography: The region under consideration is covered by Tertiary deposits of thick sand and surface limestones from the Kalahari System. Just North of the point at which the route crosses the boundary between the Okavango Native Territory and European South West Africa, which boundary is often referred to as the Gaza Line, and runs approximately along latitude 18° 36' South, there is a marked change in the topography. To the South the country undulates, forming a regular pattern of streets and dunes running in straight lines at approximately 95° to true North (see Photo 18). The terrain to the North on the other hand, is remarkably flat and exhibits practically no relief at all.

3.7.3. This sudden, and apparently arbitrary, change in topography, probably developed from a slight but critical difference in climatic circumstances. Dry conditions, where movement of sand through the agency of the wind can occur easily, favour the formation of sand dunes; while more tropical conditions result in the sand remaining wet for comparatively longer periods, and thus being more resistant to movement by wind which could produce sand dunes. The tendency for rain water to wash sand downwards into low lying areas, is yet another factor which hinders the development of dunes under heavier rainfall conditions, and which naturally leads to the formation of a relatively flat topography, wherever considerable depths of sand cover the basic geology. The interpolated annual average rainfall at Runtu, is about 580 mm. (23 inches), and this figure decreases steadily towards Grootfontein. At the intersection of the Gaza Line and the new road, the rainfall is of the order of 510 mm (20 inches) per annum, which appears to be about the critical rainfall, above which, dunes will not form in this particular region (see Fig. 2). It is possible that during the earlier formative period, the climatic conditions could have been relatively more pronounced, which would account more satisfactorily for the abruptness in the change. As a result of the depth of sand and gentle slopes, all rainfall is absorbed locally, and no surface drainage system has been able to develop.

3.7.4. The nature of the surface limestone deposits undergoes an abrupt change similar to that of the topography, and this transformation is likewise in sympathy with the variation in the rainfall. In South West Africa it has been found that calcrete develops best in areas where the annual average rainfall does not exceed 510 mm (20 inches). Rain water rises by capillary action often enough, and sufficiently close to the surface, to enable evaporation to take place, and hence also the deposition of lime. If the rainfall is higher than this critical figure, the rain water tends to sink deeper where the same degree of capillary rise and evaporation cannot take place. Lime deposits under such conditions are not so wide-spread, are generally found at greater depths, are often different in their mode of occurrence, and are usually, comparatively speaking, not so well developed. In regard to the region immediately

North of the Gaza Line, the majority of calcrete deposits are encountered at depths of at least 9 feet, are in thin layers, and are poorly developed. A few better developed deposits within reasonable depths of the surface do occur, but these are rare and are of a different form and texture from those found South of the Gaza Line. The latter calcretes are well developed to reasonable depths, and their occurrence under only a few inches of sand, is common along most of the streets.

3.7.5. <u>Vegetational cover</u>: The vegetational cover South of the Gaza Line also follows the pattern of the sand dunes and calcareous streets. The sand dunes tend to be heavily wooded, while the streets are generally only able to support a grass and scrub bush growth (see Photo 18). Over the thick sand plain North of the Gaza Line, especially towards Runtu, a concentrated growth of tall trees is the predominant cover. Open grass areas, essentially devoid of trees, also occur, and are formed from more finely graded, and sometimes slightly more plastic sands. When such areas are situated in a slight depression of reasonable size, they act as isolated pans, attracting a limited amount of local drainage (see Stereogram 28).

3.7.6. <u>Prospecting, wearing course</u>: The well developed calcretes in the streets South of the Gaza Line, were known from previous experience to make an excellent wearing course for low-trafficked gravel roads, so this section posed no serious materials problem. Owing to the obvious scarcity of calcretes between the Gaza Line and Runtu, prospecting without the aid of airphotos was carried out over this section prior to the start of construction. This investigation resulted in the discovery of the type of calcrete deposits described above. With the addition of a sufficiently plastic binder, these deposits were adjudged to be suitable for the construction of a wearing course layer (see Test Result Sheet 33). However, after the compaction of only a short section immediately North of the Gaza Line, it became obvious that the aggregate was not well enough developed to make a wearing course, even for the exceptionally low traffic counts anticipated. The aggregate proved to be far too soft, and crumbled to powder under the construction traffic. The discovery of this deficiency was serious at this stage of the project, but circumstances still permitted replanning and the allowance of sufficient time for the acquisition of a strip of airphotos, permitting a more thorough and systematic materials investigation to be undertaken (3.7.1).

3.7.7. The first investigation with the aid of the airphotos, was undertaken by an engineer unversed in the technique usually applied in South West Africa (3.2.4 to 3.2.6). The airphotos were used primarily as a base map, and the 6 weeks spent on the section proved entirely unproductive. After this lapse of time, the situation had deteriorated to the extent that an emergency had developed. The construction unit had been operational for just under a year, and nothing had been achieved in terms of completed road. It was not fully appreciated at the time, that the airphotos had not been used in the manner designed to yield well nigh foolproof information. In consequence, it was feared that to build a gravel road at all, might prove an economic impossibility. Before far-reaching decisions were taken, it was decided to confirm the findings of the two previous investigations by sending to the area yet another engineer, who had already successfully applied the technique on a number of projects. This third investigation was to establish beyond reasonable doubt, whether or not any better wearing course materials did in fact occur within the 5 mile wide airphoto strip of the first 30 miles North of the Gaza Line.

3.7.8. The road building potential of most of the area to be covered by this investigation, could be interpolated almost immediately, simply by plotting on the airphotos the positions of all holes and borrow pits previously sampled and tested. A few features however, were not covered by this analogy. These were noted and systematically field-checked. Within four days of starting, two significant gravel deposits had been located by this method. These deposits are so placed that the construction of a gravel road over this section became a definite possibility.

3.7.9. The first gravel deposit is situated about 0.8 miles from the Gaza Line, and approximately 0.5 miles West of the centre line. It is in fact very close to the construction camp, but despite this, and the

(Photo by J.H. Caiger)

Photo 19: A well-developed calcrete deposit situated immediately North of the Gaza Line in the Okavango Native Territory. It is being worked for wearing course material.

fact that the Officer-in-charge of the second prospecting party actually stayed at the camp for a month or more, the deposit still remained undetected nine months after construction had commenced (see Stereogram 27 and Fig. 10). The deposit consists of a well developed calcrete similar to those found South of the Gaza Line, and is in fact the last of its kind on the way to Runtu, and within the area covered by the airphoto strip (see Photo 19). The source is easily recognizable in the airphotos from its general relief, and from the limited drainage development which culminates in an obvious pan (see Stereogram 27). The good quality calcrete has formed along the slopes and high spots of this feature. The pan and other low lying areas contain, for the most part, a fine powdery lime with a relatively high Plasticity Index (see Test Result Sheet 34). The occurrence was covered in places by a scrub bush usually associated with surface limestones, and which often imparts a distinctive textural appearance to the airphotos (3.4.3). However, either the scale of these particular photos is too small to allow detection of any slight difference, or their obviously impaired clarity, most probably due to haze or smoke from bush fires, or possible to both, has obscured any differences in the texture of the vegetation there might otherwise have been. Also clearly noticeable in Stereogram 27, are borrow pits 1 and 2 which were located during the initial materials investigation, but which subsequently produced the soft calcrete aggregate to which reference has already been made (refer to paragraphs 3.7.4, 3.7.6 and to Test Result Sheet 33).

3.7.10. The second source of gravel discovered directly from the airphotos, is situated 29.0 miles from the Gaza Line, and 1.3 miles West of the centre line (see Fig. 10). Although also a surface limestone, its

(Photo by J.H. Caiger)

Photo 20: A view of a reef-type calcrete deposit in the Okavango Native Territory, 29.0 miles from the Gaza Line. Note the calcrete nodules in the foreground.

development and mode of occurrence are completely different from that of the first deposit. The gravel itself has formed under about 4 feet of sand, and is comprised of a hard, sandy textured, and concretionary limestone, with a honeycombed structure. It is of basecourse quality, and will be usable for gravel road construction in one form or another (see Test Result Sheet 34). The main occurrence has formed in a reef-like feature, and is not nearly as obvious on the airphotos as the pan with its accompanying drainage development, which led to discovery of the first deposit. Despite this, it is still readily distinguishable to the practiced observer, and was actually visited on the day following the first disclosure. The primary airphoto indicator is naturally the reef-type of feature formed by the deposit itself, but subsidiary to this is the growth of a number of large trees in an area which is otherwise devoid of tree vegetation (see Stereogram 28 and Photo 20). No doubt the easy access for both roots and rain water, provided by the honeycombed structure of the calcrete, accounts for the presence of these large trees. Small isolated deposits are also found in the open area West of the main reef, but these are too small to be recognized in photography of this scale.

3.7.11. A few more features unaccounted for by the initial and subsequent interpolation, were also field-checked, but brought to light no further gravel sources. Hence, it was concluded that the two deposits described above, are all that actually exist within the area investigated.

3.7.12. Prospecting by aerial reconnaissance: As the localities of these two deposits would involve hauling wearing course material for a distance of up to 15 miles, it was considered essential to prospect an additional area beyond that already covered by the airphoto strip, in the hope of locating more gravel sources of a similar nature, and thus reducing the unfavourable leads to reasonable proportions. Owing to the acute time limitation, it was further thought desirable to conduct the survey by aerial reconnaissance, provided that this method held out a reasonable chance of achieving success. As many hours had already been spent in stereoscopic examination of the airphotos, in conjunction with both available test results and systematic field-checking of all significant features, familiarity with the vertical view and the corresponding materials interpolation thereof, had become second nature. It was the considered opinion, therefore, that a carefully conducted aerial reconnaissance had a good chance of yielding reliable materials information about the terrain bordering the airphoto strip.

3.7.13. All information already to hand, indicated that the area on the north-western side of the airphoto strip, was the one more likely to produce results, and in consequence the investigation was limited to this side. To ensure reasonably accurate location from the air, traces perpendicular to the centre line and spaced at 5 mile intervals, were pushed open on this side (see Fig. 10). The first traverse was flown along a line directly over the end of these traces, and at a height of about 5,000 feet above ground level. This altitude was specifically chosen to ensure that features would be visible for a sufficiently long period to enable positive identification to be made. The locality of features which would require later ground-checking, was noted as accurately as possible on a prepared plan showing the centre line and relative position of all traces. On the second traverse, the position of all features noted on the plan, was either confirmed, or adjusted where necessary. One or two particularly promising-looking places were also examined at close quarters by flying several passes at tree top height. From this height it was possible to recognize typical types of scrub vegetation, as well as pieces of aggregate lying on the surface.

3.7.14. This air reconnaissance finally produced two new gravel sources, as well as an extension area some distance West of the calcrete already located at mile 29.0. The first discovery was made opposite mileage 8.0, and approximately in line with the end of the traces. It consists of an isolated, but well-developed calcrete deposit, similar in quality and mode of occurrence to that previously found at mileage 0.8. The second deposit to the credit of this reconnaissance, is situated about 7 miles north-west of mileage 18.5 (see Fig. 10 and Test Result Sheet 34). It occurs a short way from the source of an omuramba, which subsequently follows a general north-westerly course away from the area of interest to the road project.[1] Its mode of occurrence, and the shape and form of its aggregate, are similar to those of the deposit at mileage 29.0; but unfortunately it is positioned uneconomically far from the centre line, and will thus have no practical application apart from that of an emergency source of supply. The deposit at mileage 8.0 however, has already been used, and effects an overall reduction of from 2 to 4 miles in the maximum haul distance between the two original sources at mileages 0.8 and 29.0. As the transport of a considerable quantity of wearing course gravel was involved, this reduction has resulted in an appreciable saving in the cost of construction, and will subsequently benefit maintenance expenditure as well. Assuming the prerequisite of

[1] An omuramba is a grassed stream bed which occasionally carries water.

the existence of suitable sources of material, the success, achieved by the aerial reconnaissance, can be ascribed in large measure to the prior application of the technique over the area covered by the airphoto strip of the first 30 miles North of the Gaza Line (3.2.4 to 3.2.6). Without complete familiarity with the vertical view and corresponding materials interpolation, a survey of this kind could be misleading, and could cause faulty decisions to be made, based on unreliable information. Hence, the success of such a venture is largely dependent on the prior intensive use of airphotos of terrain similar in all respects to that which it is intended to cover by the aerial reconnaissance.

3.7.15. The cheapest route: Had the initial materials investigation been conducted with the aid of the airphotos in the manner indicated, and then extended to include this latter air reconnaisance work, the route would almost certainly have been located further to the north-west, probably by as much as 5 miles, or more, in places (see Fig.10). In this way all four gravel sources could have been utilized to their best advantage, resulting in the cheapest possible gravel road under the particular conditions dictated by nature. The fact that the gravel deposits first found were thought to be of wearing course quality, would not automatically have ensured the adoption of the present, and shortest route. The four gravel sources discovered later, apart from their obviously superior quality, would in any case have been considered the more economical proposition, as all of these occur, either on the surface, or under a thin sand layer only; while the general limestone deposits of the area, were found to occur in thin layers under at least a 6 foot thickness of sand, and consequently would have been relatively expensive to work.

3.8. THE KALAHARI GEMSBOK NATIONAL PARK

3.8.1. Introduction: The main road running along the Auob River, and then passing through the Kalahari Gemsbok National Park, carries an ever increasing amount of through traffic bound to and from the Republic of South Africa. It has now reached a stage where it is considered desirable to route this traffic outside the Park boundaries, and to this end the South West African Administration investigated a triangular area of country enclosed by the Auob River in the North, by the South West Africa - Cape Province boundary in the East, and by a straight line from the farm Stilledal on this boundary, to the point of entry of the Auob River to the farm Kinkel (see Figs. 1 and 11).

3.8.2. Environmental conditions: This entire region, apart from the

(Photo by J.H. Caiger)
Photo 21: A typical Kalahari sand dune and street.

northern extremity occupied by the valley of the Auob River, is thickly covered by Kalahari sand, alternating in topographic form from dunes to streets which, over much of the area, run roughly parallel to each other and at approximately 220° to true North (see Photo 21 and Stereogram 29). The monotonous pattern of this topograph promised to create such a serious problem in regard to location and orientation of both survey and prospecting field parties, that special aerial photography was flown to a scale of approximately 1 in 39,000, from which mosaics were made prior to the start of the field operations. These mosaics later proved of inestimable value in the field, and amply justified the cost of their production.

3.8.3. In the valley of the Auob River, however, erosion has not only removed the sand cover, but has also cut through lower horizons of the Kalahari System, exposing calcareous sandstones and grits, which are often capped by a hard limestone crust. Surface drainage, apart from that of the Auob River itself, is virtually non-existent; the sand absorbs all of the meagre average rainfall of about 200 mm. (8 inches) per annum, except in the vicinity of the only pan of significance within the area where a certain amount of local drainage undoubtedly occurs (see Fig. 2 and Stereogram 29). Scrub bush and an occasional tree are the only permanent vegetation, but after rain grass makes its appearance and often grows in profusion (see Photo 21).

3.8.4. Appraisal, first route: Initially a short field trip was undertaken, primarily to get acquainted with the ground conditions and their correlation with the corresponding vertical view depicted on the mosaics and individual stereopairs. During the course of this trip, it became obvious that the crux of the problem was the location of sufficient gravel sources suitable for the construction of a wearing course layer. If such sources did not exist within, or close to, the area of possible location, the question of building a gravel-surfaced road in the vicinity, would be purely theoretical. In this respect the problem resembled that which developed on the section of road between the Gaza Line and Runtu, in the Okavango Native Territory (3.7.7).

3.8.5. The first area to be investigated intensively, was a narrow strip between the farms Kinkel and Stilledal, as this particular line was favoured by the Cape Administration (see Fig. 11). Three streets, offering the most satisfactory geometric solutions, were chosen from this strip and were then prospected along their full lengths, involving a distance of approximately 55 miles per street. Auger holes to a depth of about 15 feet, and seismic readings which were reliable to about 30 feet, were taken at judicially placed low points selected directly from the mosaics. The streets and dunes are readily differentiable in these mosaics from the lighter grey tone of the latter, while low points within the streets are easily recognized from their relatively darker tone (see Mosaic 2). The information thus gleaned, confirmed the suspected fact that no calcrete had formed, and that within this strip the sand reaches a considerable depth. The construction of a gravel road along this route, was therefore considered to be impracticable.

3.8.6. Appraisal, possible route (refer to Fig. 11): Attention was now directed further to the East, where the only pan of any size occurs. The side slopes of this pan were found to contain large quantities of pebble calcrete gravel, the aggregate portion of which is of suitable size and quality for use in a wearing course layer; but the soil fines proved to be insufficiently plastic to ensure adequate cohesion of the pebbles. The floor of the pan, however, consists of a range of plastic clays, which, if judicially selected and admixed with the natural gravel from the slopes, should achieve a satisfactory end result (see Stereogram 29 and Test Result Sheet 35).

3.8.7. Following on this discovery, a narrow strip of country between the Auob River and the South West Africa - Cape Province boundary, which included sites likely to yield similar types of material, was selected for systematic investigation. One of the anticipated possibilities was a small pan on farm No. 330, where an occurrence of calcrete gravel and plastic fines, similar to that found in the larger pan, was subsequently confirmed (see Test Result Sheet 36). A third source tested was from the valley of the Auob River, where any amount of suitable gravel was already known to exist (3.8.3). From these three sources it should be possible, using maximum haul distances not exceeding 9½ miles, to gravel a satisfactorily aligned road to the South West Africa - Cape Province border, which would by-pass the Park. This possible route is roughly parallel to, and 5½ to 6 miles from, the original line favoured by the Cape Provincial Administration. The decision as to whether or not it will be adopted, now depends largely on the outcome of future negotiations with the Cape Provincial Administration.

3.8.8. Pattern of topography: The route proposed above, marks roughly the boundary between a slight but significant change in the pattern of the topography. East of this particular location, and to the limit of the region investigated, the sand dunes tend to be smaller and form a more broken pattern, such that continuous streets diminish in length and are not so well defined (see Mosaic 2). It is thought that the thickness of the sand cover decreases considerably over this section, which may account for the change in size and pattern of the dunes, and for the fact that calcrete has developed. Unfortunately, the time was not available to establish definitely whether this is in fact the case.

3.8.9. Conclusion: The aerial mosaic is without doubt the best medium for showing up slight changes in the pattern of the topography, (or for that matter in the pattern of the vegetation as well), which, as in this particular case, may be of vital importance in prospecting, and ultimately in the project as a whole. The individual stereopairs are too limited in areal scope to ensure the discovery of such changes. In this instance mosaics also enabled the field parties to locate themselves with ease, and by the use of interpolation, ensured that the investigation was finalized in a minimum of time. The usefulness of the airphotography for the materials investigation of this particular project, was hence centred primarily in the mosaics, and not in the individual stereopairs. This fact, taken in conjunction with the success achieved with stereopairs on other projects, high-lights the necessity for the use of both stereopairs and mosaics if the maximum benefit is to be derived.

CHAPTER 4.

SUMMARY AND CONCLUSIONS

4.1. PROSPECTING METHODS IN CURRENT USE

4.1.1. In the Territory of South West Africa three methods of conducting a materials investigation for rural road projects are in current use. These are as follows :

(i) The use of airphotos and airphoto interpretation in the way described in this thesis (section 3.2).

(ii) The use of airphotos and airphoto interpretation for the production of a soil engineering map coupled with prospecting during, and after, the production of the map. In this method the map, and not the airphotos, is used as an aid to prospecting (2.4.21).

(iii) Prospecting by established methods without the aid of airphotos in any form..

4.1.2. Methods (i) and (ii) were introduced almost simultaneously in an attempt to improve the indifferent results obtained, under complex and difficult conditions, by normal prospecting practices. With the experience gained, it can be stated categorically that the application of both methods has been successful, in that a considerable overall improvement has resulted in the accuracy and degree of completion of the information obtained. In other words, it is the application of airphoto interpretation to the materials field which has resulted in this improvement, the use of different approaches affecting the degree.

4.2. THE MAJOR IMPROVEMENTS TO PROSPECTING EFFICIENCY STEMMING FROM THE DIRECT AID OF AIRPHOTOS

4.2.1. The technique described in this thesis has succeeded beyond expectations, primarily due to its being specifically tailored to meet the special needs of this Territory (3.2.1). Normal prospecting methods have failed to supply, with sufficient reliability, the vital information required to fulfil these needs; but these same basic prospecting practices, improved and adapted to make full use of the potential of airphotos in the manner described, have been able to achieve remarkable results. The main improvements which stem from the direct aid of airphotos, can be summarized as follows:

(i) The reduction of unnecessary waste of time to a minimum by: (a) being able to locate easily ones own position relative to specific features which require field-checking and, (b) by completely avoiding areas where prospecting will be fruitless (3.2.5).

(ii) The use of the exaggerated vertical scale with wide coverage, to locate sources of road building material which would normally have been missed by use of the ground view only (e.g. 3.5.14 to 3.5.15).

(iii) The observation of significant patterns and the accurate delineation of their boundaries, over both small and extremely large lareas, made possible by the wide coverage provided respectively by individual stereopairs and composite mosaics (3.8.8 to 3.8.9).

(iv) The possibility, through familiarity with the vertical view and its corresponding correlation with ground conditions, of prospecting by means of aerial reconnaissance beyond the airphoto cover (3.7.12 to 3.7.14).

(v) The extended scope of interpolation, which makes possible quick materials appraisals of large tracts of country for route location purposes, and which also permits detailed prospecting to be effective over an area embracing 3 miles or more on each side of the centre line. By normal prospecting methods, a quick but accurate materials reconnaissance over a large region is virtually impossible, while detailed prospecting is rarely effective beyond a half mile from the centre line (3.2.3 to 3.2.6).

(vi) The ability to plan rationally on both a short and long term basis, which ability has led to the whole development of the technique described (section 3.2).

4.3. SOME ADVANTAGES OF THE TECHNIQUE DEVELOPED, OVER THAT OF INVESTIGATIONS BASED ON THE PRODUCTION OF A SOIL ENGINEERING MAP

4.3.1. From the concept on which the technique is based, it is readily apparent why it has achieved better overall results and more confidence at top-level in South West Africa, than the method based on the production

mapping approach (refer to texts of Chapter 3).

(ii) Despite the premise, which is undoubtedly correct, that nature is not haphazard but conforms to regular laws, basic geological formations are still encountered in which the engineering characteristics vary widely from place to place within the same formation.

of a soil engineering map (3.2.1). Some of its more obvious advantages are detailed below:

(i) The airphoto interpretation is directed at supplying in an early stage of the design, the vital information concerning the locality of ALL top-quality sources of low-cost material, substantiated by adequate test results. This is especially important where decisions on route location have to be taken before the more detailed planning can begin. In soil engineering mapping projects, the airphoto interpretation is directed primarily at the accurate demarcation of the boundaries between the basic geological formations. Delineation of the superficial surface deposits is undertaken later, but, in its application in South West Africa, has been too general to be of much engineering significance. Establishing the road-building potential of these important surface deposits is largely left to the subsequent prospecting operations, which are conducted with the aid of the map and NOT with the direct aid of airphoto interpretation. Thus the many advantages to be derived from airphoto interpretation in this all-important phase of the materials investigation are lost, with the consequence that important deposits are sometimes missed. For example, on the soil engineering mapping project between Mariental and Asab, two surface limestone occurrences close to the centre line, remained undetected as potential basecourse material until late in the construction phase. This gravel was eventually used in 11½ miles of basecourse, which on this 60 mile project, is approximately 19% of the total basecourse length. As many of the low-cost sources of good quality material are to be found in these superficial surface deposits, this deficiency is considered a major disadvantage of the soil engineering mapping approach (refer to texts of Chapter 3).

(ii) Despite the premise, which is undoubtedly correct, that nature is not haphazard but conforms to regular laws, basic geological formations are still encountered in which the engineering characteristics vary widely from place to place within the same formation.

Under such circumstances the technique developed has proved very successful in direct location of material to meet particular road-building specifications (3.5.14). The latest trend in soil engineering mapping projects, is to conduct a statistical analysis on the different materials encountered, covering the variability of the significant engineering properties. The results of such an analysis under conditions of variability within the same formation, would point to the need for the location of specific sources to meet particular requirements. Having arrived at this conclusion, the soil engineering map would be of no further use, and these sources would then have to be located by normal prospecting practices, with all their attendant disadvantages under South West African conditions.

(iii) The technique directs all its effort on solving the problems considered to be of direct and practical importance (refer to Section 3.2). In order to produce a soil engineering map, much effort is often expended on questions of no actual significance to the road project. For example, (a) in order that large areas of the map should not remain undifferentiated, accurate delineation of the boundaries between basic geological formations is still undertaken despite 10 feet or more of cover by superficial surface deposits (e.g. as in such areas as those described in 3.4.2, 3.5.3, 3.6.3, 3.7.2, 3.8.2); and, (b) detailed work in areas far from the centre line is done even in cases where road building material is plentiful much closer to hand. The incorporation of such superfluous information is not in itself harmful, but, after dissipation of so much effort on the production of a map, there is often a tendency to skimp on essential prospecting, to the ultimate detriment of the overall materials investigation.

(iv) A degree of trained and skilled geological conjecture is not necessary when applying the technique described in this thesis, as most sources of road building material can be directly distinguished as such on the airphotos (refer to relevant texts of Chapter 3). Thus, the airphoto interpretation can be done adequately by the engineer directing, and responsible for, the prospecting operations. This arrangement will also ensure that the engineer becomes familiar with the terrain, from which many direct and indirect benefits will subsequently flow. However, in the soil engineering maps produced to date, the accuracy and detail achieved, is the work of a trained geologist specialized in airphoto interpretation (2.4.16 to 2.4.17). When using such a map as the basis of the materials investigation, it is still necessary to have a specialized engineer directing the overall project. Thus an additional highly trained specialist is required for the soil engineering mapping approach; a distinct disadvantage in these days of general shortage of scientific personnel.

4.4. THE SCALE OF PHOTOGRAPHY : REQUIREMENTS COMPARED WITH THOSE FOR SOIL ENGINEERING MAPPING

4.4.1. The scale of the aerial photographs used on all the investigations described, is approximately 1 in 36,000, with the exception of those used for the Kalahari Gemsbok National Park job, where the scale is of the order of 1 in 39,000. Despite this relatively small scale when compared with the scales recommended for soil engineering mapping, in only one instance, apart from the general problem with calcretes, was difficulty encountered in delineating the boundaries of deposits, or formations, of any road-building significance (2.4.7 to 2.4.8, and 4.5.2). This was in the case of quartz gravel deposits South of Kalkrand, where the average rainfall happens to be about 8 inches per annum. These gravels have often been impregnated with calcrete to the extent that their normal airphoto indicators have become obscured, making exact boundary demarcation virtually impossible, and hence also hindering reliable detection by analogy (3.1.17 to 3.1.19). In this particular case, a larger-scale of photography may have revealed some more definite change of tone and/or texture of those deposits which happen to be relatively free from lime-impregnation and this would have made for easier and better recognition of such occurrences. However, in an area of average annual rainfall of approximately 15 inches, it was possible, when using a four magnification stereoscope, to locate a dolerite dyke in the Klein Omatako Mountains, which is too narrow to be workable in practice (3.4.4). Again between the Gaza Line and Runtu, where the average rainfall is as high as 22 inches per annum, the only two gravel deposits of wearing course quality were not difficult to detect on the airphotos (3.7.8 to 3.7.10).

4.4.2. It is concluded, therefore, that the scale of photography required for the successful application of the technique previously herein described, is considerably smaller than that needed for accurate soil engineering mapping; especially in the higher rainfall areas, where a scale a little larger than half the size of that recommended for soil engineering mapping, has proved adequate (2.4.7 to 2.4.8). The reason for this is readily apparent. Soil engineering mapping is to a large measure concerned with the demarcation lines between basic geological formations, and requires these to be established accurately, even under adverse conditions and where positioning of a particular contact line is of no importance to the road project (4.3.1 (iii), and Bibliography No. 6). A larger scale of photography is necessary to obtain the desired accuracy and to enable the interpreter to minimise his field-checking. In the application of the technique, however, the chief concern is the location of finite areas of sufficient size to be workable in practice and which are economically situated.

4.4.3. As the scale of photography necessary for the planning of various other aspects of a road project, such as survey, drainage positioning, catchment areas etc., is relatively small, the financial advantage of the smaller scale requirements is appreciable. For example, large areas of South West Africa have been flown to a scale of 1 in 36,000, and the policy of the Administration is to extend this airphoto cover still further. This scale is large enough for general engineering purposes, and is also perfectly adequate for the application of the technique, but, apart from the arid areas, would not even remotely meet the requirements for the production of an accurate soil engineering map. (see Fig. 2 and paragraphs 2.4.7 to 2.4.8).

4.5 AIRPHOTO INDICATORS

4.5.1. In the investigations undertaken, the indicators of topographic form (relief) and texture and grey tone of vegetation, were responsible for the identification of the majority of sources of road building material. Change of slope, and texture and grey tone of materials, also played a minor rôle. Linear forms consisting of a dolerite dyke, bands of crystalline limestone, and parallel rows of Kalahari sand dunes, have on occasion also been prominent indicators (4.5.4). The bands of crystalline limestone were associated in the location of important sources of material between Sukses and Otjikango (3.5.16). Drainage and erosional forms of indicator were virtually non-existent, as is to be expected in well-vegetated, undeveloped, flat terrain.

4.5.2. Surface limestones in many forms, and sometimes to considerable depths, are distributed over much of South West Africa. Their road building potential varies in proportion to their numerous modes of occurrence, and ranges from unsuitable for use anywhere in the road bed, to suitable for use in the basecourse layer. Their airphoto indicators also vary over a wide range, making interpolation, and interpretation in terms of engineering significance, very difficult. For example, in the neighbourhood of Sukses the grey tones of the calcrete vary from dark to very light. In this particular case however, this wide variation formed the basis for the differentiation of calcrete to meet shoulder specifications, from that of a much inferior quality (3.5.18). Again, between Otjiwarongo and Otjikango, it was only possible to delineate specific areas, and not actual deposits, which were likely to produce workable gravel of potential basecourse quality. These areas still required ground prospecting, as other unsuitable forms of undifferentiable calcrete were also present (3.6.11 to 3.6.12). A further example quoted elsewhere, is that of the lime-impregnated quartz gravels South of Kalkrand, which proved difficult to distinguish on the airphotos, probably due largely to the impregnation of lime (3.1.19). From these examples and from general experience, it is concluded that airphoto interpretation has its limitations in regard to the differentiation of surface limestones in terms of road building potential; and for this reason, such deposits should be given special attention in the field whenever the use of this technique is to be adopted.

4.5.3. Anthills have proved reliable indicators of the general plasticity of soils. Where these occur, the Plasticity Index of the top soil is rarely less than 8, and has a tendency to increase still further with depth. Conversely, where anthills are not found on reasonable depths of top soil, the Plasticity Index is invariably less than 8. In open country these anthills impart a pock-marked appearance to the airphotos, but in wooded areas the anthills are often obscured, making direct airphoto recognition difficult. In such cases the limits of the anthills can be checked on the ground, after which the demarcation lines between plastic and less plastic soils can often be delineated from other indicators. A similar relationship between anthills and the corresponding plasticity of the soil, has been reported from Nyasaland (Bibliography 28).

4.5.4. It has been suggested that the elements of aerial photographic patterns such as dykes, faults, joints, bedding planes, fracture traces, bands of metamorphic rocks, reefs, sand dunes etc., be classified separately under the heading of "elements of line" (Bibliography No. 2, volume 2, page 63). However, such elements are usually identified initially in the airphotos by their linear form (3.4.4, 3.5.16). If an additional breakdown is considered desirable, it would therefore seem more logical to classify such a group under another subdivision of the "elements of form". It could be justified by the fact that such features are often striking in their own right, although they are still differentiable from, and classifiable under, one or other of the existing breakdown of the elements into form, tone, and texture (2.4.6). However, by analogy with this argument, man-made geographic features would also justify separate classification, although these again are identifiable from the basic elements as listed. It would appear, therefore, that if the list of elements is not to become unwieldy, it should be confined as far as possible to those elements which are essential for differentiation and classification purposes. Despite the linear occurrences encountered in South West Africa, the basic elements of form, tone, and texture, have still been found adequate for all general purposes.

4.6 THE IMPORTANCE OF THE CORRECT USAGE OF STEREOPAIRS AND MOSAICS

4.6.1. The importance of continued and detailed study of stereopairs before and during the materials investigation of any project can hardly be overemphasised (3.2.4). Many of the indications are only identifiable on perception of the relative vertical and horizontal relationships between formations of differing origin. A great potential advantage of aerial photography in the materials field is being sacrificed if stereoscopic examination of the airphotos is in any way neglected.

4.6.2. Occasionally however, mosaics will not only fulfil their normal routine function, but will even play a more dominant rôle than that of the individual stereopairs (3.2.7). This is especially true where gradual changes in the pattern of the topography over large areas are significant, and may prove difficult to detect on the limited area imaged by stereopairs (3.8.8 to 3.8.9).

4.6.3. If the full potential of aerial photography in the materials field is to be realized, therefore, it is imperative that both stereopairs and mosaics are used correctly and intelligently.

4.7 THE RELATIVE ECONOMICS OF MATERIALS INVESTIGATION METHODS

4.7.1. No costing has as yet been undertaken on the various aspects entailed in the application of the technique described in this thesis.

From a comparative point of view however, detailed costing of any method on a few specific projects only, is of limited value, due primarily to the variable factors which occur under widely different local circumstances, and which cause a large percentage fluctuation in the cost per mile. A comparison of the field operations, as being the most costly items involved in all three methods of materials investigation in current use in South West Africa, forms possibly a more suitable basis on which to guage their true relative costs.

4.7.2. The technique forming the main subject-matter of this thesis, involves two distinct field operations; the first is the recognition of all features in the airphotos, and the sampling of typical profiles to establish their engineering potential and to provide the basis for later direct interpolation in terms of engineering significance; the second is the systematic sampling of sufficient borrow pits, to give the most economic usage of materials when the road is ultimately built. On the other hand, normal prospecting methods constitute one continuous field operation; namely that of sampling sufficient promising sources of material to build the road, if, and only if, such sources happen to be found without too much difficulty. From this it is reasonable to conclude, that the actual cost of the application of the technique is not likely to be less than that of normal prospecting, but is probably not appreciably more either, due to the elimination of much of the duplication of effort usually inherent in normal prospecting practices.

4.7.3. Theoretically, investigations based on a soil engineering map are also subject to two distinct field operations; namely that of the production of the map, followed by that of detailed prospecting with the aid of the map. Production of the map alone has been costed at from R75 to R120 per mile on various projects in Southern Africa (Bibliography No. 33). To this, of course, must be added the cost of the second field operation. On account of the detailed work required in the production of the map, coupled with the fact that the use of the map for the second field operation is often not as satisfactory as the use of the airphotos themselves, it is concluded that the application of the technique described hereinbefore, is less costly than a complete investigation based on the initial production of a soil engineering map. This comparison assumes that suitable airphoto cover is available. All of South Africa and much of South West Africa already has airphoto cover which is suitable for the application of the technique described, but much of which may not be suitable for soil engineering mapping purposes (Bibliography No. 6). The comparison in general therefore, tends to favour still further financially, the method of direct application of airphoto interpretation to borrow pit location.

4.7.4. An inference which can be drawn from the foregoing, is that the difference in costs between all three methods of investigation, is negligible when compared with the overall cost of the average road project. The really important economic consideration, from the Administration's point of view at any rate, is to discover in the time available, the criteria for the minimum possible cost of construction under the prevailing conditions. From intimate experience of the use of all three methods in South West Africa, it is concluded that the proper application of the technique described in this thesis, has the best potential of achieving the maximum possible reduction in construction costs, especially where distribution of high-quality road-building material is the determining factor in the route location; and that the amount of money which can thus be saved, is out of all proportion to any possible increase in the cost of the materials investigation due to the choice of this particular approach.

4.8 INVESTIGATIONS BY CONSULTING ENGINEERS FOR CONSTRUCTION BY CONTRACT

4.8.1. During the planning stage of any job being investigated for the Administration by consulting engineers, much of the interest of the Client is vested in ensuring that the most favourable contract tender prices will be obtained for the items in the bill of quantities, which will have the greatest effect on the eventual cost of construction. The primary requisite in the pursuit of this aim is that these quantities be realistic and bear a reasonably close relationship to the final quantities used. To achieve this, an accurate knowledge is required of the most economic sources of material available for the construction of the significant layers of the road. Only then can such questions as the most suitable distances for free haul, the quantities of overhaul and of the different classes of natural and processed materials needed for the various layers, be intelligently estimated. If the road as built, differs appreciably from the proposed construction on which the bill of quantities was based, and the cause is not unexpected relative tender prices but the lack of sufficient knowledge in the planning phase, then the Client may stand to lose an appreciable amount of money. This can happen, amongst others, in the following ways:

(i) High tender prices being quoted for unrealistically small quantities reflected in the bill, when much larger quantities were in fact used, for which lower tender prices would undoubtedly have been forthcoming.

(ii) Ridiculously low prices being tendered for small quantities shown in the bill. If much larger amounts of items priced in this way are subsequently used, then the contractor could be seriously embarrassed even to the extent of going bankrupt. Such an eventuality could seriously hinder, or completely halt progress of the work, resulting in very adverse financial repercussions to the Administration (3.1.14 to 3.1.16).

(iii) The acceptance of a tenderer who was in reality not the lowest.

(iv) The uneconomic use of the materials available.

4.8.2. Much of the initial work undertaken by consulting engineers in South West Africa (and for that matter by the Administration as well), showed the above symtoms to such a degree, that a much more thorough materials investigation has for some time now been insisted upon (3.1.3 to 3.1.19, and 4.3.1 (i)). Following on this insistence, consulting engineers using normal prospecting methods, have found that two separate field operations usually become necessary. In one instance, between Asab and Wasser in the South, where the investigation was actually based on the initial production of a soil engineering map, it was still deemed advisable to undertake a second prospecting operation, making three separate field operations in all. As such additional field parties are not planned for at the outset, it often necessitates the alteration of much of the work already completed, and may even render some ot it redundant. More serious still is the delay caused by such unscheduled field prospecting, which has in the past resulted in construction projects being postponed for anything from four months to a year.

4.8.3. It is considered that the intelligent application of the technique described is the best solution to this problem and could benefit all parties concerned. The Client would benefit from the bill of quantities reflecting more assuredly than ever before, the actually prevailing situation. He would also be in a position to plan the construction programme, and corresponding financial spending, with a greater degree of certainty. The consulting engineer would have to arrange his investigations from the outset on the basis of two distinct field operations, but in so doing, would almost certainly eliminate the waste of time and energy resulting from an unplanned second field prospecting party. He would achieve a better overall result in a shorter time, and at a cheaper cost to himself and at the same time would increase his early chances of receiving further work from the Client. The good contractors, once confidence had been gained, would be able to plan their plant requirements, or plant usage, more accurately and hence be in a position to price on the same profit margin but with less element of risk, or, alternatively, to price more competitively on the same risk basis.

4.9 THE USE OF AIRPHOTO INTERPRETATION FOR ROAD PROJECTS IN OTHER COUNTRIES

4.9.1. The United States of America is the only country which makes use of soil engineering maps to any great extent, but as the emphasis is on the reinterpretation of existing agricultural maps, the technique of airphoto interpretation is not always applied. However, every state using airphoto techniques in the preparation of soil engineering maps, still acknowledges heavy reliance on conventional methods for the location of suitable sources of material.

4.9.2. In recent years a number of countries have also reported a limited amount of work with a similar approach to that described in this thesis, but adapted to meet their particular local needs. In both Nyasaland and Southern Rhodesia lateritic deposits have been detected directly by photo interpretation (Bibliography Nos.1 and 27). In Southern Rhodesia the laterite, or quartzose lateritic gravels, located overlaying granitic rocks, were reported to be of low plasticity, which finding corresponds with that obtained under similar circumstances in South West Africa (3.4.5 to 3.4.6). From the Federation of Malaya, work has also been reported on the direct airphoto identification of areas of lateritic soils suitable for road construction purposes (Bibliography No. 10). It is interesting to note that the above three countries all face problems analogous to some, if not all, of those encountered in South West Africa.

4.10 THE APPLICABILITY AND POSSIBLE FUTURE SCOPE FOR THE TECHNIQUE DESCRIBED IN THIS THESIS

4.10.1. Any appraisal of the possible advantages, or disadvantages, for any particular project, of the use of the technique hereinbefore described, should take into consideration the conditions pertaining in the area, and also, whether or not the concept on which the technique is based, is still applicable. Under certain circumstances there would be very little, if any, point in using such finesse. For example, (i) in the better developed European counties where detailed information and knowledge is already available, (ii) in areas where the naturally occuring gravel deposits of good quality have already been expended, (iii) in areas where good quality gravels are abundant and easy to locate, and (iv) in areas where the geology, including surface deposits if any, is uniform in composition and quality in terms of road building potential. Such conditions obviously do exist, and in countries where they are widespread, the necessity for deviation from established practices would not arise.

4.10.2. The greatest applicability and future scope for the use of the technique, lies in the underdeveloped countries of the world, and especially in those on the continent of Africa where the concept, and many of the conditions on which the technique was developed, still hold true (3.2.1 and 3.1.2). It is stressed, however, that a limited amount of training is required, followed by practice until the various steps of the technique become routine. When this stage is reached the full potential of the use of airphotos in the present state of the art can be realised; and under conditions which dictate its use, engineers should avoid the mistake of lightly underestimating this potential in terms of ultimate financial benefits. The technique has already proved itself in the Territory of South West Africa to the extent that it has been accepted as a routine procedure on all materials investigations undertaken directly by the Administration, and also to the extent that the authorities now encourage consulting engineers working in the Territory to adopt it in part, if not in its entirety.

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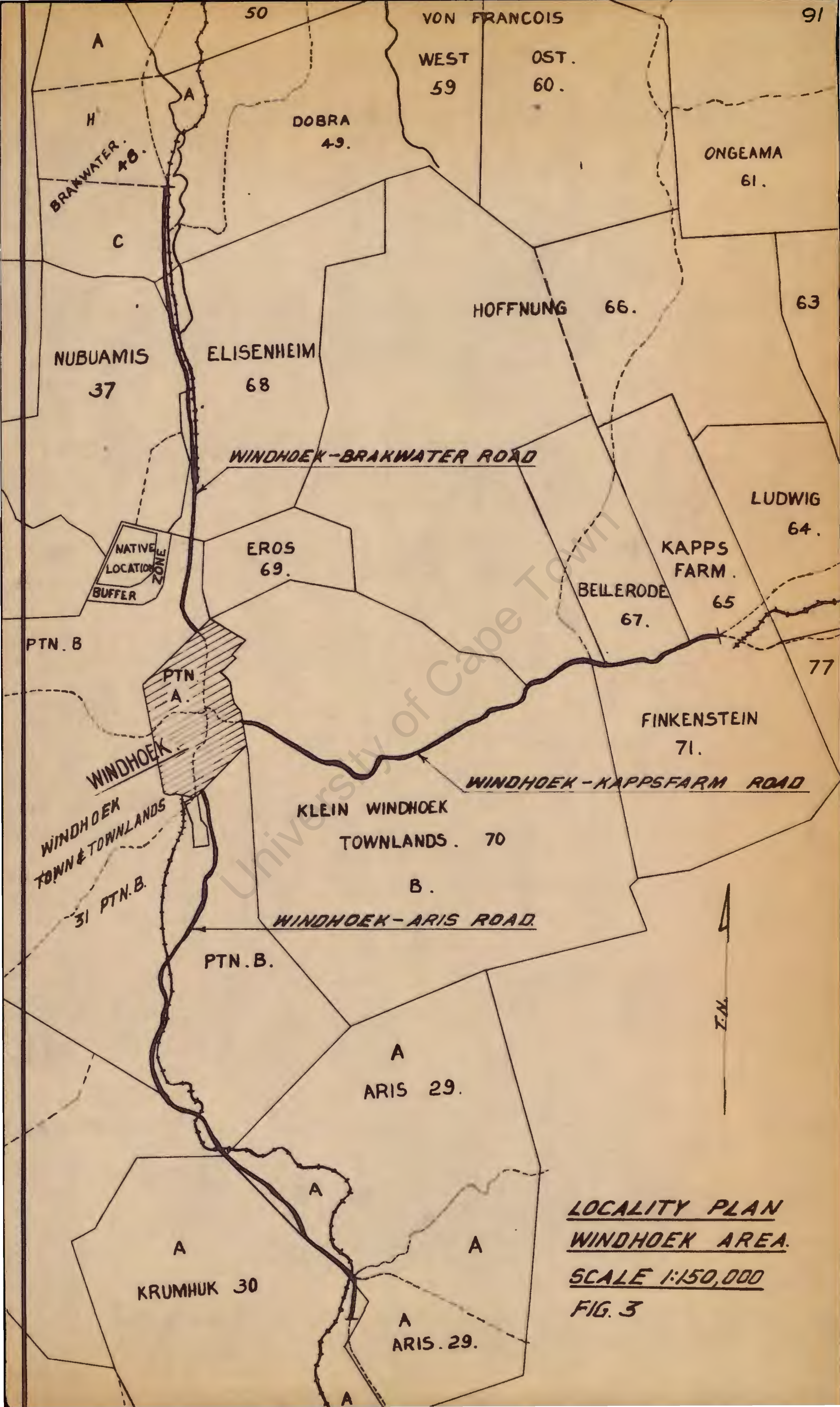
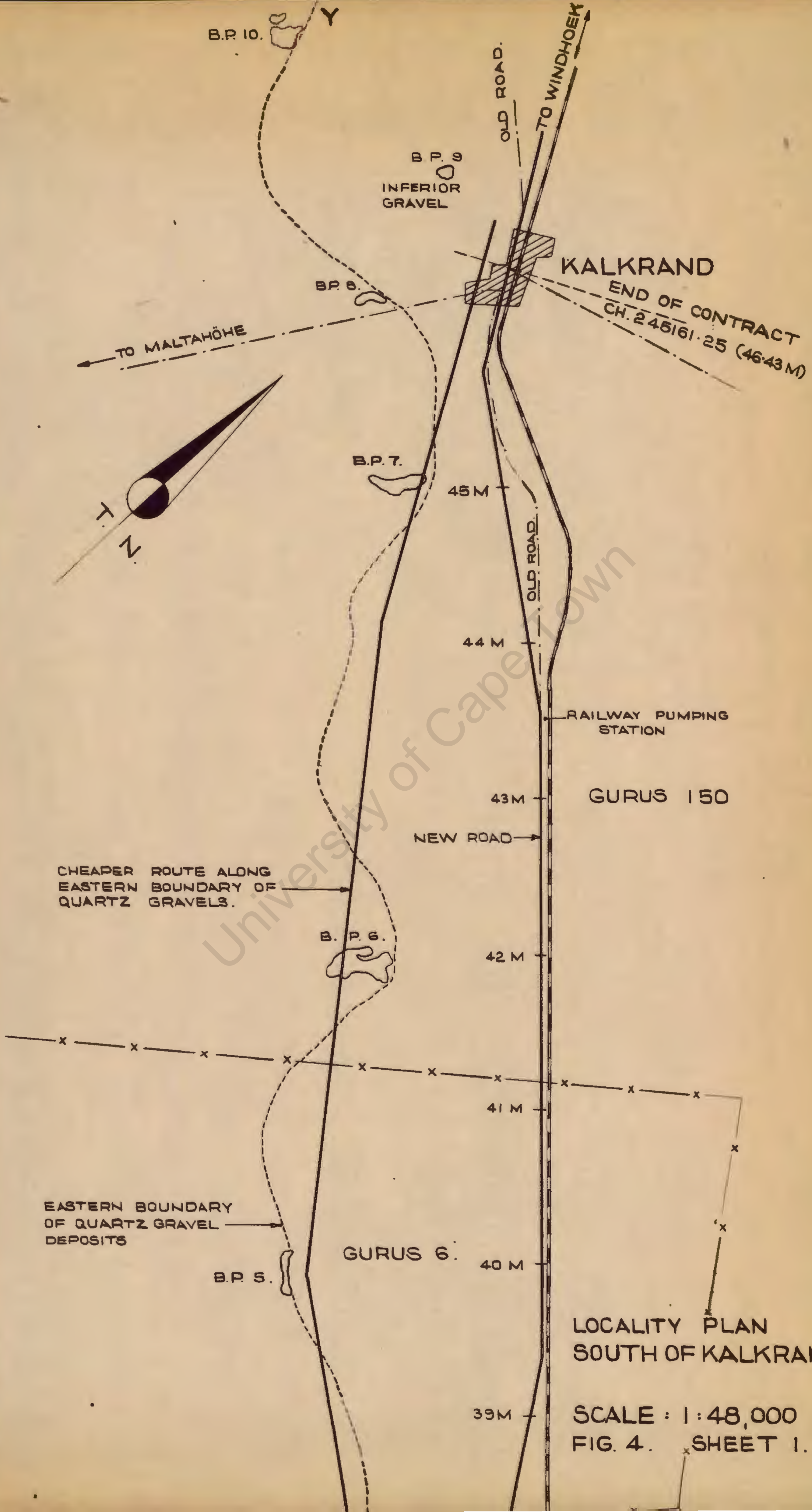
APPENDIX A : FIGURES 1 TO 11

LOCALITY CHART FOR SOUTH WEST AFRICA.
SCALE 1:5,000,000
FIG. 1.

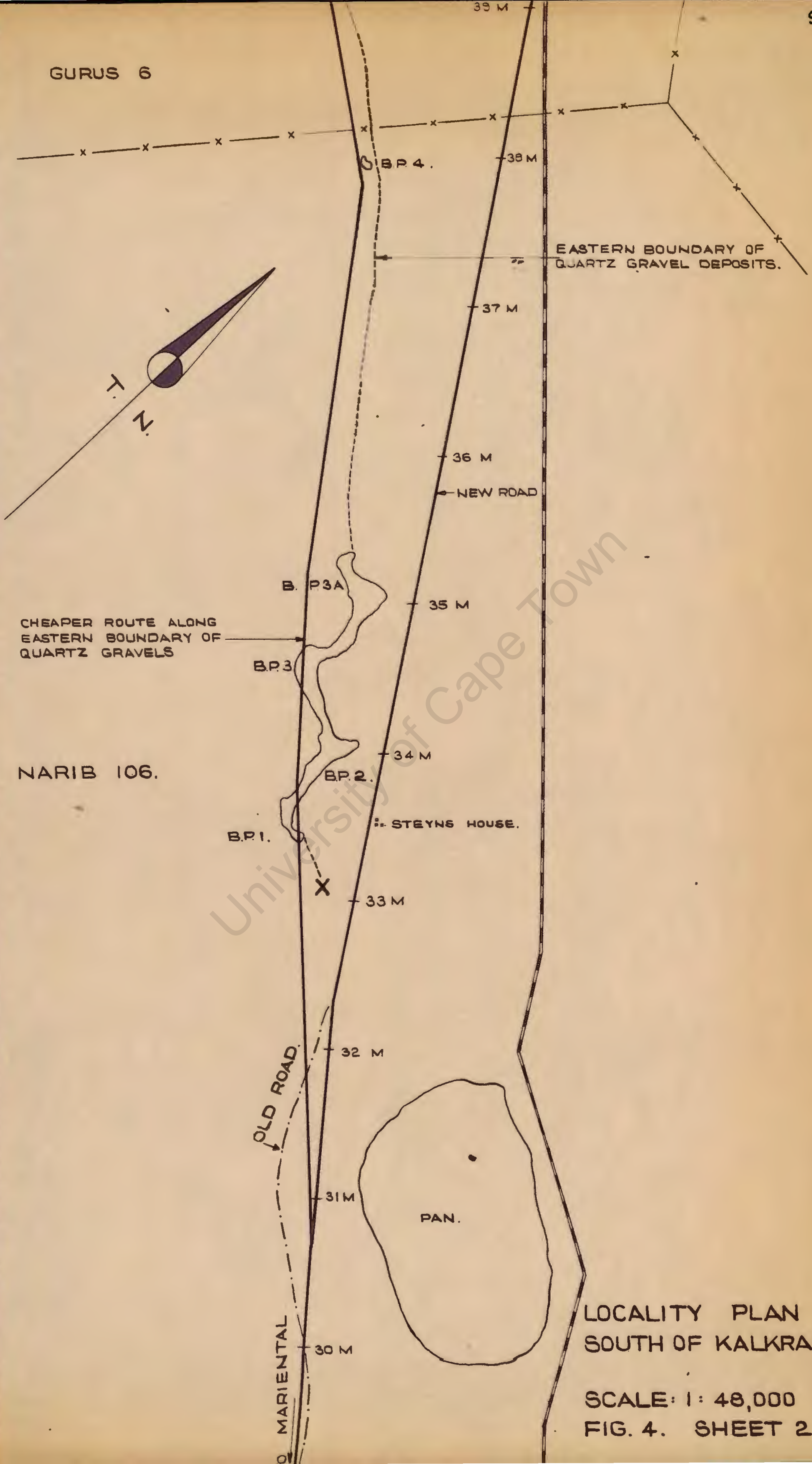


LOCALITY PLAN
WINDHOEK AREA.
SCALE 1:150,000
FIG. 3



LOCALITY PLAN
SOUTH OF KALKRAND.

SCALE : 1 : 48,000
FIG. 4. SHEET 1.

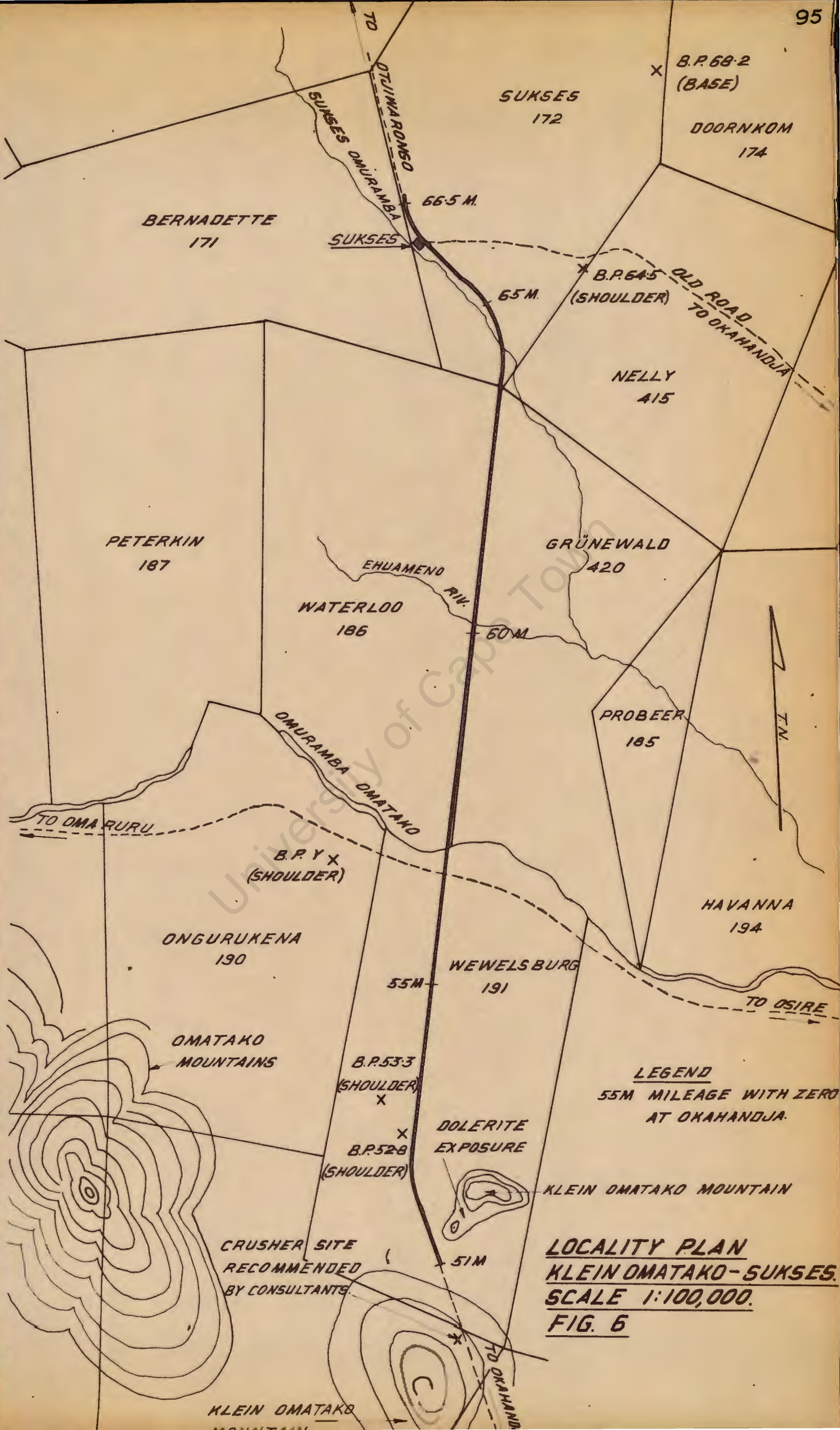


LOCALITY PLAN SOUTH OF KALKRAND.

SCALE: 1 : 48,000

FIG. 4. SHEET 2.

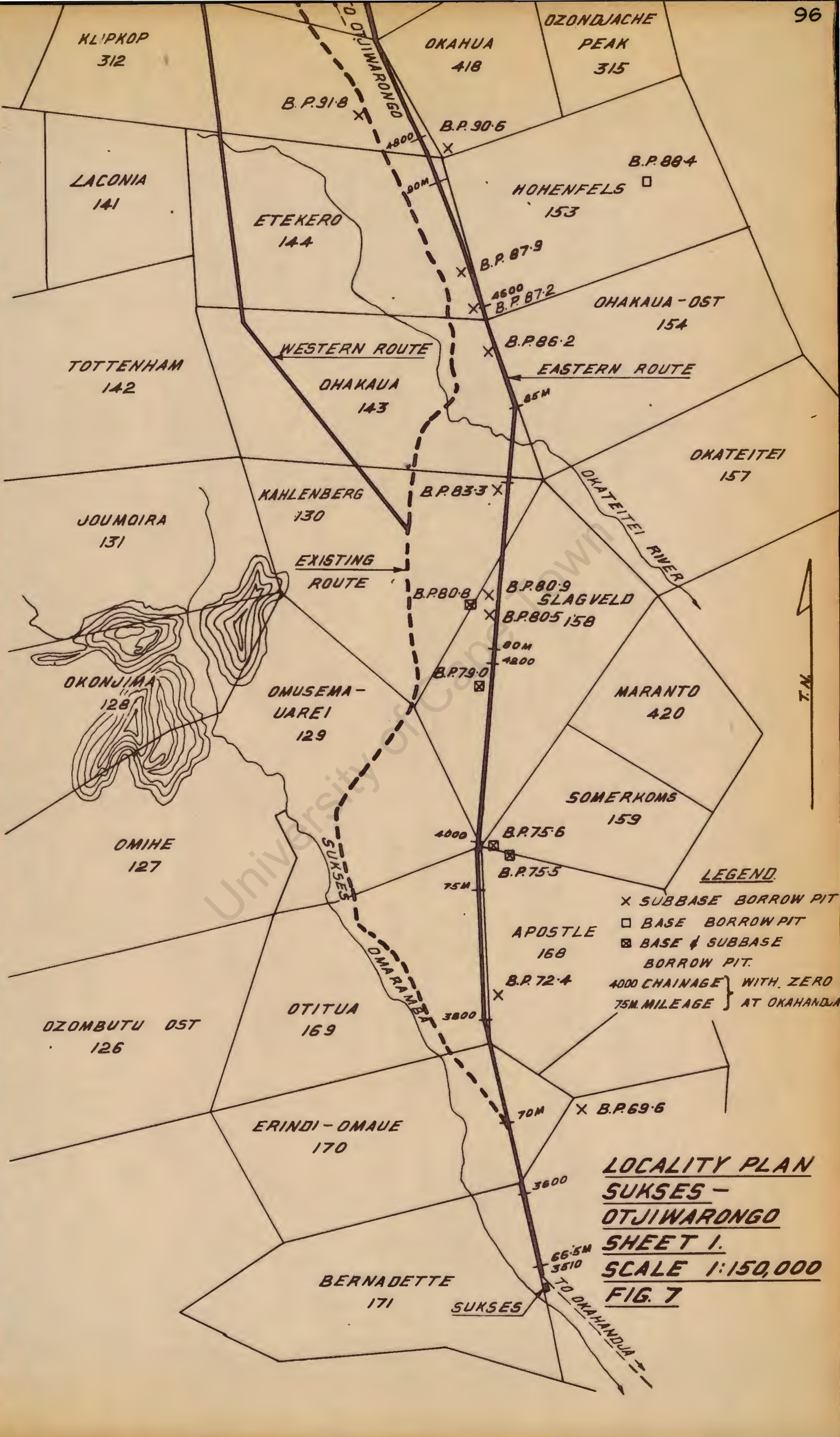
LOCALITY PLAN.
SEEIS - OMITARA
SCALE 1:150,000
FIG. 5



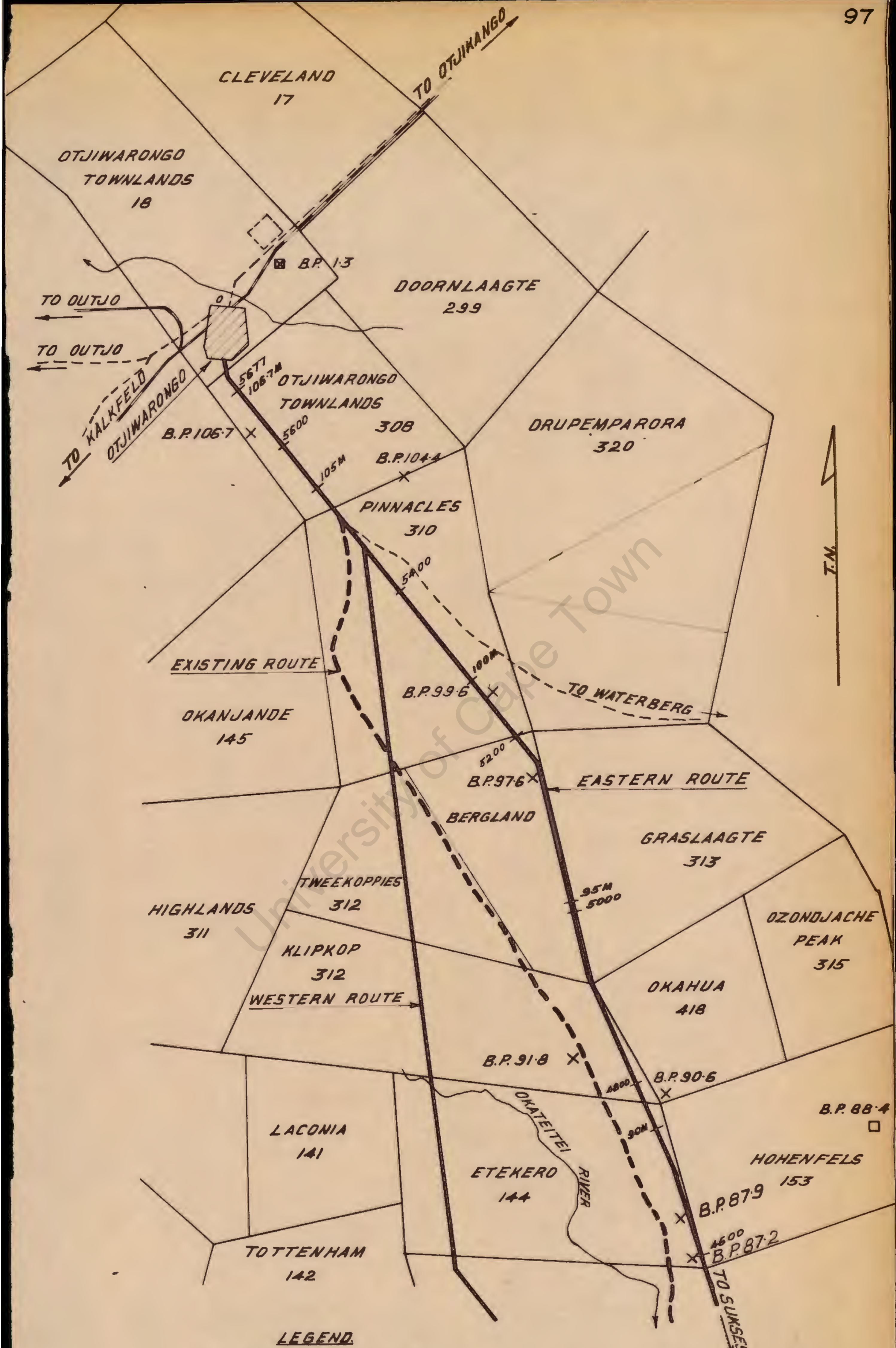
LEGEND

55M MILEAGE WITH ZERO AT OKAHANDJA.

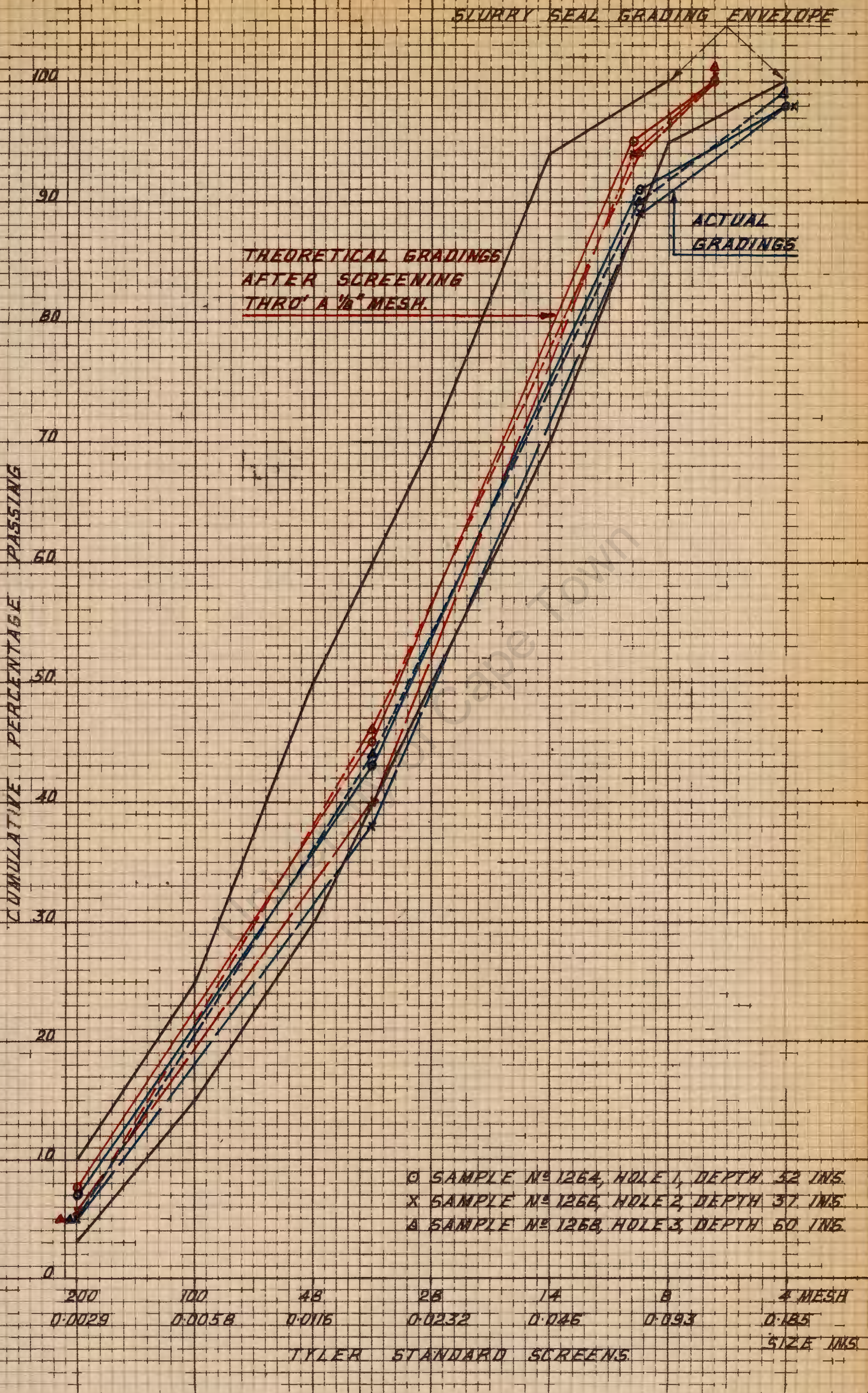
LOCALITY PLAN
KLEIN OMATAKO-SUKSES.
SCALE 1:100,000.
FIG. 6



LOCALITY PLAN
SUKSES –
OTJIWARONGO
SHEET 1.
SCALE 1:150,000
FIG. 7



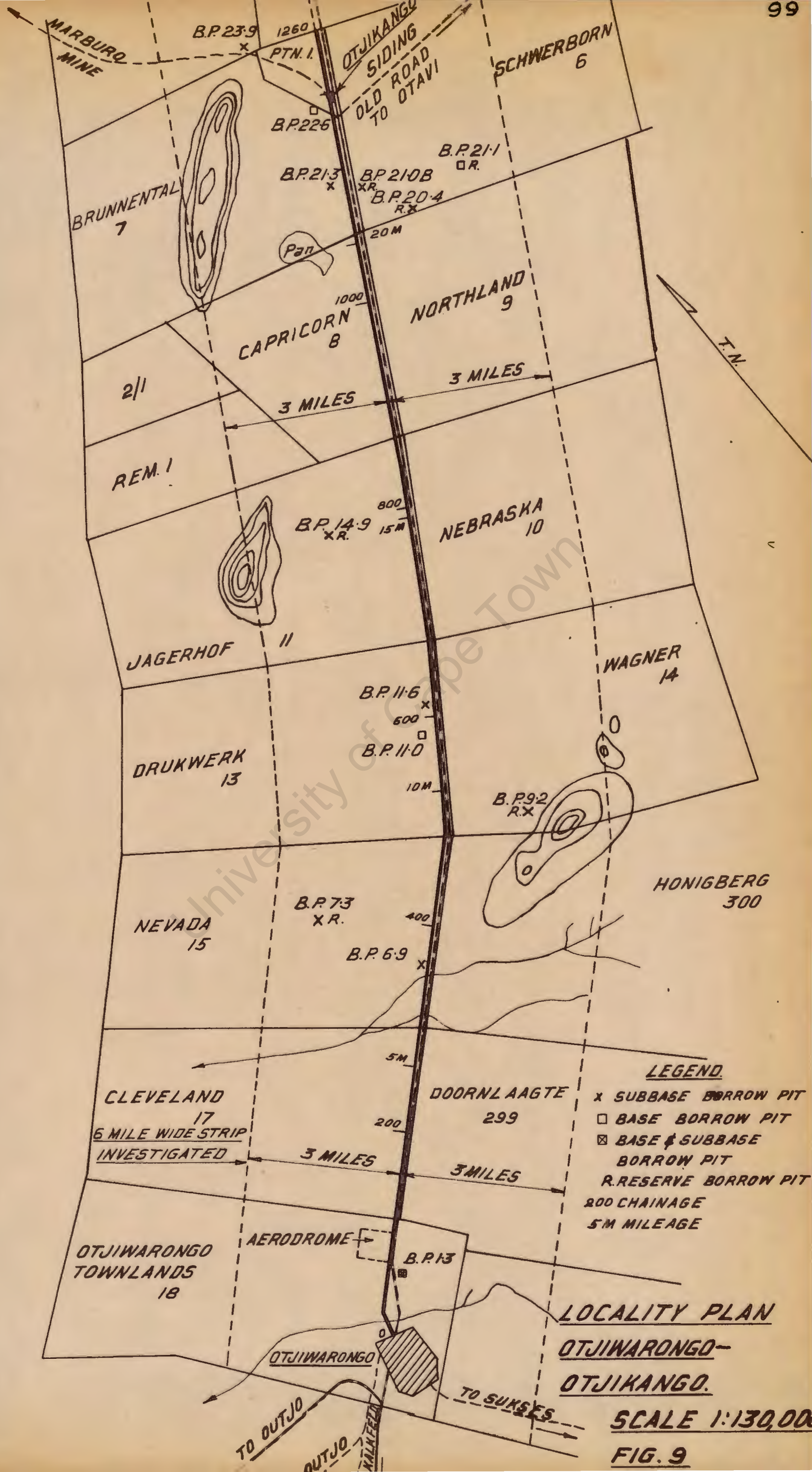
LOCALITY PLAN
SUKSES - OTJIWARONGO
SHEET 2
SCALE 1:150,000
FIG. 7



GRADINGS OF SAND FROM AN OLD RIVER BED NEAR SUKSES USED FOR SLURRY SEALING

FIG. 8

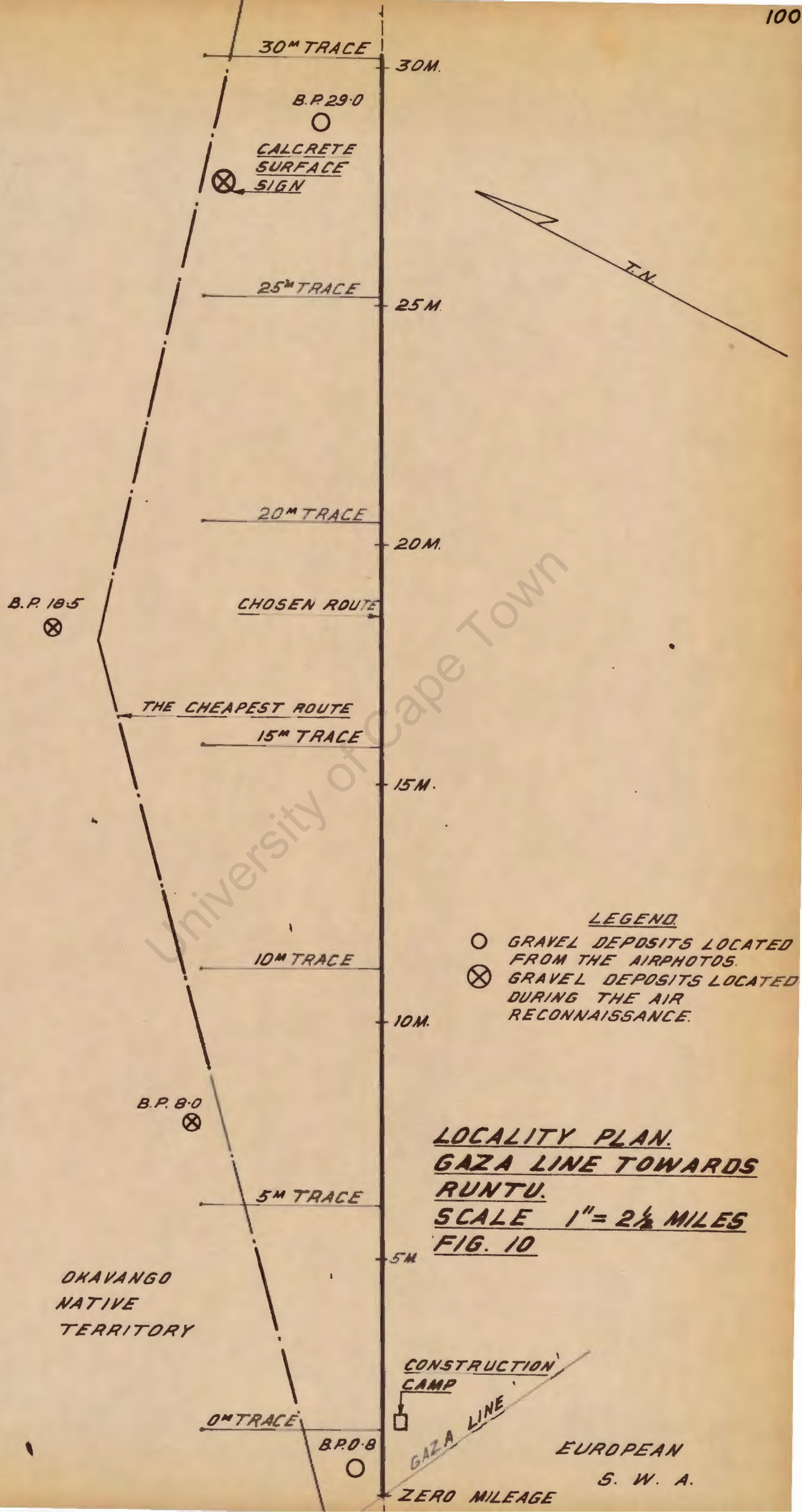
FIG. 8



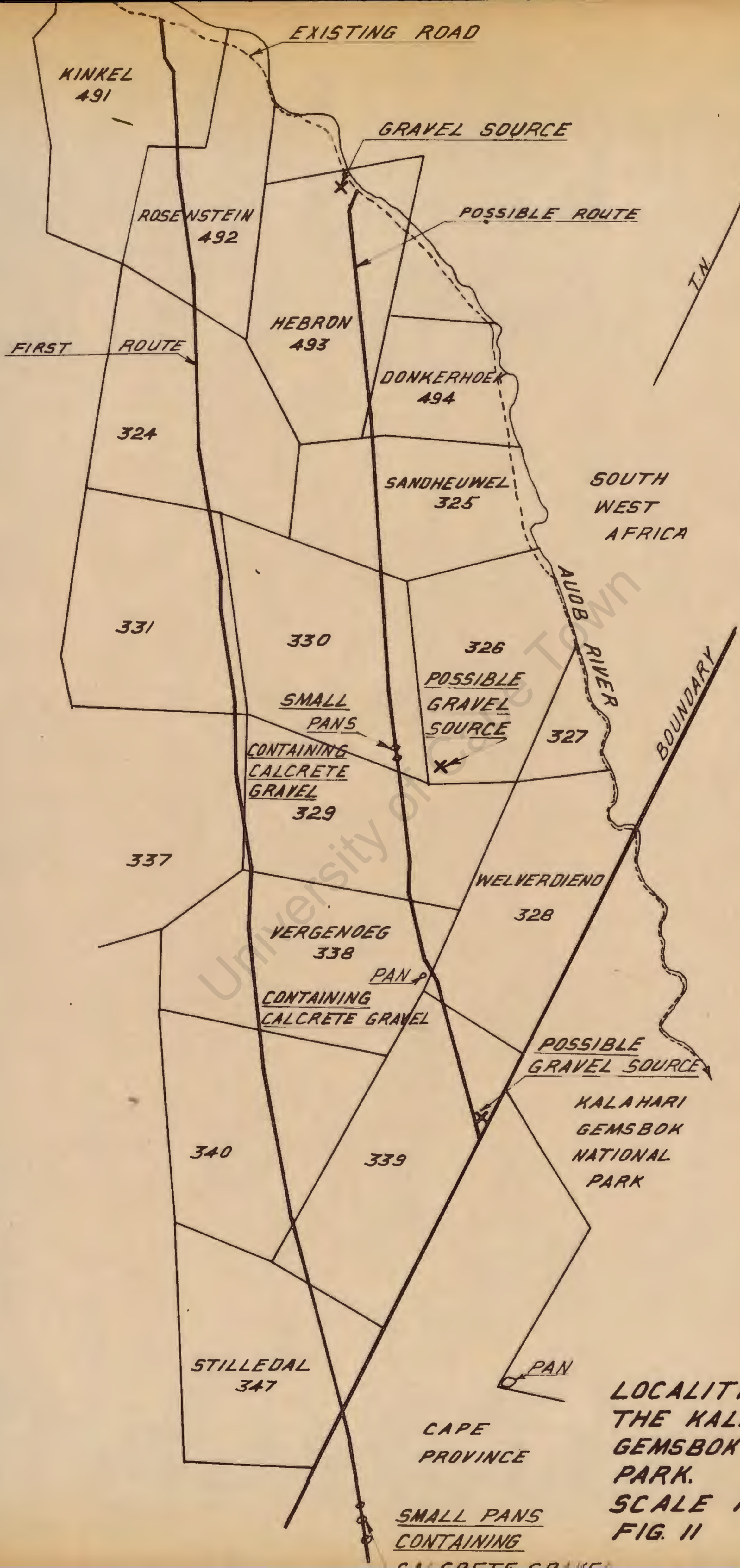
LOCALITY PLAN OTJIWARONGO– OTJIKANGO.

SCALE 1:130,00

FIG. 9



LOCALITY PLAN.
GAZA LINE TOWARDS RUNTU.
SCALE 1"= 2½ MILES
FIG. 10

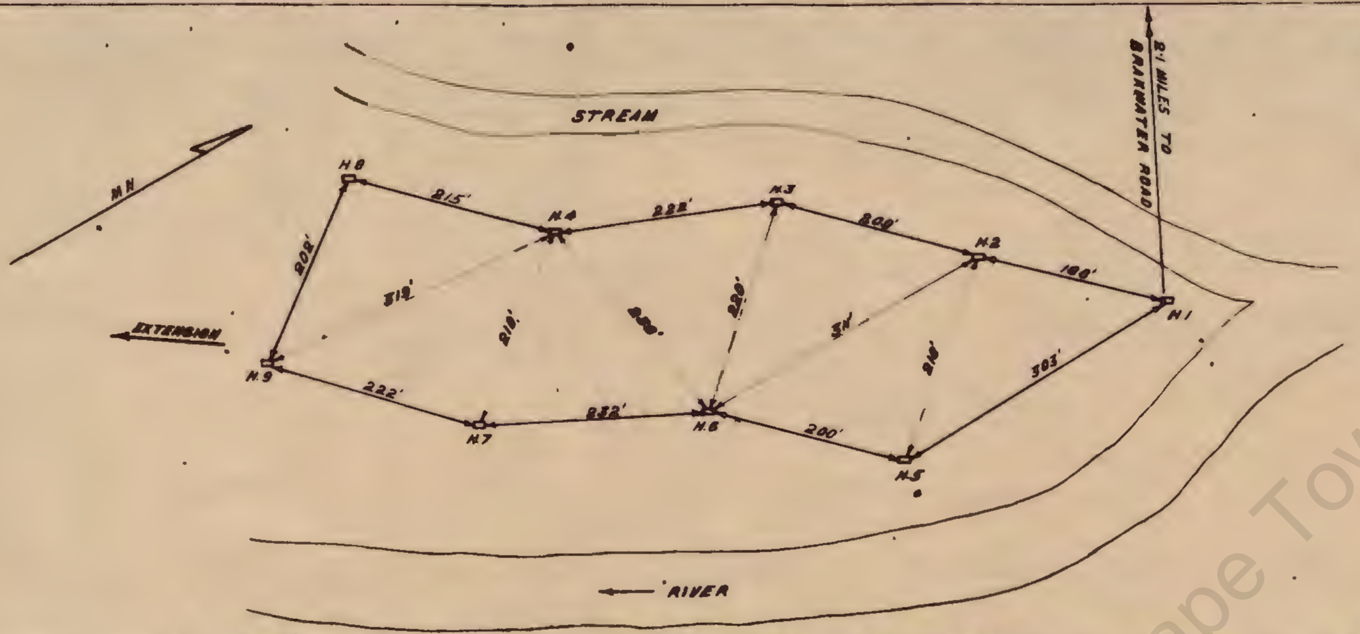


LOCALITY PLAN
THE KALAHARI
GEMSBOK NATIONAL
PARK.
SCALE 1:250,000
FIG. 11

APPENDIX B : TEST RESULT SHEETS 1 TO 36

Test Result Sheet No.	Title
1	Natural basecourse gravel near Brakwater.
2	Natural basecourse gravel on the road to Kapps Farm.
3	Natural subbase gravel on the road to Kapps Farm.
4 and 4A	Natural basecourse gravel on the road to Aris.
5	Typical plastic gravel of workable depth situated on the road to Kapps Farm.
6	Typical gravel deposits between Seeis and Omitara.
7	Calcrete shoulder borrow pit 64.5.
8	Calcrete shoulder borrow pit Y.
9	Quartzose lateritic gravel deposit used in the basecourse.
10 and 10A	Basecourse and subbase gravel, typical of the occurrences South of the Okateitei River.
11 and 11A	Basecourse and subbase gravel, typical of the occurrences South of the Okateitei River.
12	Subbase gravel just South of the Okateitei River.
13	Base and subbase gravel, typical of that occuring in the features South of the Okateitei River.
14 and 14A	A subbase deposit South of the Okateitei River.
15, 15A and 15B	Low plasticity dec. granite subbase North of the Okateitei River.
16	Low plasticity dec. granite subbase North of the Okateitei River.
17	Low plasticity dec. granite subbase North of the Okateitei River.
18	Dec. granite of subbase quality, typical of that occuring in contact with bands of crystalline limestone.
19 and 19A	Dec. granite subbase occuring in the zone of contact with a band of crystalline limestone.
20	Calcrete of shoulder quality near Sukses.
21	Calcrete of shoulder quality near Sukses.
22	Surface dressing sand in the Sukses Omuramba.
23	Surface dressing sand in the Okateitei River.
24	Sand for surface dressing near Otjiwarongo.
25 and 25A to 25D	Nodular calcrete deposit North of Otjiwarongo, suitable for use in the basecourse.

Test Result Sheet No.	Title
26 and 26A	Nodular calcrete deposit mid-way between Otjiwarongo and Otjikango, suitable for use in the basecourse.
27 and 27A	Nodular calcrete deposit near Otjikango, suitable for use in the basecourse.
28 and 28A	Quartzose lateritic gravel deposit near Otjikango, suitable for use in the basecourse.
29 and 29A	Typical subbase granite between Otjiwarongo and Otjikango.
30 and 30A	Typical subbase granite between Otjiwarongo and Otjikango.
31 and 31A	Subbase granite in contact with a band of crystalline limestone near Otjikango.
32	Quartzite subbase near Otjikango
33	Typical soft-aggregate calcrete and plastic binder from North of the Gaza Line.
34	Wearing course quality calcrete from North of the Gaza Line.
35	Calcrete gravel and clay from a pan in the Kalahari.
36	Calcrete gravel and clay from a small pan in the Kalahari.



BORROW PIT INFORMATION | BORROW PIT Nº

Farm Elisenheim No. 68. | Owner : A.H. du Plessis

Chainage :

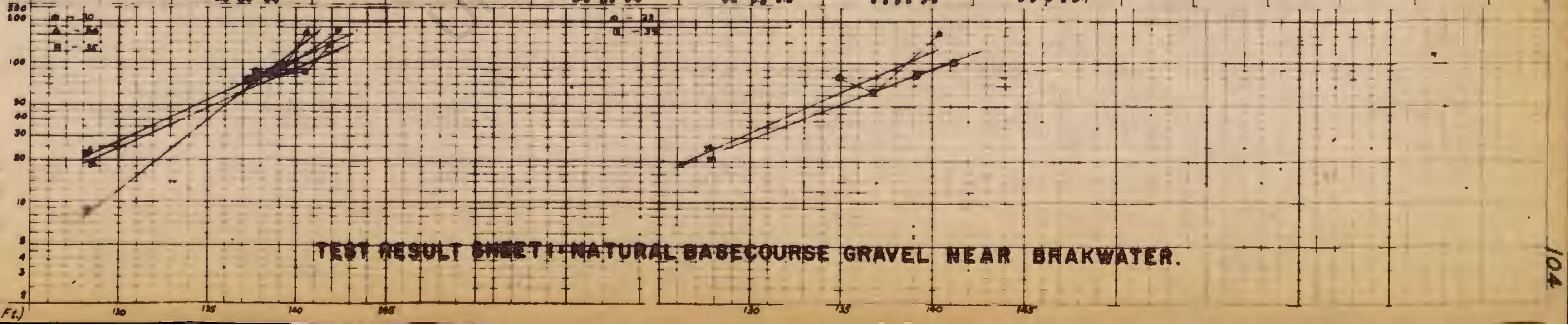
COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of base	Min % of mod. AASHO Density required	Range of Opt. moist content	Approx. Quantity yds ³
Base	0 – 4	98 %	3·9% – 6·0%	18,000

REMARKS

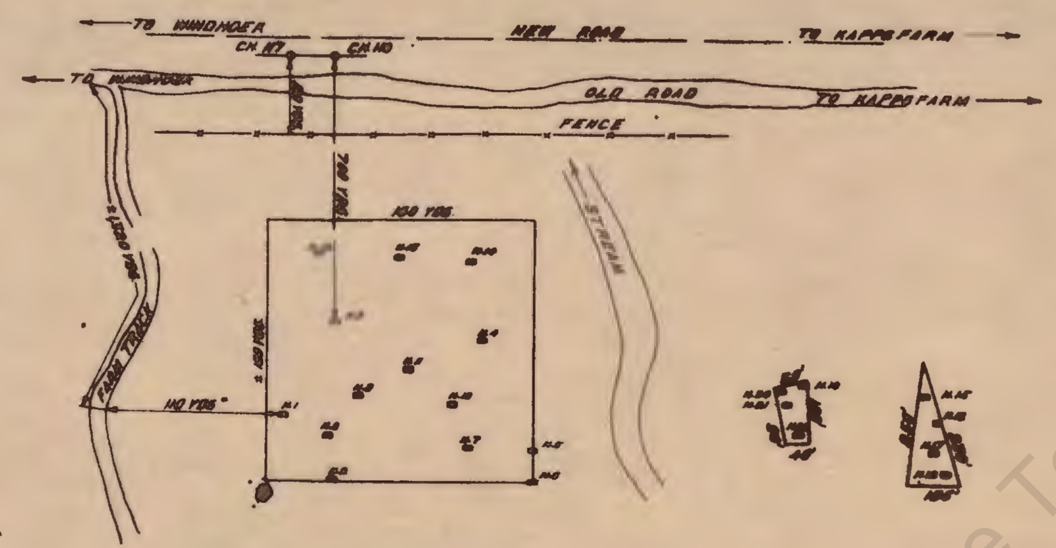
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Visual Description		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		[illegible]	
Stabilized with/Ex mould					ex mould					ex mould		ex mould		ex mould		ex mould
Sample Nº	IND/CBR	28 –	29 –	30	30 –	31	32 –	33 –	34	34 –	35	35 –	36 38	38 –	37 39	39 –
Hole/depth below exist. grd. level		1 0-15"	1 15"-46"	3 0-36"	3 0-36"	3 36"-46"	4 0"-49"	6 0-[illegible]"	7 0-28"	7 0-28"	8 0-36"	8 0-36"	8 36"-47"	8 36"-47"	9 0-37"	9 0-37"
P R A classification (group index)		A1-a [0]	A1-a [0]	A1-a [0]	A1-a [0]	A2-4 [0]	A1-a [0]	A1-a [0]	A1-a [0]	A1-b [0]	A1-a [0]	A2-4 0	A1-a [0]	A1-a [0]	A1-a [0]	A1-b [0]
Screen analysis	− 1½" / − 3/4"	89 61	81 58	74 57	100 96	94 66	85 64	82 54	89 72	100 98	77 54	100 97	82 60	100 98	85 64	[illegible] 87
	0·185" / − 0·078"	31 24	32 23	36 26	51 37	41 30	35 29	24 20	38 30	59 48	26 17	45 30	28 18	55 35	31 22	52 [illegible]
	0 0164" / −0 0029/0 0021"	11 6/4	10 2/2	22 9/7	29 11/9	23 [illegible]	25 [illegible]	19 7/5	25 [illegible]	40 10/11	14 4/3	27 7/5	13 4/4	20 2/7	20 7/5	[illegible] 11/[illegible]
Soil mortar grading	coarse sand / C. fine sand	29 11	36 15	15 6	21 7	23 8	14 7	5 5	13 7	17 8	18 7	27 7	20 9	43 8	9 7	[illegible] 7
	M. fine sand / F. fine sand	16 26	12 9	18 25	17 32	16 26	22 27	23 45	21 37	19 24	25 33	20 29	10 24	14 17	28 37	[illegible]
	Silt / Clay	12 6	5 4	15 11	18 10	16 13	13 7	19 10	14 8	13 9	8 9	8 9	7 4	7 11	11 13	[illegible] 11
Atterberg Limits	L.L. / P.I.	5 P	5 P	20 3	5 P	20 7	5 P	5 P	5 P	3 P	3 P	3 P	30 7	21 8	5 P	[illegible] –
	L. SH		0.5	2.0	4.0	3	0.5	1.0	1.0	1.0	0.5	1.0	3.0	3.5	1.0	1.5
Opt moisture / Density at mod. AASHO				4.2 109.6					4.0 141.9		5.5 [illegible]		3.9 [illegible]		6.0 [illegible]	
Mould moisture content / Density/C.B.R 95% 90%				[illegible]					130.1/35		135.2/30		133 8/53		136 6/63	
				4.8 [illegible]/22					3.8 127.3/7		5.0 128.1/[illegible]		3.7 126 8/21		5.4 129.5/27	
Density				120.4 [illegible] 130.5					140.4 [illegible] 137.1		149.9 [illegible] [illegible] 7		140.4 138 130.9		141.2 [illegible]3 139.2	
C B R				173 [illegible] [illegible]					[illegible] [illegible] 75		105 [illegible] 80		143 65 80		103 [illegible] 85	
Swell				0.0 0.0 0.0					0.0 0.0 0.0		[illegible] 0.0 0.0		0 0 0 0 0.0		0.0 0 0 0.1	

C. B. R Density Diagrams



TEST RESULT SHEET 1 - NATURAL BASECOURSE GRAVEL NEAR BRAKWATER.

Dry Density (Lbs/Cub. Ft.)



BORROW PIT INFORMATION . BORROW PIT Nº 118

Farm

Owner

Chainage

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of base	Min % of mod AASHO Density required	Range of Opt. moist. content	Approx. Quantity yds³

REMARKS

Visual Description

Stabilised with 'E' mould

Sample No | ND CBR

Hole/depth below exist. grd. level

P R A classification (group index)

Screen analysis: 1½" | 3/4" ; 0 .85 | 0 0.076 ; 0 0.64 | 0 0088, 0.002

Soil mortar grading: coarse sand | fine sand ; fine sand | F fine sand ; Silt | Clay

Atterberg Limits: L.L. | P.I. ; L.S.

Opt. moisture | Density at mod AASHO ; Mould moisture content | Density | CBR

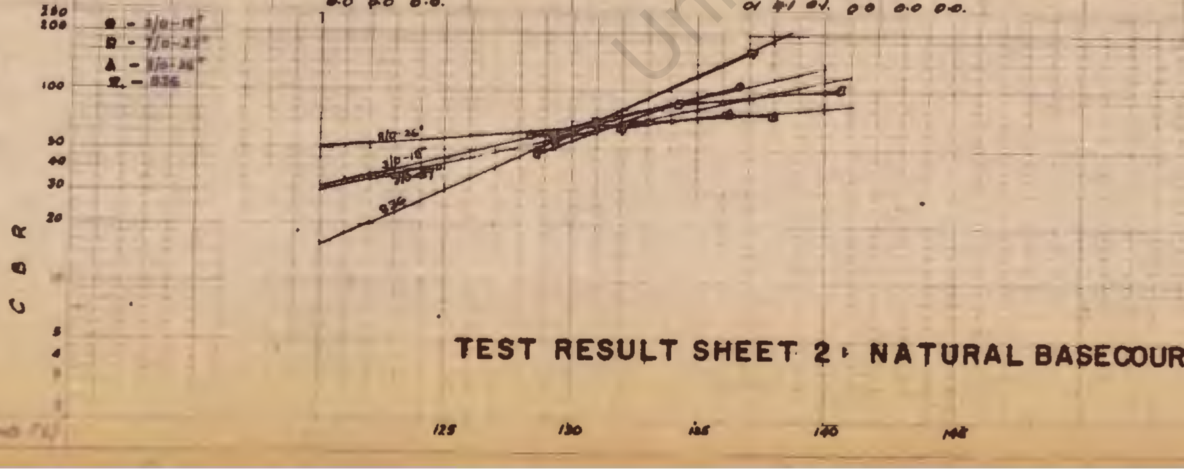
Density

C B R

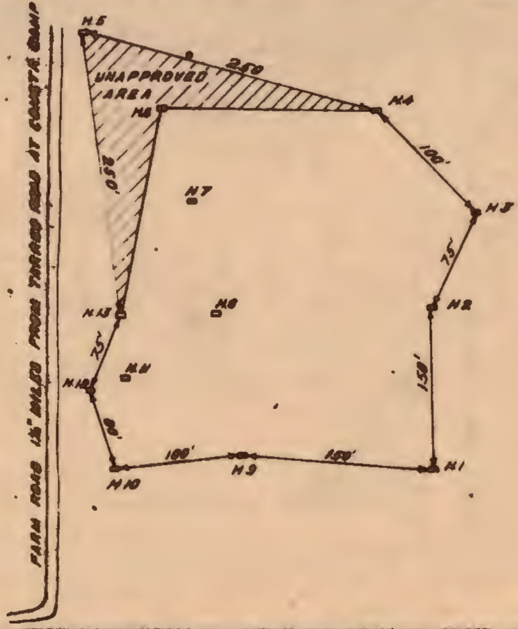
Swell

												47 -	48 -	49 -	50	836	837 -	839 -	841
1 0-13"	2 0-12"	3 0-18"	4 0-21"	5 0-13"	6 0-21"	7 0-21"	8 0-26"	8 26"-34"	9 0-15"	10 0-6"	11 0-13	12 0-88	13 0-8"	14 0-12"	3-26"	15 0-16"	16 0-12"	17	18 0-18
		A1-a [0]		A1-a [0]			A1-a [0]	A2-4 [0]				A1-a [0]	A1-a [0]	A1-a [0]	A1-a [0].	A1-a [0].	A1-a [0]	A1-a [0]	A1-a [0]
83 64	93 69	69 30	69 46	49 [illegible]	81 58	57 41	80 42	78 49	88 62	79 55	69 41	81 [illegible]	80 52	100 75	68 54	98 81	97 73	97 74	91 [illegible]
26 22	30 22	4 9	24 20	30 [illegible]	32 27	20 18	24 21	36 33	22 16	28 19	21 9	23 19.	28 28	36 31	33 30	37 29	37 33	40 34	47 43
19 -	19 -	8 6	18 -	22 12½	24 -	16 -	19 9	30 14½	13 -	17 -	17	16 4.5	20 8/7	27 [illegible]	26 [illegible]	[illegible]	24 [illegible]	30 [illegible]	38 [illegible]
x 13	x 16	x 12	x 10	[illegible]	x 13	x 14	x 10	x 10	x 15	[illegible]	x 9	12 15	13 11	12 13	12 14	14 15	14 [illegible]	12 15	10 7
● 63	● 61	● 62	● 62	● 62	● 63	● 64	● 71	● 74	● 60	● 64	● 41	22 27	20 28	23 28	21 [illegible]	27 [illegible]	26 [illegible]	25 23	25 26
19.6	20.5	18.7	21.7	16.7	15.5	19.4	12 4	13 3	18 -	20 5	[illegible]	16 10	18 10	14 10	14 13	12 6	12 [illegible]	16 8	15 7
24.5	sl. pl.	sl. pl.	23 3	sl. pl.	sl. pl.	sl. pl.	sl. pl.	24 10	sl. pl.	sl. pl.	sl. pl.	sl. pl.	sl. pl.	sl. pl.	sl. pl.	sl. pl.	sl. pl.	20 4	sl. pl.
2.0	1.0	2.0	1.5	1.5	0.5	1.0	0.0	5.0	1.5	2.0.	2.0.	2.0	2.0	0.	2.0	5	1.5	2.0	5
		4.0 133.6 / 126.9/52				5.0 129.2 / 128.7/53	5.7 138.5 / 132.7/66									4.6 137.4 / 133.3/86			
		3.2 120.0/32				4.2 126.3/101	5.8 126.3/57									4.4 123.6/25			
		136.6 129.2 128.4				140.6 134.2 128.7	138.0 136.2 132.0									137.4 132.0 129.4			
		113 50 60				100 89 49	77 79 64									162 70 56			
		0.0 0.0 0.0.				0.1 0.1 0.1.	0.0 0.0 0.0.									0.0 0.0 0.0			

CBR Density Diagrams



TEST RESULT SHEET 2: NATURAL BASECOURSE GRAVEL ON THE ROAD TO KAPPS FARM.



BORROW PIT INFORMATION BORROW PIT Nº

Farm

Owner ·

Chainage · 238

COMPACTION REQUIREMENTS and QUANTITY

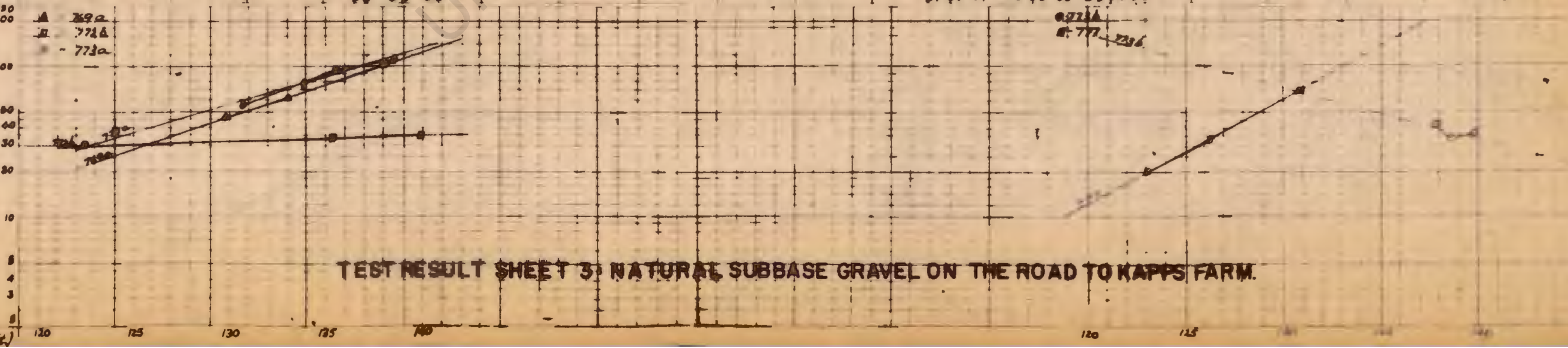
Material	Horizon measured from top of base	Min % of mod. AASHO Density required	Range of Opt moist content	Approx Quantity yds 3
QUARTZ GRAVE	SUBBASE	98 %	4.8% 6.4	

REMARKS

The gravel must be compacted to a minimum relative density of 98% modified AASHO density.

Visual Description	[illegible] Gr. Sl	[illegible]	[illegible]	[illegible]	[illegible]	Gr. Sl. + gr pbls	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible] br. sl.
Stabilized with Ex mould																				
Sample Nº IND/CBR	[illegible] -	[illegible] -	[illegible] -	[illegible] -	769a	770 -	[illegible]	[illegible] -	[illegible] -	772 ?	[illegible]	772b	773a	773b	[illegible] -	775 -	[illegible] -	[illegible] -	- 777	[illegible] -
Hole/depth below exist grd level	1 0-12"	1 12-36"	2 0-11"	2 0-12	4 0-11"	5 0-11"	5 11-20"	6 0-10"	6 [illegible]	7 [illegible]	7 [illegible]	7 16"-26"	8 5-18"	8 18-37"	9 0-10"	10 0-5"	10 5-14"	11 8-18"	12 0-9"	12 9-31"
PRA classification (group index)	A-2 [0]	A-2 [0]	[illegible] [0]	A-1-b [0]	A-2 [0]	A-2 [0]	A-2 [0].	A-2 [0].	A-1-b [0]	A-2-4 [0]	A-2-4 [0]	A-2-4 [0].	A-1-b [0]	A-2 [0].	A-1-b [0].	A-1-b [0]	A-2-4 [0]	A-1-b [0].		A-1-b [0].
screen analysis 1½ / - 3/4"	97 66	[illegible]	95 76	88 74	97 78	100 99	87 83	94 84	93 76	100 87	84 61	84 67	82 64	86 72	80 70	92 87	96 78	87 76		82 69
0.83" / - 0.078"	31 25	54 [illegible]	48 36	44 40	37 32	90 85	71 66	67 63	50 [illegible]	77 68	44 42	49 47	39 35	46 36	47 36	52 [illegible]	43 36	53 47		56 50
0.0164" / -0.0088/0.0021	22 9/8	38 [illegible]	32 12/9	34 18/9	29 10/8	75 23/15	59 23/19	57 17/12	37 [illegible]	63 21/17	38 [illegible]	44 16/13	32 11/8	29 11/9	33 [illegible]	49 17/12	32 [illegible]	43 [illegible]		46 17/14
Soil mortar grading: coarse sand / C. fine sand	12 9	14 9	11 8	14 8	9 9	11 10	9 9	9 10	15 15	7 9	7 8	7 9	9 10	19 8	7 8	8 9	11 8	7 10		8 9
M fine sand / F. fine sand	20 29	19 26	25 30	24 30	26 33	25 36	22 31	26 36	27 31	26 34	26 34	25 31	27 31	21 26	20 33	26 34	21 28	24 33		24 31
Silt / Clay	25 5	24 8	18 8	18 6	18 5	13 5	19 10	16 5	16 6	17 8	19 9	20 8	17 6	17 9	20 9	17 6	21 11	17 9		19 9
Atterberg limits LL / PI	26 8	27 10	S P	S P	S P	S P	21 6	S P	S P	20 4	22 7	23 7	S P	22 6	21 6	20 3	27 10	21 5		22 6
L Sh.	[illegible]	5.0	1.0	1.6	1.5	<0.5	2.5	0.5	1.5	2.5	4.0	4.0	1.5	3.5	[illegible]	1.5	5.5	3.0		3.0
Opt moisture/Density at mod AASHO					5.1 137.6							5.1 140.5	5.3 138.0	4.8 [illegible]					6.4 132.7	
Mould moisture content/Density CBR 98% / 95%					130.5/135 5.1 123.8/25							133.5/33 5.0 126.4/31	131/14 5.1 124.3/35	[illegible] 4.9 [illegible]					125.9/32 6.8 119.1/10	
Density					138.0 130.0 129.8							139.9 135.2 122.4	128.5 126.5 124.0	[illegible] 137.9					130.8 128.0 123.0	
C B R					102 67 46							35 33 31	14 [illegible] 54	36 30 42					70 38 20	
Swell					0.0 0.0 0.0							0.1 0.1 0.1	0.0 0.0 0.0	0.0 0.0 0.0					0.3 0.3 0.3	

C B R Density Diagrams



TEST RESULT SHEET 3: NATURAL SUBBASE GRAVEL ON THE ROAD TO KAPPS FARM.

BORROW PIT INFORMATION

BORROW PIT Nº 90

Farm	Owner:
	Chainage:

COMPACTION REQUIREMENTS and QUANTITY

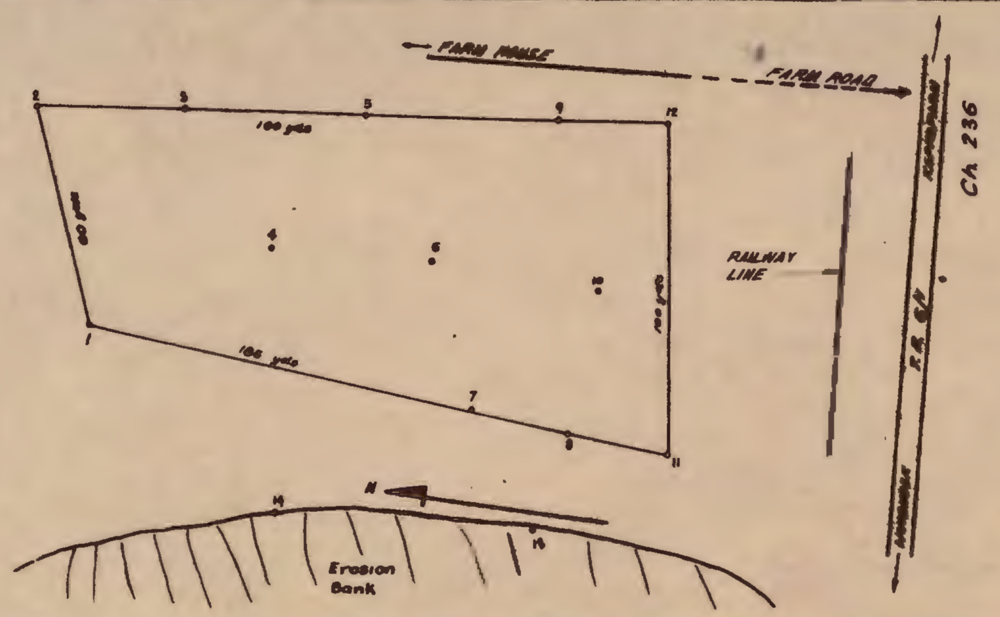
Material	Horizon measured from top of base	Min % of mod. AASHO Density required	[illegible]	Approx. Quantity yds³

REMARKS

Visual Description	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Stabilized with % mould										
Sample Nº IND C.B.R.	[illegible]	[illegible]	117	118	119	120	[illegible]	[illegible]	[illegible]	[illegible]
Hole/depth below exist. [illegible] level	13 0-16"	14 0-21"	[illegible]	16 0-15"	17 0-24"	18 0-15"	19 0-23"	[illegible]	21 0-[illegible]"	[illegible]
PRA classification (group index)	A-1-b [0]	A-1-b [0]	A-1-b [0]	[illegible]	A-1-a [0]	A-1-b [0]	A-1-b [0]	[illegible]	A-1-b [0]	[illegible]
Screen analysis 1½" / ¾"	[illegible] 67	[illegible]	71 [illegible]	[illegible]	61 36	91 72	91 69	[illegible]	[illegible] 67	[illegible]
0.187" / 0.078"	37 [illegible]	[illegible]	[illegible]	31 [illegible]	19 17	46 42	42 39	[illegible]	40 [illegible]	[illegible]
0.0[illegible] / 0.0[illegible]/0.0021	33 [illegible]	31 [illegible]	32 [illegible]	27 [illegible]	16 5/8	40 10/7	37 12/[illegible]	[illegible]	35 11/7	37 [illegible]
Soil mortar grading: coarse sand / C fine sand	6 5	3 4	3 5	4 [illegible]	6 [illegible]	5 5	5 4	3 4	3 3	3 3
M fine sand / fine sand	19 51	19 55	20 54	18 65	21 51	19 54	18 52	[illegible]	[illegible]	18 [illegible]
Silt / Clay	11 8	12 7	10 8	4 8	9 9	11 6	14 7	14 6	12 7	14 11
Atterberg Limits LL / PI	s p	n p	s p	[illegible]	s p	n p	2 p	s p	n p	s p
L SH	0.5	0.0	0.5	[illegible]	0.5	0.0	0.5	[illegible]	0.0	1.5
Opt moisture / Density at mod AASHO			4.6 / 130.0		5.0 / 137.2		5.3 / [illegible]			
Mould moisture content / Density / C.B.R.			6.0 / 125.0 / 16		5.2 / 133.3 / 56		5.4 / [illegible]			
Density			134.3 130.0 129.6		137.6 130.5 130.3		[illegible]			
C.B.R.			204 [illegible] 27		184 [illegible] 123		128 [illegible] 90			
Swell			0.0 [illegible] 0.9		0.0 0.0 0.0		[illegible]			

C.B.R. Density Diagrams

TEST RESULT SHEET 4A: NATURAL BASECOURSE GRAVEL ON THE ROAD TO ARIS.



BORROW PIT INFORMATION

BORROW PIT Nº ch 236

Farm :

Owner :

Chainage :

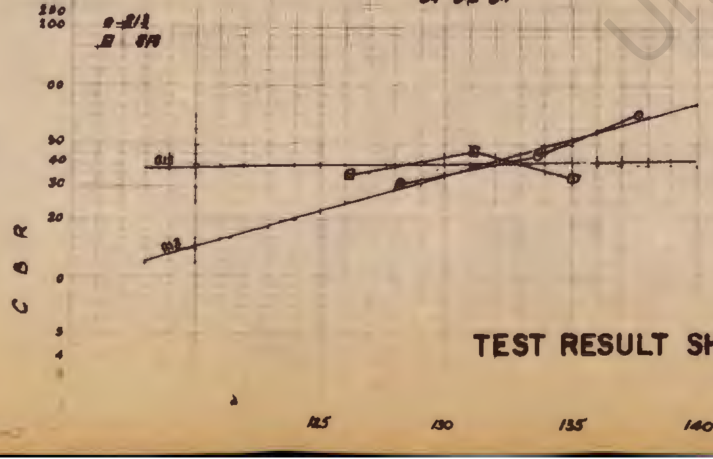
COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of base	Min. % of mod AASHO Density required	Range of Opt moist content	Approx. Quantity yds 3

REMARKS

Visual Description Stabilized with Ex mould	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sample Nº / Hole depth below exist grd level	810 - 1 0-17"	811 - 2 0-16"	812 - 3 0-15"	813 4 0-17"	814 - 5 0-12"	815 - 6 0-11"	816 - 7 0-12"	817 - 9 0-12"	818 10 0-20"	819 - 11 0-14"	820 - 12 0-12"	821 - 13 0-12"	822 - 14 0-14"
PRA classification / group index	A2-6 [0]	A2-6 [0]	A2-6 [0]	A2-6 [0]	A2-6 [0]	A2-6 [0]	A2-6 [0]	A2-7 [0]	A2-6 [0]	A2-6 [0]	A2-6 [0]	A2-6 [0]	A2-6 [0]
Screen analysis 1½" 3/4"	87 68	89 [illegible]	71 52	65 36	81 29	82 51	86 61	77 55	58 26	82 60	[illegible]	75 44	72 46
0 .83 / 0 .078	35 25	20 17	28 19	19 17	25 19	28 24	30 26	32 25	24 21	32 31	26 17	31 28	[illegible]
0 .0164 / 0 .0058/0 .0021	19 [illegible]	15 6/5	17 6/5	15 6/5	16 4/5	21 9/8	23 8/7	21 [illegible]	18 7/6	28 [illegible]	14 6/4	25 [illegible]	[illegible]
Soil mortar grading: Coarse sand / C fine sand	26 9	12 5	13 8	12 7	16 9	13 7	10 9	16 9	13 7	13 10	[illegible] 11	11 9	[illegible]
M fine sand / F fine sand	15 22	24 36	24 23	21 29	19 21	19 29	17 32	18 27	25 30	28 30	20 25	24 32	23 26
Silt / Clay	17 13	13 10	16 10	17 14	13 12	15 17	19 12	19 13	18 10	16 9	11 13	17 17	17 16
Atterberg limits L.L. / P.I.	25 12	32 14	27 10	32 14	32 13	34 14	32 12	42 [illegible]	35 14	30 11	33 13	36 15	36 15
L.SH.	7.0	6.5	6.5	6.0	6.5	7.0	7.5	9.5	8.0	6.0	6.0	8.0	6.5
Opt moisture / Density at mod. AASHO / Mould moisture content / Density, CBR 95% 90%				6.4, 128.7 130.6/38 6.9, 127.8/20					6.1, 130.0 128.4/40 6.6, 121.6/39				
Density				127.7 [illegible] 128.2					135.0 [illegible] 136.1				
C B R				72 45 32					33 [illegible] 35				
Swell				0.1 0.2 0.1					0.1 0.[illegible] 0.3.				

C B R Density Diagrams



TEST RESULT SHEET 5: TYPICAL PLASTIC GRAVEL OF WORKABLE DEPTH SITUATED ON THE ROAD TO KAPPS FARM.

BORROW PIT INFORMATION | BORROW PIT Nº

Farm
Owner :
Chainage.

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of base	Min % of mod AASHO Density required	Range of Opt moist content	Approx. Quantity yds ³

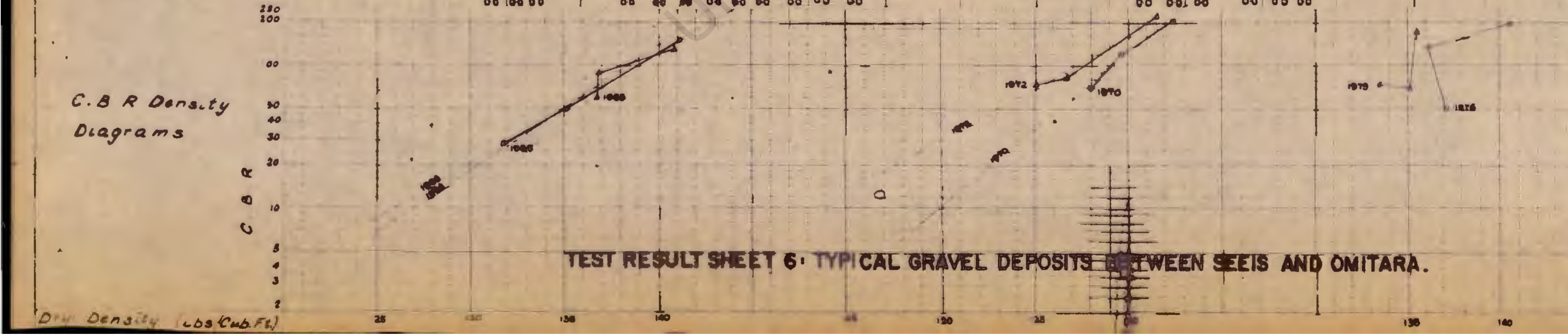
REMARKS

1 SAMPLES A TO I WERE TAKEN FROM HOLES ALONG THE SOUTHERN ROUT

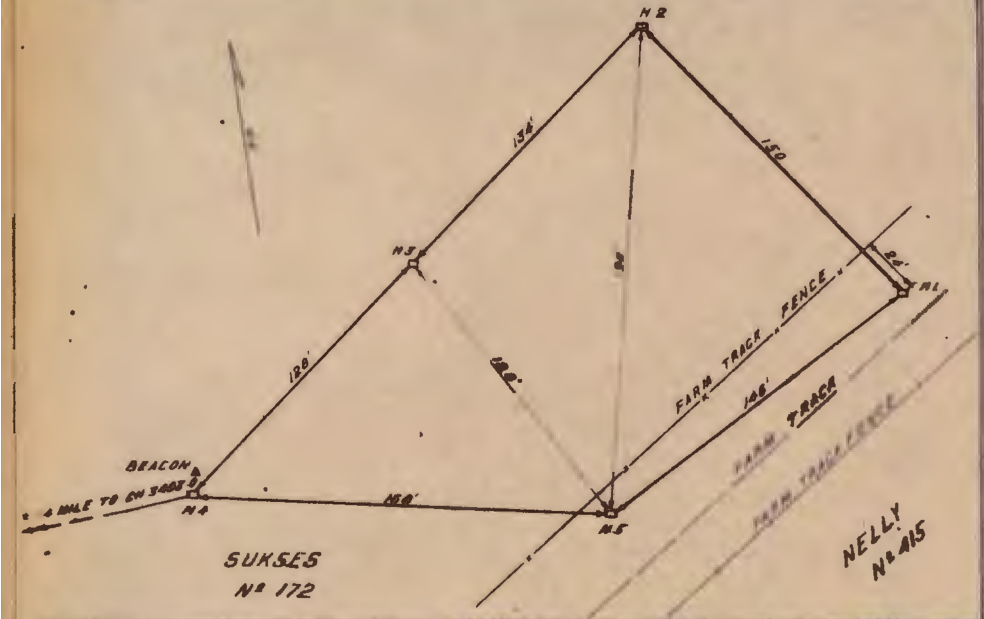
2 SAMPLES J TO M WERE TAKEN FROM HOLES ALONG THE NORTHERN ROUT

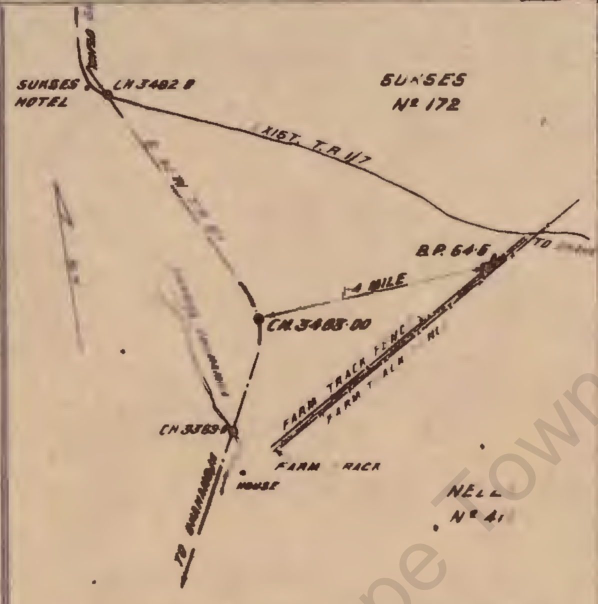
3 REFER TO FIGURE 5

			SOUTHERN ROUTE									NORTHERN ROUTE			
Visual Description		qtz pble + br sdy sl	qtz pble + d br sl.	qtz pble + d br sl	qtz pble + d br sdy sl.	qtz pble + l br sdy sl	qtz pble + br sdy sl	qtz pble + rdsh br sl.	qtz pble + rdsh br sl	qtz pble + br sdy sl	qtz pble + l br sdy sl	qtz pble + l br sdy sl	qtz pble + br sdy sl	qtz pble + br sdy sl	qtz pble + br sdy sl
Stabilized with Ex mould															
Sample Nº	ND CBR	1966	1967	1964 1965	1966	1962 1963	1968 1970	1971 1972	1973	1974	1977	1975 1976	1978 1979	1980	1981
Hole/depth below exist grd level		A 13"-26"	B 16"-27"	C 0"-24"	D 32"-48"	E 2"-31"	F 12"-30"	G 9"-36"	G 35"-47"	H 10"-24"	I 4"-60"	J 0"-36"	K 2"-31"	L 6"-65	M 6"-36"
PRA classification (group index)		A1-a [0]	A2-4 [0]	A1-a [0]	A1-a [0]	A1-a [0]	A1-a [0]	A1-a [0]	A2-4 [0]	A1-a [0]	A1-a [0]	A1-a [0]	A1-a [0]	A1-a [0]	A1-a [0]
screen analysis	1½ | 3/4	64 48	66 32	93 86	84 64	86 70	81 60	87 60	86 59	100 75	83 56	96 75	34 60	76 59	87 64
	0 85 | 0·075	19 17	17 16	43 34	29 22	29 16	30 23	35 25	25 21	33 25	36 24	32 22	39 27	29 20	33 26
	0 0'64 | 0026 0 002	15 4/3	14 4/3	30 11/8	20 4/3	16 4/3	20 5/4	22 6/4	16 5/4	26 6/3	22 6/3	19 4/3	23 6/3	17 5/4	24 7/6
Soil mortar grading	coarse sand | C fine sand	12 16	12 16	12 11	9 19	11 12	11 18	10 14	14 16	7 16	6 16	12 18	15 13	18 7	6 11
	M fine sand | F fine sand	26 28	22 30	22 31	29 26	28 32	26 28	28 30	23 26	31 34	29 35	29 29	28 32	23 36	31 33
	Silt | Clay	8 10	10 10	14 10	6 9	9 9	8 9	9 9	8 11	8 8	6 6	7 5	6 8	11 8	9 10
Atterberg Limits	L L L | P I.	S R	22 S	20 5	S R	S P	S R	18 6	21 T	S P.	n P.	S R	n P	S P	S P
	L SH.	0 5	2 5	3 0	< 0 5	< 0·5	0 5	1 5	3 0	< 0·5	0	< 0 5	0	0 5	1 0
Opt moisture Density at mod AASHO				4 9 | 140 9		4·8 | 140 9	4 2 | 142 0	5 0 | 142 9				4 3 | 140 6	3·7 | 138·4		
% moisture content | Density, CBR 95% 90%				135 9/42 3 9 | 128 6/11		135 9/44 4 8 | 128 6/11	134·9/24 9 2 | 127 8/6	135 6/76 4 7 | 128 9/83				133 6 4 3 | 126 3	131·5 3 7 | 126·6		
Density				141 1 135 1 131 7		140 9 138 0 126 7	142 4 135 6 129 0	141 4 135 8 129 0				140·6 136 1 127 1	138 5 133 1 128 5		
C B R				153 80 29		133 80 60	204 130 70	232 82 74				195 123 80	175 70 74		
Swell				0 0 0 0 0 0		0 0 0 0 0 0	0 4 0 0 0 0	0 0 0 0 0 0				0 0 0·0 0 0	0·0 0 0 0 0		



TEST RESULT SHEET 6: TYPICAL GRAVEL DEPOSITS BETWEEN SEEIS AND OMITARA.





LOCALITY SKETCH

BORROW PIT INFORMATION

BORROW PIT Nº 64.5

Farm Nelly Nº 41 Suk[illegible]

Owner Mrs L.R. [illegible]

Chainage [illegible] 3 [illegible]

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of base	Min % of mod AASHO Density required	Range of Opt moist content	Approx Quantity yds 3
Gravel	5	[illegible]	[illegible]	[illegible]

REMARKS

1 Remove all [illegible]

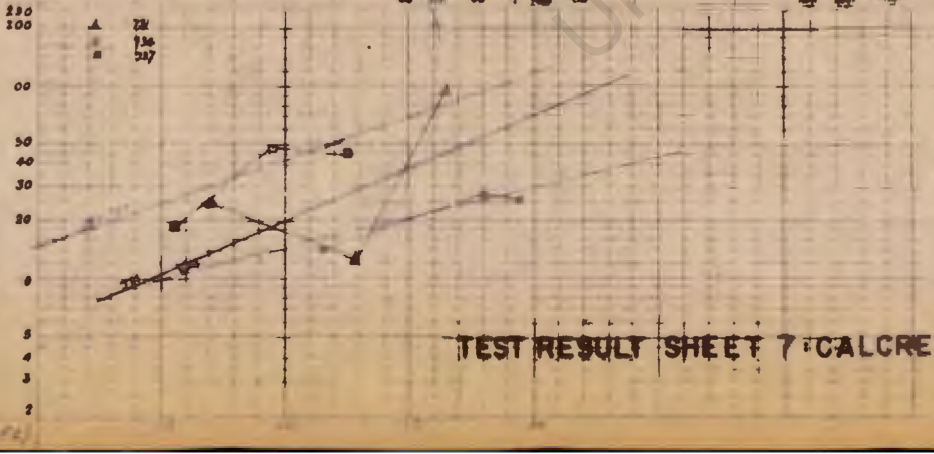
2 The gravel is approved for use in the [illegible]

3 [illegible] either [illegible]

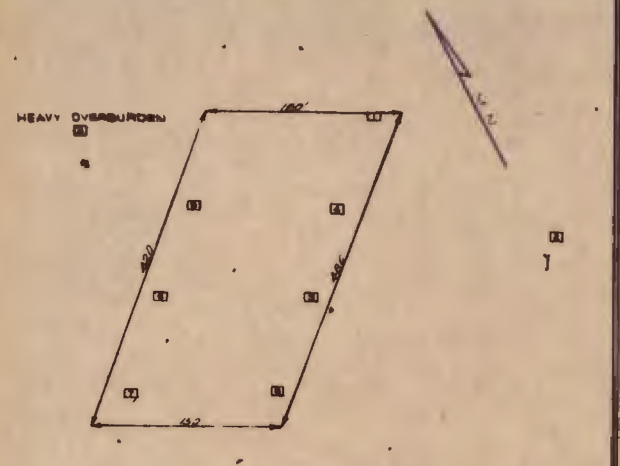
Visual Description
Stabilized with Ex mould
Sample Nº
Hole Depth below exist grd level
PRA Classification (Group index)
Screen Analysis
Soil Mortar Grading
Atterberg limits
Opt moisture content
Density at mod AASHO
Density
C B R
Swell

						Ex mould
729	[illegible]	[illegible]	[illegible]	723	726	727
24	[illegible]	2 18-41	[illegible]	4 28-47	5 24 31	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	A-2-6(0)	A-2-6(0)	[illegible]-6(0)
[illegible]	[illegible]	[illegible] 00	[illegible]	98.27	73.58	[illegible].00
[illegible]	[illegible]	[illegible]	[illegible]	61.42	38.36	[illegible]
25/14	[illegible]	[illegible]	[illegible]	[illegible]	19 0/6	[illegible]
[illegible]	[illegible]	[illegible] 9	[illegible]	[illegible] 9	27.10	33 8
26	[illegible]	[illegible]	[illegible]	9.21	11 30	9 28
[illegible]	[illegible]	[illegible]	9	15 8	16 6	[illegible] 10
[illegible]	[illegible]	[illegible]	[illegible]	33 16	22 12	34 [illegible]
[illegible]	[illegible]	6 5	[illegible]	6.0	[illegible] 0	6 0
		[illegible]	90 [illegible] 90 110.5/14			[illegible] 123.9 119/30 116 110/15
		125.4 [illegible] 122.9	[illegible] 121.7			122.5 [illegible].5 115.4
		75 [illegible] 12	26 36 14			46 39 19
		06 [illegible] 06	1 06 06			[illegible]

C B R Density Diagrams



TEST RESULT SHEET 7 : CALCRETE SHOULDER BORROW PIT 64·5



LOCALITY SKETCH

BORROW PIT INFORMATION

BORROW PIT Nº Y

Farm : ONGURUKENA 190

Owner :

Chainage : 2990·0

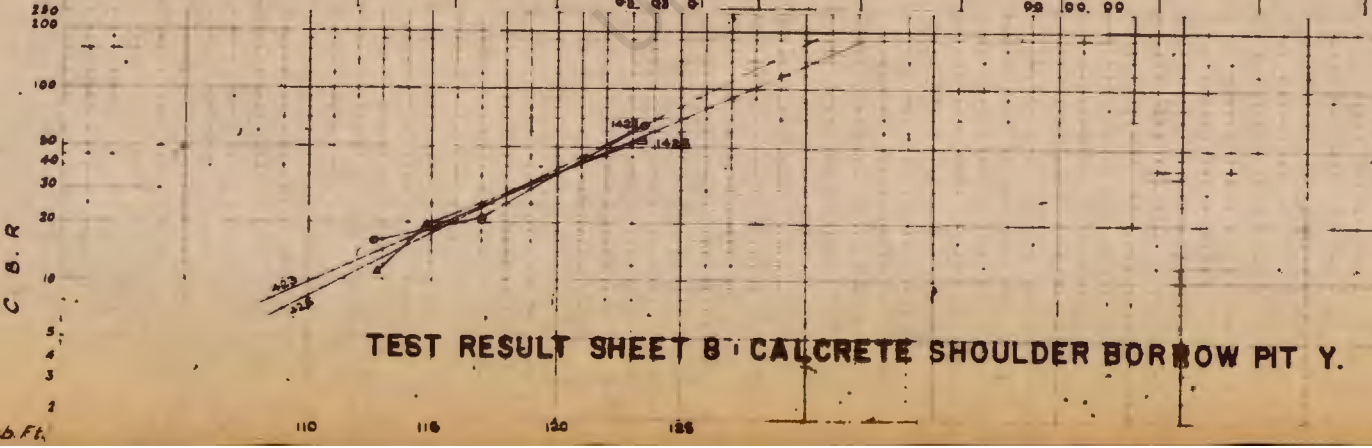
COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of base	Min % of mod AASHO Density required	Range of Opt. moist content	Approx Quantity yds ³
CALCRETE GRAVEL	SHOULDER	95	± 9·4	7,000

REMARKS

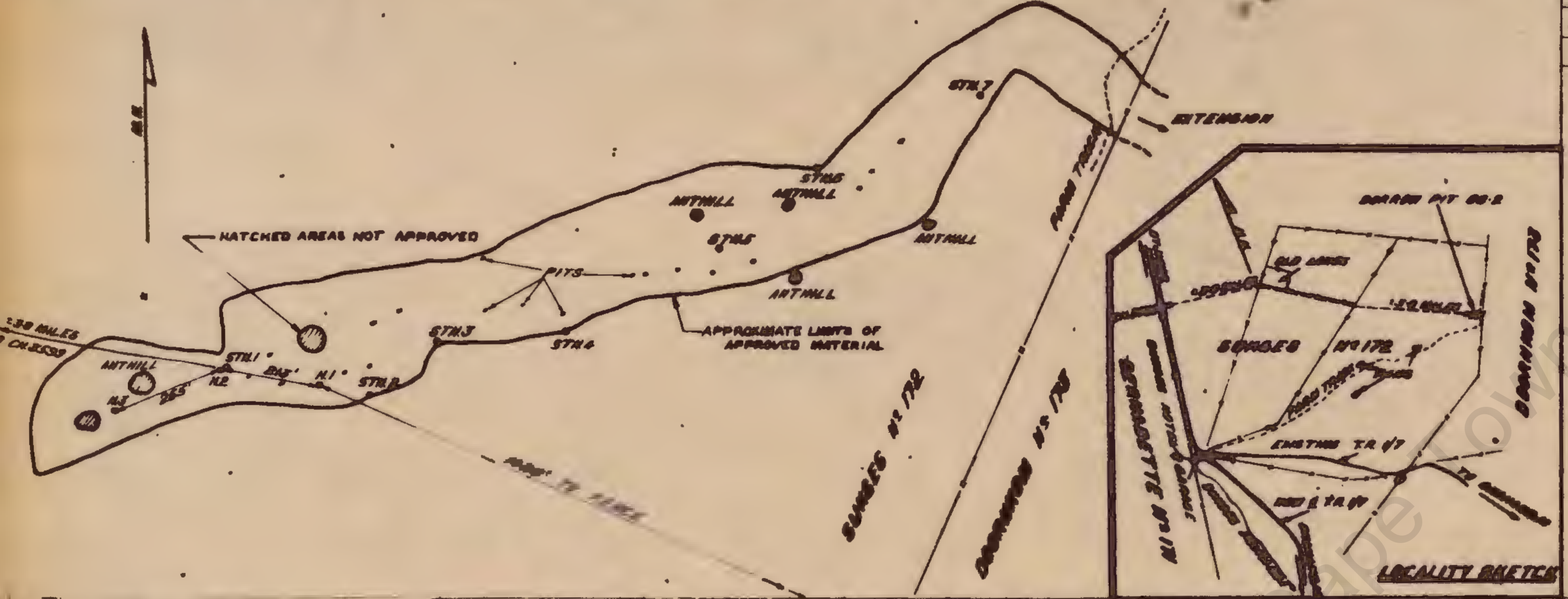
Visual Description	mod lat [illegible] white gr. sl.	[illegible]	Heavy Overburden	mod lat + shle pebs + gry sl.	mod lat + shle pebs + gry sl.	mod lat + shle pebs + gry sl.	lat [illegible] gry sl.	lat [illegible] gry sl.	mod lat	lat + shle pebs + gry sl.
Stabilized with Ex mould						Ex mould				
Sample Nº ND/C.B.R	1421			1422	1423	1422 1422	1424	1425		1426 1426
Hole/depth below exist. grd level	1 15"-52	2	3	4 12"-48"	5 14"-44"	5 16"-44"	6 18"-42"	7 18"-50"	8	9 12"-30"
P R A classification (group index)	A 2-4			A2-6	A2-6	A2-6	A2-6	A2-6		A2-6
Screen analysis 1½" / - ¾"	98 86			90 76	93 87	100	95 88	89		97 85
0·185" / - 0·078"	46 36			44 31	61 41	96 71	62 42	72 52		68 51
0·0164" / -0·0029/0·0021	26 2/7			25 12/10	30 15/13	56 28/29	24 10/13	45 21/18		42 26/16
Soil mortar grading: coarse sand / C fine sand	28 18			20 9	28 9	21 8	18 8	17 10		18 9
M fine sand / F fine sand	18 21			11 27	9 22	10 27	8 30	11 24		10 31
Silt / Clay	12 8			21 12	18 13	27 7	21 15	31 12		21 11
Atterberg Limits L.L. / P.I.	28 9			29 11	29 11	29 6	29 13	31 15		30 12
L. SH.	3 6			7 0	6 0	5·0	6·5	3·0		7 0
Opt moisture / Density at mod AASHO						9 4 124·7				9 4 123·8
Field moisture content / Density for C B R 95% 90%						118·8/26 9 3 112·2/13				117·0/24 9 3 110·8/2
Density						123 5 117·0 112·6				123 5 116 7 112 9
C B R						94 21 16				54 19 11
Swell						0·2 0·3 0·1				0·2 0·0 0·0

C.B R Density Diagrams



TEST RESULT SHEET 8 · CALCRETE SHOULDER BORROW PIT Y.

Dry Density (Lbs/Cub.Ft.



BORROW PIT INFORMATION

BORROW PIT Nº 68·2

Farm SUKSES No 172

Owner : Mrs. J.E. MEYER

Chainage : 3599·00

COMPACTION REQUIREMENTS and QUANTITY

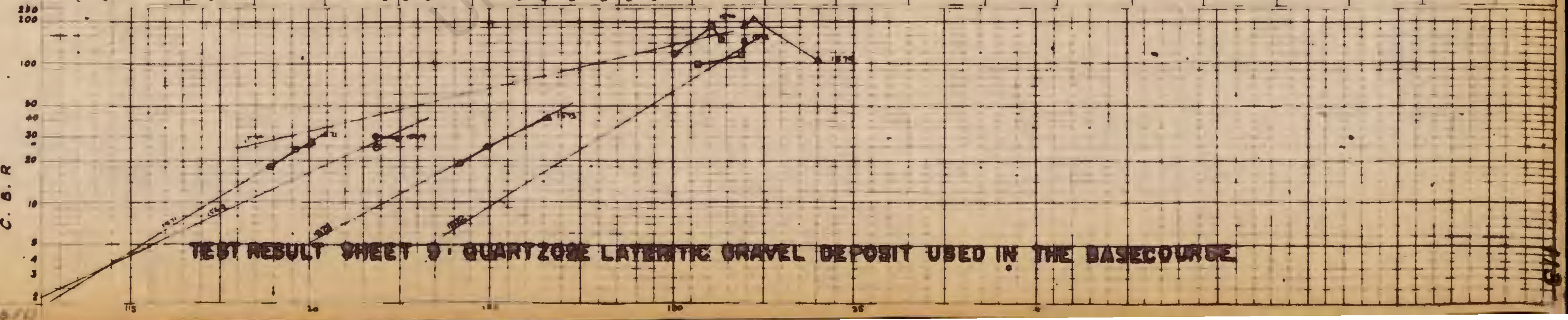
Material	Horizon measured from top of base	Min % of mod. AASHO Density required	Range of Opt. moist. content	Approx. Quantity yds³
Gravel	0" - 4"	100	6·8 - 8·5 %	37,300

REMARKS

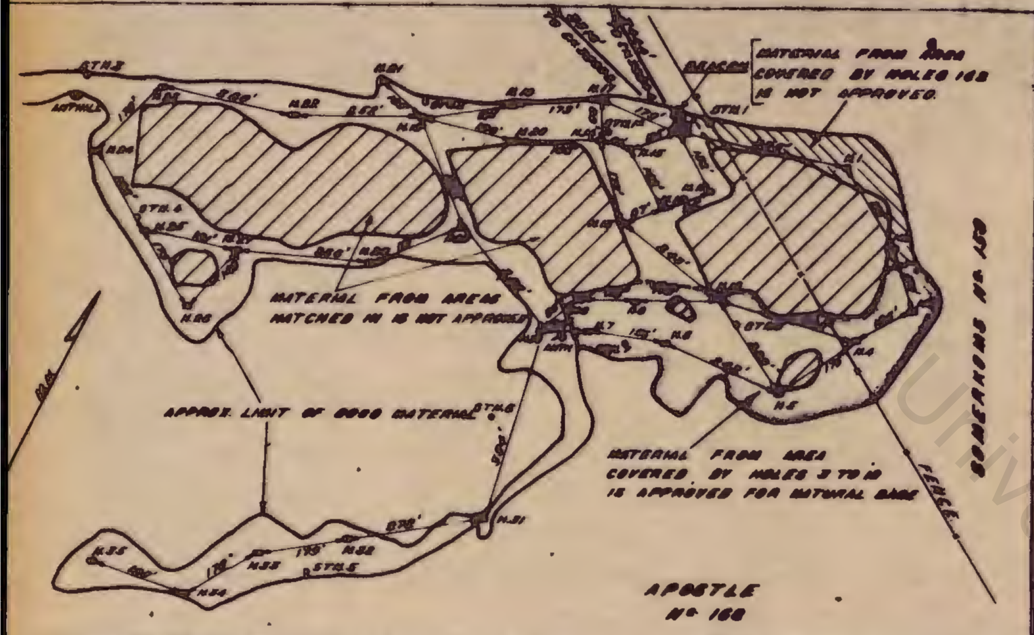
1. Remove all overburden
2. The natural gravel is approved for use in the base compacted to a min relative density of 100%.
3. The material underlying the approved gravel appears to be more plastic and should be avoided.
4. Anthills within the approved area are to be avoided.

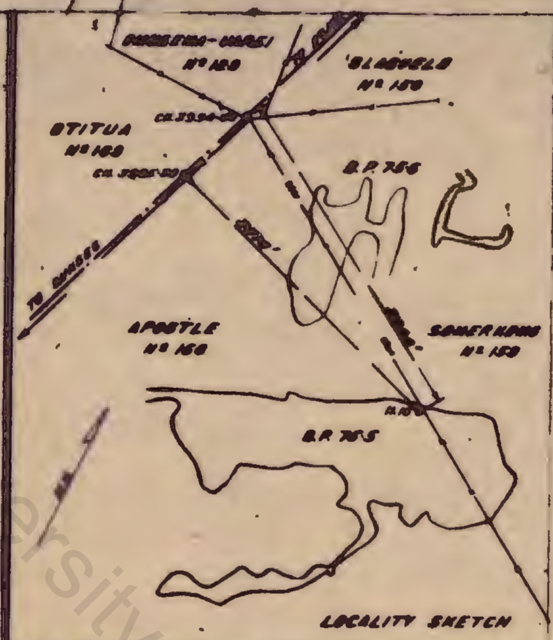
Visual Description	H br sdy gl	lat qtz. pbs	H br gl	H. br. gl	H. br. gl lat pbls.		H br gl	lat., qtz. Sdst., H. br. gl.	
Stabilized with/Ex mould			Ex Mould			Ex Mould			Ex Mould
Sample Nº IND/C.B.R.	1569 1569	1570 1570	1570	1571 1571	1572 1572	1572	1573 1573	1574 1574	1574
Hole/depth below exist. grd level	1 0"-60"	1 60"-82"	1 60"-82"	2 0"-60"	2 60"-79"	2 60"-79"	3 0"-61"	3 61"-82"	3 61"-82"
PRA classification (group index)	A2-4 [0]	A1-a [0]		A2-4 [0]	A1-b [0]		A2-4 [0]	A1-a [0]	
Screen analysis − 1½" / − ¾"		69 58	100		92 81	100		84 73	100
0·185" / − 0·078"	100 97	35 29	58 46	100 96	65 56	56 42	100 96	52 43	70 54
0·0164" / −0 0029 0 0021	54 13/7	17 3/2	24 6/4	52 10/5	29 6/4	24 7/5	55 14/9	35 4/3	30 7/4
Soil mortar grading: coarse sand / C fine sand	41 13	41 24	43 22	46 14	48 15	38 15	43 14	42 17	44 17
M. fine sand / F. fine sand	15 24	12 17	12 15	14 20	13 17	15 21	14 20	13 20	12 19
Silt / Clay	3 4	4 2	3 5	4 2	4 3	6 5	5 4	5 3	5 3
Atterberg limits: L.L. / P.I.	n p	n p	n p	n p	n p	n p	n p	n p	n p
L SH	0	0·5	0	0	0	0	0	0	0
Opt moisture / Density at mod AASHO	8·3 121·8	8·5 131·1		7·8 130·1	7·2 132·4		8·1 126·7	6·0 130·6	
Mould moisture content / Density/C.B.R. 95% 90%	8·3 115·6 8 109·5 0	9·7 124 116 0 27		7·8 124 8 108·1 0	7·3 125·6 18 119·1 0		8·8 120·3 0 114·0 0	6·9 127·4 121·1	
Density	131·8 122·0 121·0	134·1 134·8 130·1		130·1 119·7 119·9	31·8 132·0 130·7		126·7 120·9 129·2	132·2 132·0 134·0	
C B R	30 29 25	182 207 119		27 24 18	114 144 97		41 65 19	211 182 107	
Swell	1 0 0	0 0 0		0 0 0	0 0 0		0 0 0	0 0 0	

C. B. R Density Diagrams



TEST RESULT SHEET 9 · QUARTZOSE LATERITIC GRAVEL DEPOSIT USED IN THE BASECOURSE





BORROW PIT INFORMATION

BORROW PIT Nº 75·5

Farm: SOMERKOMS No. 150, APOSTLE No. 160

Owner: M. BARUS, R.W.S DIERMANN

Mileage:

Chainage: 3985·20

COMPACTION REQUIREMENTS and QUANTITY

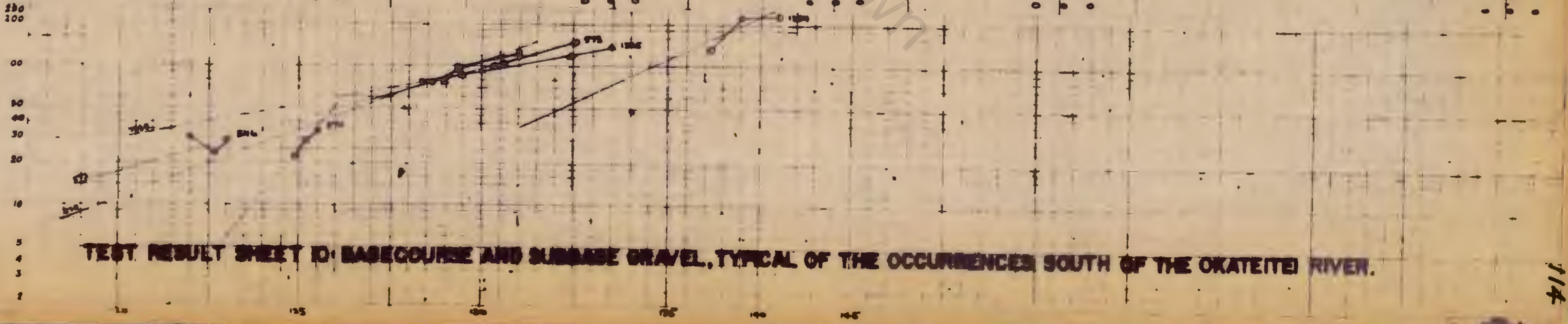
Material	Horizon measured from top of Base	Min % of mod AASHO Density required	Range of opt. moist. content	Approx. Quantity yds³
Gravel (Holes 3-10)	0"-4"	98	5·5 - 6·0 %	18000
Gravel (Holes 11-35)	4"-10"	98	4·6 - 7·3 %	20,700

REMARKS

SHEET 1

1. Remove overburden from the approved area:
2. The gravel is approved for Base (natural), holes 3-10, and for 4"-10" holes 11-35 as indicated on the sketch.
3. The material underlying the approved gravel is plastic and must be avoided.
4. Antihills within the approved area are to be avoided.
5. In order to adhere to the planned design additional basecourse gravel may be require This can be obtained by screening out the -⅜" material from a portion of the gravel covered by holes 14-22 inclusive, and then mixing the +⅜" product so obtained with nat ural gravel from the same area. A proportion by weight of 1 screened to 2 natural should prove satisfactory. The gravel covered by these holes should be reserved f this purpose until sufficient base gravel has been proved in stock pile for the section [illegible]

Visual Description
Stabilized with / Ex mould
Sample Nº IND/C.B.R.
Hole/depth below exist. grd level
P.R.A. classification (group index)
1½ | ⅜
0 85 | 0 078
0 0 64 | 0 0008 / 0 0051
coarse sand | C fine sand
M fine sand | F fine sand
Silt | Clay
Atterberg L.L. | P.I.
Limits | L. SH.
Opt. moisture | Density at mod AASHO
Mould moisture content | Density
Density
C.B.R.
Swell



C.B.R Density Diagrams

TEST RESULT SHEET 10: BASECOURSE AND SUBBASE GRAVEL, TYPICAL OF THE OCCURRENCES SOUTH OF THE OKATEITEI RIVER.

BORROW PIT INFORMATION | BORROW PIT Nº 75·5

Farm: [illegible] No 184 / Apostle No 128
Owner: M. Bakoe / R.W.G. Diekmann
Mileage:
Chainage 3985·20

COMPACTION REQUIREMENTS and QUANTITY

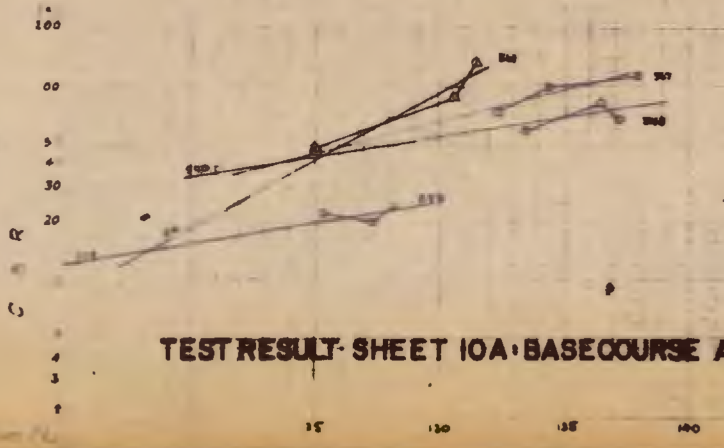
Material	Range measured from top of Base	Min % of mod AASHO density required	Range of Opt. moist content	Approx Quantity yds³
Gravel (holes 3–10)	6"–18"	90	6·0–8·0 %	[illegible]
Gravel (holes 11–19)	6"–18"	98	4·6–7·3 %	20,900

REMARKS SHEET 2

Visual Description
Stab[illegible] Ex mould
Sample No [illegible] CBR
[illegible]
[illegible] Class[illegible]
1½ 3
[illegible] 85
[illegible] 0·64 0·028
S[illegible] coarse sand & fine sand
[illegible] sand & fine sand
[illegible] S
[illegible] P
[illegible] S
[illegible] Dens & CBR
Density
CBR

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Ex found	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
547	548 548	549	550	551	552	553	558 558	555	556	557	550	558	560 564	564	560	562	563	566	567 567
11 24"-28"	11 28"-65	12 0"-36"	12 36"-66"	13 0"-18"	13 18"-93"	13 43"-70"	14 0"-41"	14 41"-75"	15 0"-41"	15 41"-70"	16 0"-48"	16 48"-65"	17 25"-65"	17 30"-40"	17 10"-18"	18 0"-40"	18 60"-75"	19 0"-57"	19 57"-[illegible]
A 2-4 [0]	A 1-a [0]	A 2-4 [0]	A 1-a (0)	A 1-4 [0]	A 2-4 [0]	A 1-a [0]	A 2-4 [0]	A 1-a [4]	A 2-4 [0]	A 1-a [0]	A 2-4 [0]	A 1-a [0]	A 2-4 [0]		A 2-4 [0]	A 2-4 [0]	A 1-a [0]	A 2-4 [0]	A 1-a [0]
100	100 98	100	100 97	100	100	73 93	100	100 92	100	81 85	100	97 93	100 90	100	100		86 77	100	100 95
98 91	64 40	94 89	53 38	90 95	97 91	84 38	97 95	99 39	97 93	48 26	97 96	57 41	50 40	81 62	99 96	100 97	41 21	90 92	80 37
58 10/18	25 8/6	57 15/10	24 8/6	64 15/10	60 12/18	22 8/4	37 17/10	20 7/6	50 16/10	24 5/3	54 10/10	28 7/6	35 9/7	36 10/6	64 11/10	63 18/13	20 6/4	57 13/10	20 8/6
34 16	38 10	26 14	37 18	38 16	30 18	34 19	48 16	35 17	44 16	49 22	42 12	44 15	39 14	44 11	36 16	35 15	39 21	38 15	13 17
11 21	9 29	16 24	12 19	16 26	13 34	14 24	16 17	12 17	12 31	15 14	12 22	12 16	11 10	10 12	14 23	14 23	14 17	17 20	20 17
9 5	8 6	6 4	7 7	5 4	7 7	14 2	6 6	9 6	5 6	5 4	5 6	7 6	11 7	15	6 6	7 6	7 6	15	19
S P	4 P	S P	S P	S P	S P	S P	6 P	10 4	3 P	6 P	5 P	14 2	31 6	24 7	S P	6 P	S P	S P	[illegible]
1·5	<0·5	<0·5	1·0	<0·5	<0·5	<0·5	1·0	2·5	<0·5	<0·5	<0·5	1·0	4·0	3·0	0·5	0·6	<0·5	<0·5	8·0
	6·6 135·4						8·4 126·8						6·6 120·7						6·0 136·4
	130·8 | 33						[illegible]						120·1 | 16						137·2 | 65
	6·6 122·0 | 38						7·4 [illegible]						6·4 117·6 | 18						5·8 133 [illegible] | 30
	131·2 136·5 138·5						128·2 127·8 125·8						131·6 130·6 116·0						37·8 134·4 131·4
	67 82 59						24 24 22						136 88 48						114 99 74
	0 0 0						0 0 0						0 0 0						0 0 0

C B R Density
Diagrams



TEST RESULT SHEET IOA: BASECOURSE AND SUBBASE GRAVEL, TYPICAL OF THE OCCURRENCES SOUTH OF THE OKATEITEI RIVER.

BORROW PIT INFORMATION | BORROW PIT Nº 75·6

Farm SOMERKOMS No 159
APOSTLE No 168

Owner : M BAADE
R.W.G. DIEKMANN

Chainage 3993·80

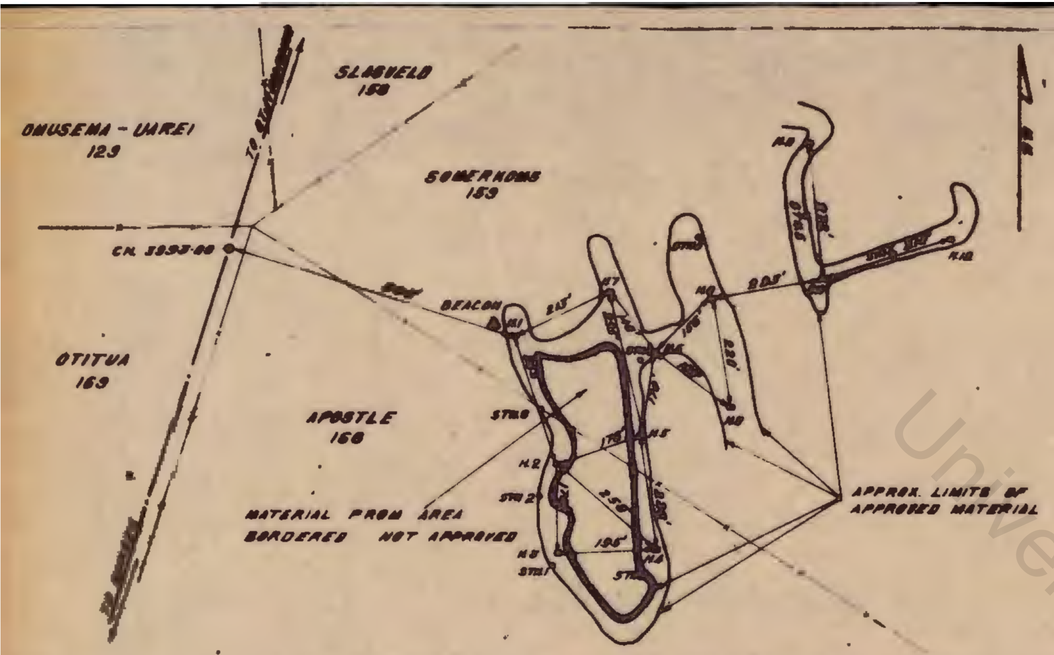
COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of Base	Min % of mod AASHO Density required	Range of Opt moist content	Approx Quantity yds ³
Overburden	10"-18"	95 depend on control test results.	69 - 79 %	18,100
Gravel	4"-10"	95	69 71 %	
	0"-4" stab - 3% lime	98	66 - 82 %	11,800

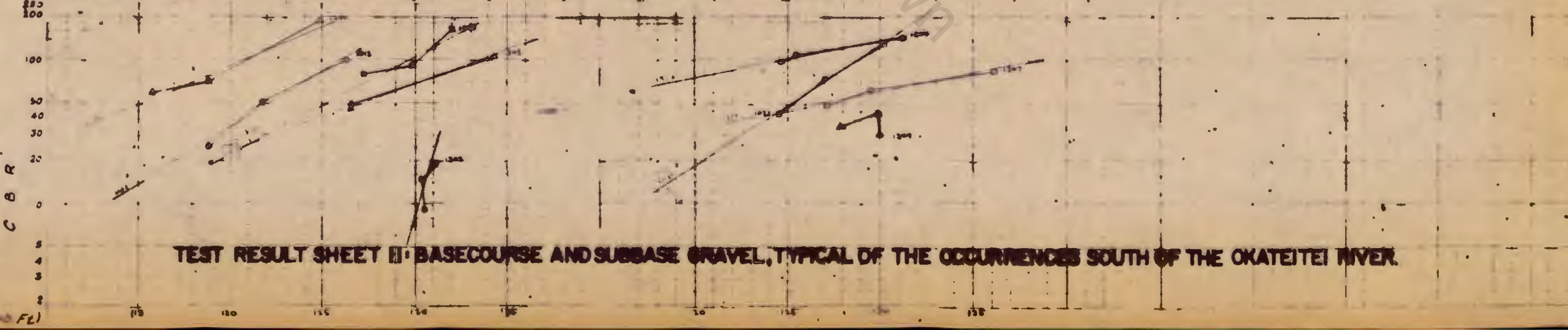
REMARKS

1 Overburden and gravel are to be worked seperately
2 The overburden is approved for use in the 10"-18" layer compacted to a min relative compaction of 95 %, provided that control test results confirm this compaction as being adequate
3 The gravel is approved for use in the 4"-10" layer and in the base course layer stabilized with 3 % lime
4 The plasticity of the gravel varies from N.P to 11 If large amounts of N.P or S.P gravels are encountered together, it should, preferably, be reserved for the 4"-10" layer, as stabilizing it for base might present unnecessary construction difficulties

Note: Remarks continued on SHEET No. 2



Visual Description
Stabilized with Ex mould
Sample No
No CBR
Hole, depth below exist grd level
A.A.S. classification (group index)
1½ | ¾
0 85" | 0 078
0 0 64 | 0 0028 0 002
coarse sand | C fine sand
M fine sand | F fine sand
Silt | Clay
Atterberg LLL | PI
Limits | L SH
Opt moisture Density at mod AASHO
%ound moisture content Density/CBR 95% 100%
Density
C.B.R
Swell



C B R Density Diagrams -

TEST RESULT SHEET II BASECOURSE AND SUBBASE GRAVEL, TYPICAL OF THE OCCURRENCES SOUTH OF THE OKATEITEI RIVER.

BORROW PIT INFORMATION

BORROW PIT No 75·6

Farm : SOMERKOMS No. 159
 APOSTLE No 168

Owner : M [illegible]
 R.W.G. [illegible]

Chainage : 393380

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of Base	Min. % of mod AASHO Density required	Range of [illegible]	Approx. Quantity [illegible]
Overburden	10" - 16"	90 to 95 depend on control test results.	69-79 %	18,400
Gravel	4" - 10" 0 - 4" stab -3% [illegible]	95 98	59-74 % 66-82 %	11,800

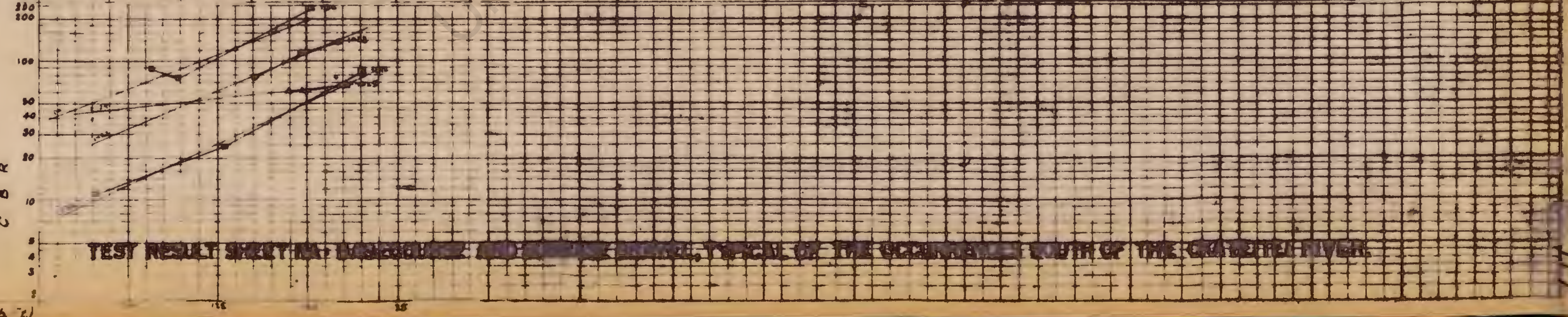
REMARKS continued from SHEET No 1.

5 The gravel breaks down rather easily. Too much manipulation on the road could result in it becoming too fine for a standard lime stabilized base. This aspect should be checked with a short test section in the subbase layer

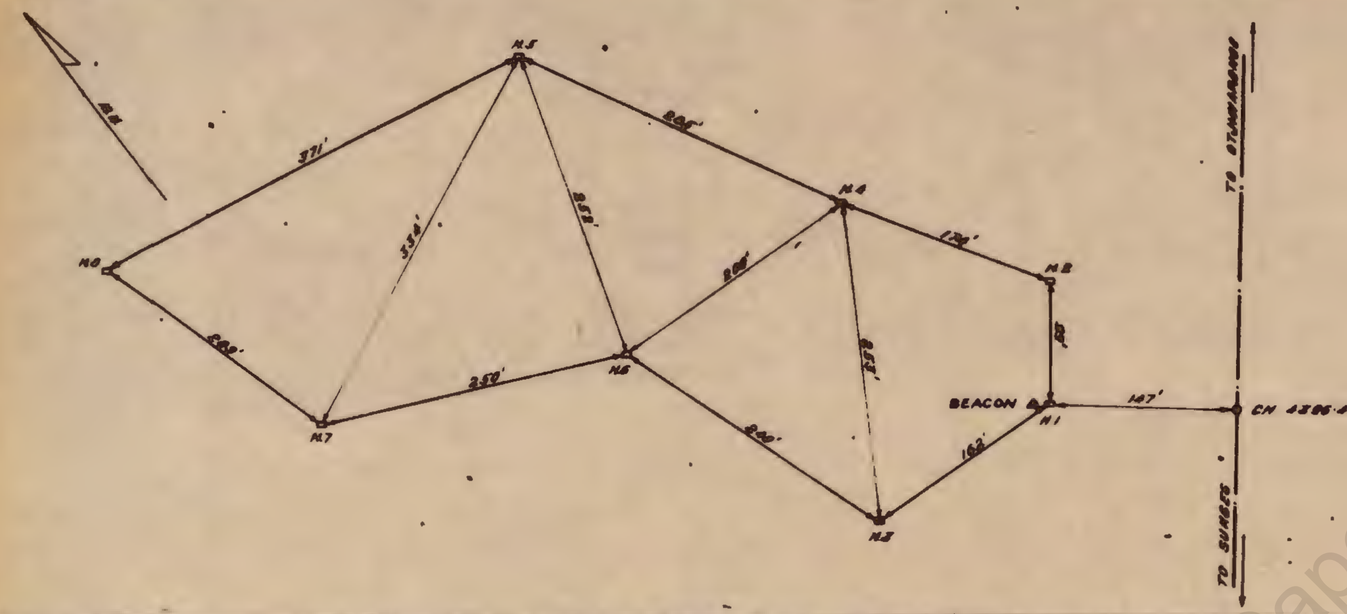
6 The material underlying the approved gravel is of high plasticity and must be avoided

Visual Description		dec qtz pbls, y 8			dec qtz pbls, y 8	9? y 4	dec qtz pbls, y 11		
Stabilized with/Ex mould				Ex mould				Ex mould	+3% [illegible]
Sample No	IND/CBR	[illegible]	1022 1023	1023	1024	1212 1212	1025 1025	1026	1310 1310
Hole/depth below exist. grd level		9 33"-50"	10 31"-53"	10 31"-53"	11 33"-50"	12 0"-30"	12 36"-59"	12 36"-59"	12 36"-59"
PRA classification (group index)		A [illegible] [0]	A 1-0 [0]		A 1-4 [0]	A 1-4 [0]	A 2-4 [0]		
Screen analysis - 1½"	- 3/4"	90 71	98 80	100	100 99	100	98 91	100	100
0 185"	- 0 078"	39 34	40 29	55 40	64 47	99 96	46 33	76 62	71 81
0·0164"	-0 0036/0 0021"	31 4/3	19 6/8	24 7/6	27 11/9	70 25/20	22 8/7	36 13/10	80 10/7
Soil mortar grading coarse sand	C fine sand	39 20	35 21	40 18	36 14	27 16	31 16	35 17	44 15
M. fine sand	F. fine sand	12 32	12 16	12 15	11 10	12 24	12 21	16 17	12 19
Silt	Clay	6 3	7 9	9 6	12 9	10 11	9 12	12 7	20 3
Atterberg limits L L	P.I.	np p	3 p	3 p	26 10	19 8	24 7	25 9	3 p
	L. SH	0	0.5	1.0	4.5	4.0	3.0	9.5	2.05
Opt moisture	Density at mod AASHO		6.7 131.5			7.1 130.1	7.1 132.6		6.6 134.7
Mould moisture content	Density/C B R 95% 90%		6.4 129.9 [illegible] 110.2 26			7.0 126.9 [illegible] 119 [illegible]	7.0 125.0 [illegible] 119 [illegible]		7.5 [illegible] 110 [illegible]
Density			131.7 129.7 127.1			133.1 125.4 118.2	133.8 130.9 129.6		130.3 130.0 131.4
C B R			139 116 78			84 24 11	67 [illegible] 61		[illegible] 80
Swell			0 0 0			0.2 0.4 0.2	0 0 0		0 0 0

C B R Density Diagrams



TEST RESULT SHEET IIA: [illegible] AND [illegible] GRAVEL, TYPICAL OF THE OCCURRENCES SOUTH OF THE [illegible] RIVER.



BORROW PIT INFORMATION

BORROW PIT Nº 83·3

Farm KAHLENBERG No 130 | **Owner :** [illegible]
Chainage : 4396·42

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon	Min % of mod AASHO Density required.	Range of Opt. moist content	Approx. Quantity yds³
Overburden	4' - 18'	95	6·6 - 6·9 %	16 000
[illegible]	4' - 10'	95	[illegible] 7·0 %	50[illegible]

REMARKS

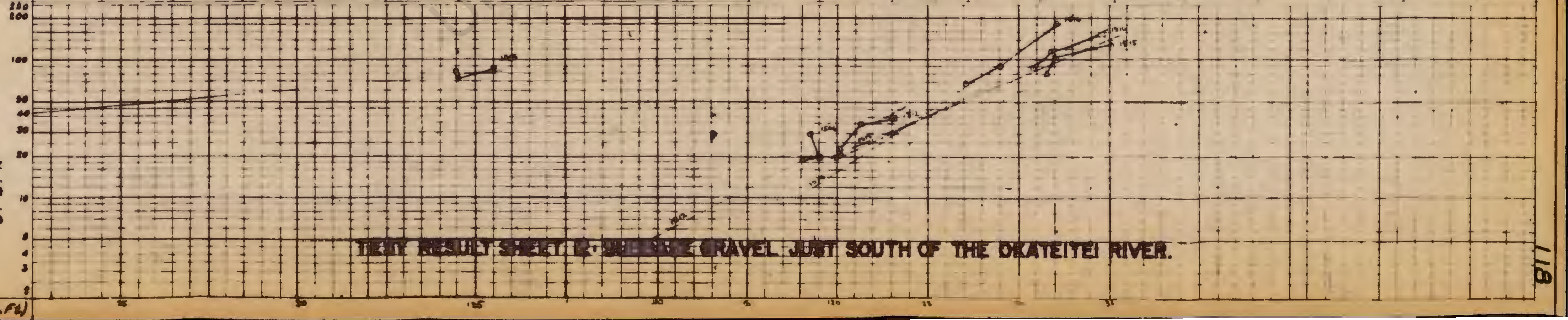
1 The overburden is approved for the 0' - 18' layer compacted to a min relative density of 95 %.

2 The gravel is approved for the 4'-10' (Subbase) layer compacted to a min relative density of 95 %.

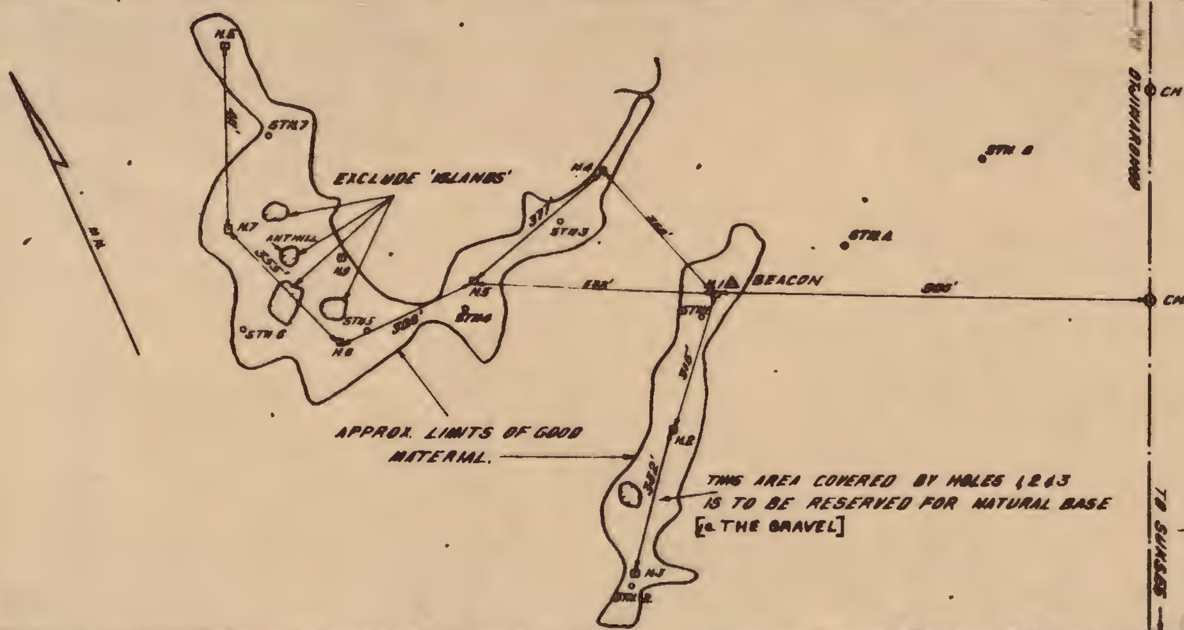
3 The material underlying the approved gravel is either hard granite formation or dec granite with high plasticity fines The latter is to be avoided.

Visual Description	dr grte / qtz pbls lt br si		[illegible] dy si	dec grte fbh / pbls [illegible]	gry sdy si / grt pbls	gry sdy si dec / grte [illegible]	dec [illegible]	qtz pbls lt br sdy si		gl gry sdy s	[illegible] qtz pbls / gr sdy	dec grte [illegible] pbls		dec [illegible], qtz pbls	br sdy si
Stabilized with / Ex mould		Ex Mould						Ex Mould					Ex Mould		Ex Mould
Sample No IND / C.B.R	1505 / 1506	505	1504 / 1506	507	1508	1509	1510 / 1510	1510	1511	1512 / 1512	1513	1514 / 4	15 4	5	15 5
Hole / depth below exist. grd level	1 / 17-52	1 / 7 52	2 / 0 48	2 / 48 64	3 / 0 42	3 / 42 75	4 / 35 56	4 / 35 56	5 / 37 66	6 / 0 3x	6 / 3	7 / 35	7 / 35 62	8 / 6	8 / 42 60
P.R.A classification (group index)	A2 / 4[0]		A2	A1	A1	A1 / 6[0]	A1		A2 4	A	A / 4	A / 4		A	
Screen analysis −1½" / −3/4"	98 / 94	100	100	98 / 96	100	98 / 85	100 / 98	100	100 / 96	100	9 / 85	99 / 96	100		100
−0·185" / −0 078"	65 / 45	78 / 49	99 / 97	59 / 45	68 / 2	81 / 78	57 / 4	81 / 55	57 / 38	99 / 9	5 / 38	69 / 50	83 / 63	4	00 / 42
−0·0164" / −0 0083"/0 0081"	24 / 9/8	26 / 9/8	64	25 / 7/6	17 / 7 5	45 / 12 9	27 / 9	35 / 12/9	22 / 10/	42 / 16/10	24 / 8	29 / 9/8	34 / 2/1·0	8	38 / 12
Soil mortar grading: coarse sand / C fine sand	47 / 2	47 / 3	38 / 16	44 / 18	48 / 14	41 / 16	34 / 18	37 / 17	40 / 15	34 / 4	37 / 18	42 / 8	43 / 16	18	39 / 7
M. fine sand / F. fine sand	8 / 16	8 / 16	5 / 22	11 / 16	10	13 / 18	2 / 20	12 / 19	10 / 17	15 / 26	10 / 20	10 / 15	10 / 16		18
Silt / Clay	8 / 9	7 / 9	5 / 4	5 / 6	7 / 3	5 / 6	10 / 6	8	10 / 8	6 / 4	9 / 6	8	8 / 7		8 / 7
Atterberg Limits L.L. / P.I.	21 / 8	20 / 7	n / p	s / p	n / p	s / p	s / p	s / p	19	n / p	s / p	18 / 3	7 / 1		s / p
L.S.H.	4 0	3 5	c	0 5	0	0 5	1 0	1 0	3 0	c	1 0	1 5	0 5	6	1 0
Opt moisture / Density at mod AASHO	6·5 / 135 5		6 9 / 190				6 9 / 345			6 6 / 123 1		6 5 / 132 2		7 / [illegible]	
Mould moisture content / Density C.B.R 90% 95%	6·7 / 128 0/00, 122 0/00		6 8 / 113 5, 107 1				7 2 / 127 8/60, 121 0/23			6 7 / 117, 109 6		6 5 / 135 0, 119 0,12		6 9 / 23	
Density	136 / 135 5 84 5		118 6 / 0 118				34 / 3 6 1307			128 / 124 120		322 / 129 127 2		36 / 0 3	
C.B.R	73 / 82		29 / 9				54 / 88			38 / 34 22		102 / 90 69		120 / 80	
Swell	0 / 0		0 0 / 0				0 0			0 / 0		0 / 0 0			

C.B.R Density Diagrams.



TEST RESULT SHEET ... SUBBASE GRAVEL JUST SOUTH OF THE OKATEITEI RIVER.



BORROW PIT INFORMATION

BORROW PIT Nº 79·0

Farm: SLABVELD No 138

Owner: N.K.C. GRENSING

Chainage: + [illegible] 00

COMPACTION REQUIREMENTS and QUANTITY

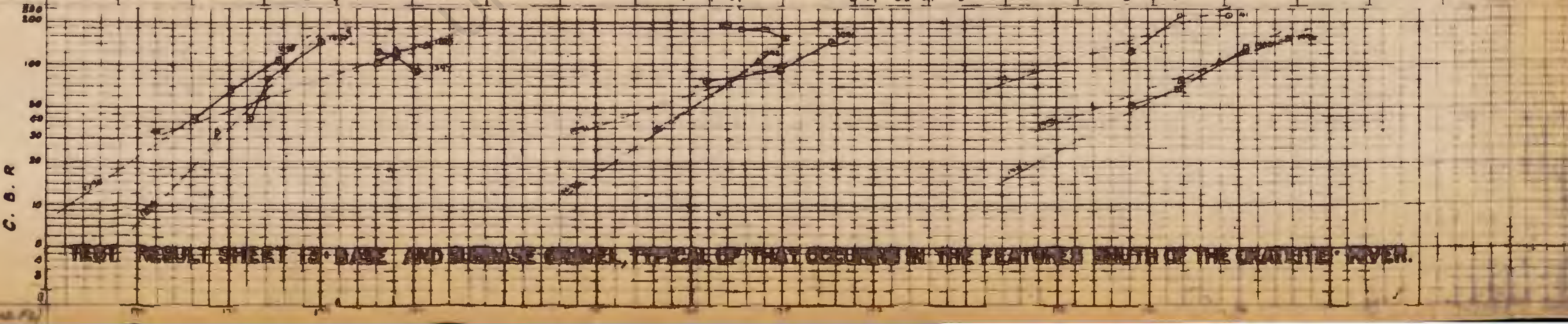
Material	Horizon measured from top of Base	Min % of mod. AASHO Density required	Range of Opt moist content	Approx Quantity yds 3
Overburden	4" - 10"	98	5·7 [illegible]	3 [illegible]
	10" - 16"	95		
[illegible]	[illegible]	98	[illegible]	)
	Shoulders 6" - 16"	95	4	2[illegible]

REMARKS

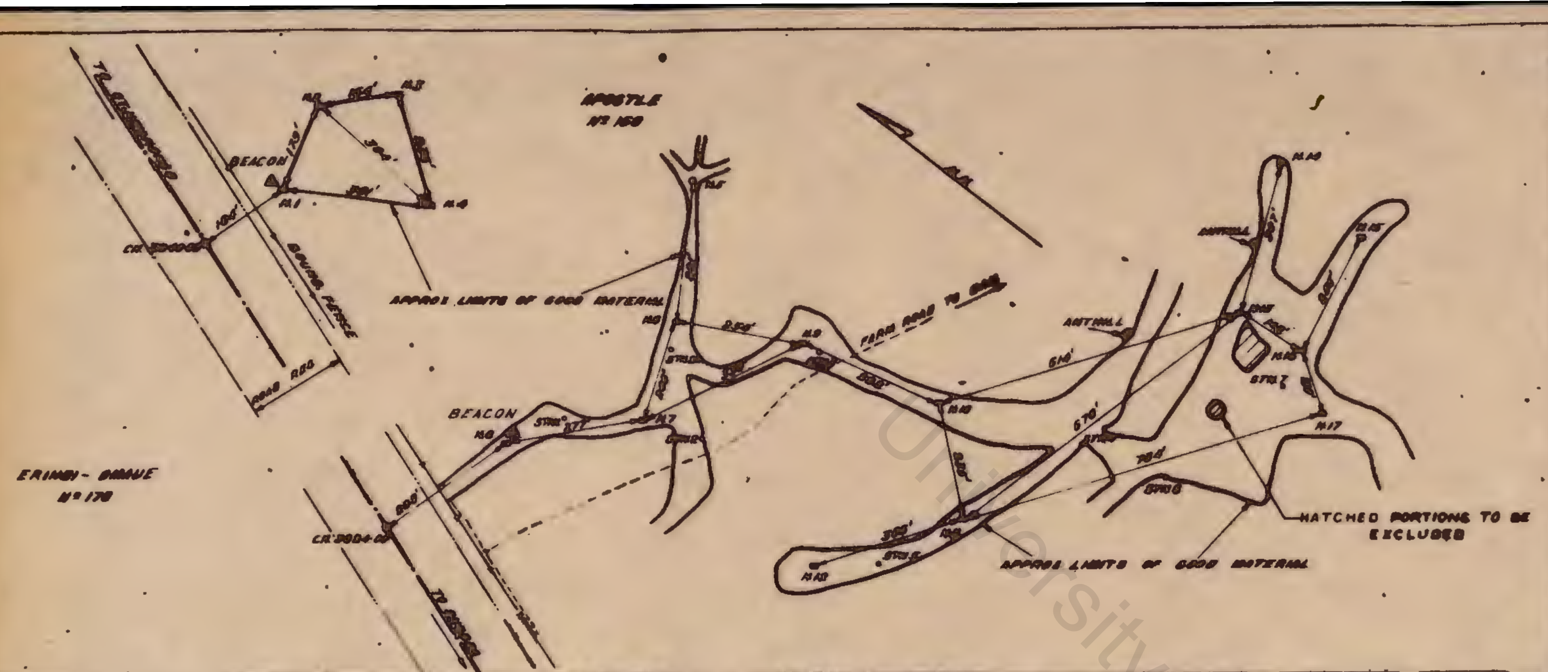
1. The overburden is approved [illegible] Subbase [illegible] 10" - 16" [illegible] a min relative d[illegible] 98 [illegible]
2. [illegible] gravel from the feature covered by holes 1, 2 and 3 is to be reserved for natural base [illegible] it. control test results confirm its suitability for this purpose
3. The gravel from the feature covered by holes 4 5 6 7 8 and 9 is approved for use in the base course stabilized with 3% lime in the shoulders and in the subbase [illegible]
4. The gravel is graded on the fine side [illegible] base course so unnecessary manipulation on the road should be avoided to ensure a min of breakdown
5. Underlying the approved gravel highly plastic soil is encountered. Test results of this clayey material [illegible] from Hole 5, depth 78"+ are recorded below. This dangerous clay must be avoided at all costs.

Visual Description	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]			[illegible]			[illegible]	[illegible]	[illegible]	[illegible]		Clayed.
Stabilized with Ex mould			Ex Mould			Ex Mould				Ex Mould	+3% lime		Ex Mould	+3% lime					Ex Mould	
Sample No IND/C.B.R.	1394 394	1395 396	1395	1396 1396	1397 1397	1397	1409	1490	1491 1491	1491	40 40	1492 1492	1492	41 41	1493 1493	1494	1495	1496 1496	1496	[illegible]
Hole/depth below exist grd. level	[illegible] 46"	1 46" [illegible]	1 46-73"	2 0-35"	2 35-70"	2 35-70"	3 37-66"	4 43-67"	5 36-75"	5 36-75"	5 36-75"	6 37-68"	6 37-68"	6 37-68"	7 0-34"	7 34-62"	8 36-59"	9 40-67"	9 40-67"	5 78"
P R A classification (group index)	A [illegible]	A1-0 [illegible]		A2-4[0]	A1-0[0]		A1-0(0)	A2-4[0]	A2-4/0]			A2-4[0]			A2-4(0)	A2-6[0]	A2-4[0]	A2-4[0]		A2-10-[illegible]
Screen analysis 1½" | -3/4"		94 83	100	00	67 29	100	89 87	99 92	96 93	100	100	99 96	100	100 98	100	99 95	96 87	00 94	100	100
0·185" | -0·078"	[illegible] 90	65 28	61 43	99 93	8 3	55 40	58 38	62 40	63 43	62 43	49 32	69 43	68 45	64 39	99 94	6 39	49 32	67 41	72 44	[illegible] 78
0·0164" | -0·0058/0·0021"	[illegible] 14	35 8/6	27 9/7	54 15/11	2 1/1	25 9/7	22 7/5	27 9/7	26 10/8	24 10/8	18 6/5	30 12/9	32 13/13	22 8/7	58 19/14	27 4/8	21 7/5	29 12/10	34 12/10	[illegible]
Soil mortar grading coarse sand | C. fine sand	40 3	34 16	37 15	14 15	32 11	37 14	37 16	22 17	40 19	40 15	44 18	30 13	29 13	44 17	30 15	31 15	34 16	29 14	32 13	41 2
M fine sand | F. fine sand	12 21	12 21	2 18	14 20	11 27	11 19	12 28	12 21	11 18	9 10	10 12	10 24	10 22	10 11	12 20	10 28	11 23	0 22	7 22	7 [illegible]
Silt | Clay	6 8	10 7	8 10	6 5	13 5	10 9	10 3	11 7	10 7	10 8	15	13 8	10 12	13	7 8	14 5	11 6	14 1	12 13	8 21
Atterberg Limits L.L. | P.I.	8 P	4 P	17 4	5 P	20 7	18 3	11 P	19 7	19 7	19 5	6 P	21 9	20 8	6 P	15 2	24 11	20 8	20 7	21 8	[illegible] 28
L. SH.	1 0	1 0	2 0	0 5	3 8	1·5	0	8 0	3	3 0	2 06	4 0	4 0	2 05	1 0	5 0	3 5	4 0	3 0	[illegible]
Opt moisture | Density at mod. AASHO	6 2 135·2	5 4 144·2		5 7 132·6	5 6 139 4				5·6 137·6		6 6 137 2	5 9 128 6		6·8 134 8	6 2 135 4			5·7 137 7		
Mould moisture content | Density/C.B.R.	5 9 130·5/22 121 0/5	6 3 134 1/[illegible] 137 3/34		5 6 126 0/[illegible] 129 3/7	5 6 132 3 120 4				5 7 130 0/66 128 9 32		6 3 130 3 122 6	5 8 125 [illegible] 67 122 9/11		6 6 130 6/132 131 2/[illegible]	6 0 [illegible] 166 130 0 15			5 4 [illegible] 173 133 8/27		
Density	135 1 132 3 131 2	140 6 139 1 138 4		132 6 130 1 128 6	139 2 140 2 138 2				137 6 130 9 128 9		136 2 134 132 9	133 6 131 1 128 4		34 5 131 9 129 1	36 8 132 7 129 1			137 7 134 0 126 9		
C B R	147 0 62	187 25 101		09 66 42	16 90 35				146 49 79		155 [illegible] 179	108 7[illegible] 36		720 720 121	132 47 51			153 102 77		
Swell	0 0 0	0 0 0		0 0 0	0 0 0				0 1 0 1 0 1		0 0 1 0 2	0 1 0 2		0 0	0 0 0			0 0 0		

C. B. R. Density Diagrams



TEST RESULT SHEET 13: BASE AND SUBBASE GRAVEL, TYPICAL OF THAT OCCURING IN THE FEATURES SOUTH OF THE [illegible] RIVER.



BORROW PIT INFORMATION

BORROW PIT Nº 72·4

Farm APOSTLE No. 168
ERINDI-OMAUE No. 170

Owner : R.W.G. DIEKMANN
Mrs. M.F. BEHRENS

Chainage 3824·00

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of Base	Min % of mod AASHO Density required	Range of Opt. moist content	Approx. Quantity yds ³
Overburden	10" - 18"	90 (depending on control test results)	6·3-7·4 %	33,300
Gravel	4" - 10".	95	5·2-7·7 %	14,100

REMARKS

SHEET No. 1

1 The overburden and gravel. are to be worked separately

2. The overburden, which has an average depth of 47", is approved for use in the 10"-18" layer compacted to a min. relative density of 90 % depending on control test results

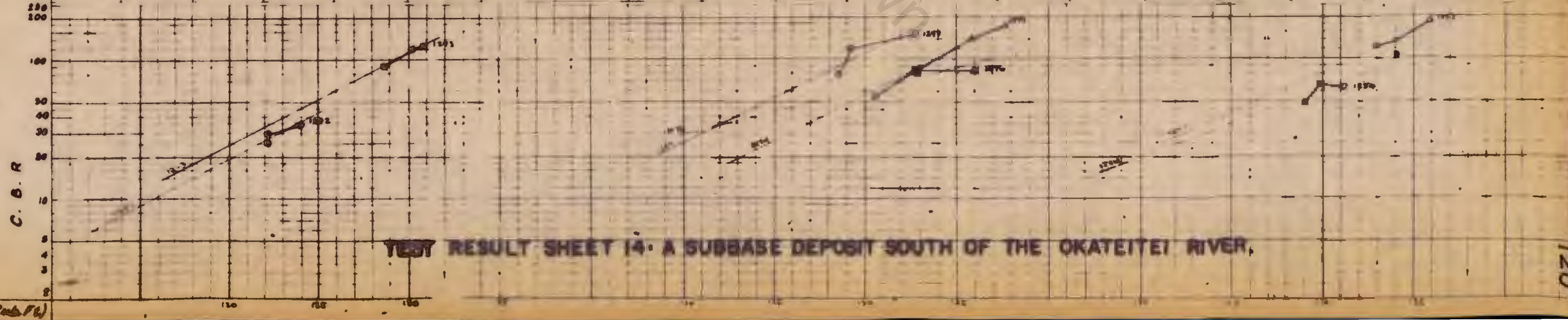
3. The gravel which averages 21 ins in thickness, is approved for use in the 4"-10" layer compacted to a min. relative density of 95 %.

4. Underlying the approved gravel plastic dec. granite is encountered This must be avoided at all costs. (continued on sheet

Visual Description	br Sl		dec gran, lat pbls, br Sl		dec gran, lat pbls br Sl	lat, dec gran pbls, br Sl	br Sl.	dec gran., lat pbls, br Sl.		[illegible]
Stabilized with/Ex mould		Ex mould		Ex mould					Ex Mould	
Sample Nº IND/CBR	1242 1242	1242	1243 1243	1243	1244	1245	1246	1247 1247	1247	1473
Hole/depth below exist. grd level	1 [illegible]	1 0"-36"	1 36"-65"	1 36"-65"	2 36"-68"	3 58-72	4 0"-35"	4 35"-63"	4 35"-63"	[illegible]
P R A classification (group index)	A2 [illegible]		A1-a [0]		A1-a [0]	A1-a [0]	A2-4 [0]	A1-a [0]		A1-a [0]
Screen analysis 1½" - 3/4"	100	100	100	100	100	100	100	100 93	100	100 94
0 .188" - 0.078"	99 96	99 96	53 40	67 48	71 49	69 47	99 97	44 32	60 45	[illegible]
0·0164" - 0 0029/0 0011"	61 15/9	62 15/9	28 8/5	31 10/8	30 10/6	38 8/6	64 12/8	21 5/4	20 9/7	30 8/6
Soil mortar grading coarse sand - c. fine sand	36 12	36 14	30 20	38 19	39 16	40 16	35 15	34 23	30 21	38 19
M fine sand - R fine sand	15 20	13 26	14 13	11 19	10 30	11 19	16 27	12 18	12 13	12 18
Silt - Clay	6 3	6 3	10 3	4 5	11 4	10 4	6 2	7 6	9 6	8 5
Atterberg Limits L.L. - P.I.	n p	n p	5 p	5 p	16 5	6 p	n p	n p	5 p	n p
L. SH.	0	0	1.0	1.0	2.0	1.0	0	0	<0.5	0
Opt moisture - Density at mod AASHO	7.4 123.9		7.7 130.8					6.2 132.6		
moisture content - Density/C B R 90% 95%	7.4 117.5 111.4		7.7 125.1 16 117 17					6.2 126.0 119.3		
Density	123.9 122.2 122.2		130.8 130.2 128.6					132.6 129.4 126.6		
C B.R	34 29 25		127 131 90					150 119 97		
Swell	0 0 0		0 0 0					0 0 0		

Visual Description	lat, dec pbls, grv.		dec qtz, grv [illegible] grv. Sl.	[illegible] grv [illegible]	[illegible] pbls, [illegible] Sl.		lt br Sl		lat pbls, lt br Sl.
Stabilized with/Ex mould		Ex mould				Ex mould		Ex mould	
Sample Nº IND/CBR	1476 1476	1476	1475	1474 1474	1253 1253	1253	1254 1254	1254	1255
Hole/depth below exist. grd level	6 44"-75"	6 44"-75"	7 46"-59"	8 60"-80"	9 55"-72"	9 55"-75"	10 0"-48"	10 0"-48"	10 48"-65"
P R A classification (group index)	A2-4 [0]		A1-a [0]	A1-a [0]	A1-a [0]		A2-4 [0]		A1-a [0]
Screen analysis 1½" - 3/4"	99 95	100	90 92	99 95	100 97	100	100 99	100	98 89
0 .188" - 0.078"	68 50	89 69	65 50	73 51	[illegible] 64	67 57	98 94	99 93	60 46
0·0164" - 0 0029/0 0011"	30 11/9	44 16/13	31 11/9	29 8/5	16 7/5	26 8/6	60 17/13	60 10/14	28 9/0
Soil mortar grading coarse sand - c. fine sand	38 14	44 13	37 15	43 14	40 18	48 18	36 14	37 16	40 15
M fine sand - R fine sand	11 18	9 18	11 18	13 19	11 19	10 17	12 24	13 21	9 19
Silt - Clay	8 8	7 16	8 11	7 4	7 5	7 6	8 5	10 5	9 8
Atterberg Limits L.L. - P.I.	33 9	31 8	30 5	n p	n p	6 p	10 3	14 4	19 6
L. SH.	3.5	3.5	3.0	0	0	<0.5	1.5	2.0	2.5
Opt moisture - Density at mod AASHO	6.6 136.0			3.8 127.6	7.3 136.3		6.3 136.6		
moisture content - Density/C B R 90% 95%	6.4 [illegible]			5.8 128.8 122	7.3 134.5 70 133.0 32		6.5 130.0 135 118.5 17		
Density	136.0 136.6 134.5			137.6 135.0 132.7	135.9 131.1 133.0		131.2 130.8 129.0		
C B.R	84 84 54			173 192 82	185 126 157		63 67 49		
Swell	0 0 0			0 0 0	0 0 0		0 0 0		

C B.R Density Diagrams



TEST RESULT SHEET 14: A SUBBASE DEPOSIT SOUTH OF THE OKATEITEI RIVER.

BORROW PIT INFORMATION

BORROW PIT Nº 72·4

Farm : APOSTLE No 168
BRINDI-OMANE No. 170

Owner : R. W. & DICKMANN
Mrs. H. F. BEHRENS

Chainage : 3824·00

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of Base	Min % of mod. AASHO Density required	Range of Opt. moist. content	Approx. Quantity yds ³
Overburden	18" - 18"	90 (depending on control test results)	6·2 - 7·4 %	33,200
Gravel	6" - 18"	95	5·2 - 7·7 %	14,100

REMARKS SHEET No. 2

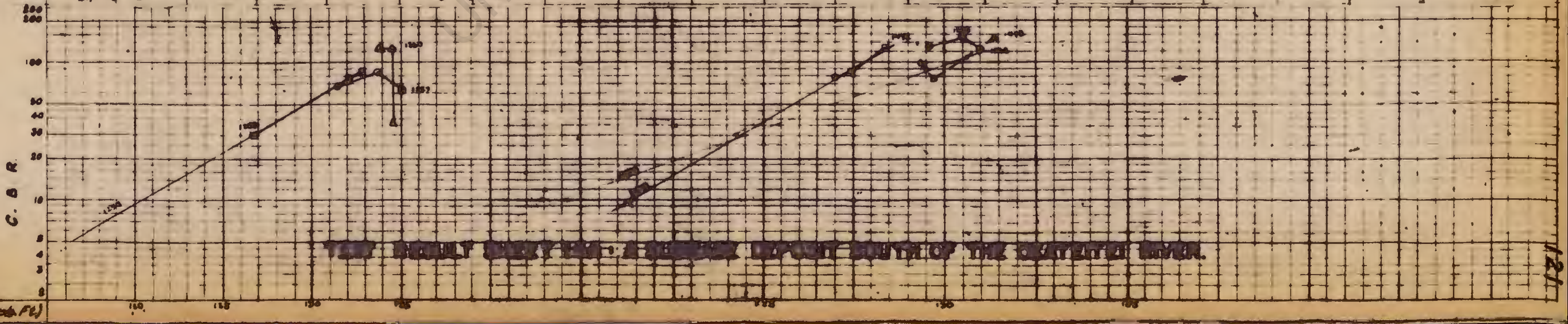
(SEE SHEET No. 1)

5. The test results on the overburden indicate a variation of max. density of from 133·9 to 132·9 lbs/cuft. The average max. density used for control purposes should therefore be chosen with care.

6. Hatched portions within the approved area are to be avoided.

Visual Description	[illegible]		[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]			
Stabilised with / Ex mould		Ex Mould		Ex Mould			Ex Mould				Ex Mould		Ex Mould		Ex Mould
Sample Nº IND / CBR	1257 1257	1257	1258 1258	1258	1259	1260 1260	1260	1261	1262	1263 1263	1263	1272 1272	1272	1273 1273	1273
Hole / depth below exist. grd level	11 30"-50"	11 30"-50"	12 0"-49"	12 0"-49"	12 49"-65"	13 50"-60"	13 56"-60"	14 0"-48"	14 48"-73"	15 50"-70"	15 50"-70"	16 60"-80"	16 60"-84"	17 40"-68"	17 40"-68"
P R A classification (group index)	A-1-a [0]		A-2-4 [0]		A-1-a [0]	A-1-a [0]		A-2-4 [0]	A-1-a [0]	A-1-a [0]		A-1-a [0]		A-1-a [0]	
Screen analysis 1½" / - ¾"	100 95		100	100 98	100	99 95	100	100	90 88	97 88	100	99 80	100	96 85	100
0·185" / - 0·078"	50 30	87	99 97		65 46	64 40	71 53	96 92	47 45	54 43	64 50	59 03	72 58	58 41	69 48
0·0164" / - 0·0029/0·0021"	15 8/6	17 11/10	59 10/13	68 31/17	28 9/7	30 7/8	32 9/7	58 17/13	21 6/6	27 6/4	31 7/6	24 5/3	31 9/6	32 4/3	26 6/5
Soil mortar grading: coarse sand / C fine sand	35 18	33 14	39 15	31 14	38 10	37 22	30 19	45 13	62 15	36 21	38 20	47 18	47 16	44 20	63 20
M. fine sand / F fine sand	11 19	11 17	13 20	15 23	11 10	13 17	12 18	15 23	9 12	13 30	10 19	12 15	12 18	13 18	13 16
Silt / Clay	7 10	7 12	7 6	10 7	9 6	6 5	5 8	8 6	6 4	5 7	6 3	5 3	6 4	5 3	6 3
Atterberg Limits L L / P.I.	19 5	19 7	16 3	17 3	5 P	N P	4 P	17 8	4 P	N P	N P	N P	N P	N P	N P
L SH	2·0	3·0	1·5	2·0	1·0	0	0·6	2·5	0·5	0	0	0	0	0	0
Opt moisture / Density at mod AASHO	7·4 125·1		6·6 128·9			7·1 133·6				7·2 133·9		7·0 128·3		5·2 131·2	
Mould moisture content / Density CBR 90% / 95%	7·4 128·3 121·6		6·6 126·5 119·0			7·1 129·7 121·0				7·0 127·1 120·5		7·1 125·8 118·4		5·2 125·0 118·2	
Density	128·1 130·6 126·5		132·9 132·2 126·7			134·0 133·0 130·5				128·5 130·0 130·0		128·3 129·0 127·0		131·3 129·7 130·0	
C. B. R.	64 85 66		86 70 80			128 103 27				150 133 108		120 90 79		161 97 99	
Swell	0·1 0 0		0 0 0			0 0 0				0 0 0		0 0 0		0 0 0	

C. B. R Density Diagrams



[illegible] DEPOSIT SOUTH OF THE [illegible] RIVER.

BORROW PIT INFORMATION	BORROW PIT No 86.2
Farm : Ohakaua No 143	Owner : L. Steenkamp
	Chainage : 4552.33

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of Base	Min. % of mod. AASHO Density required	Range of Opt. moist content	Approx. Quantity yds ³
Area A: Gravel - both layers	6" - 10" 10" - 16"	90% 98% (or 95% depending on control test results)	5.2% - 6.7%	12,900
Area B Gravel - both layers	6" - 10" 10" - 18"	98% 90% (or 95% depending on control test results)	4.4% - 8.3%	22,000

REMARKS

Area A:

1) Where sand overburden is encountered, such as in the vicinity of holes 9 & 10, it is to be removed.

2) The gravel consists of a quartz pebble layer of 12" average thickness overlying dec. gte. Both these materials are approved for use in the 6"-10" and 10"-16" layers, compacted to a relative density of 90% and 98% (or 95%) respectively, and can be worked either separately or together. The dec. gte can be used as deep as workable

3) No material is to be removed from within the road reserve

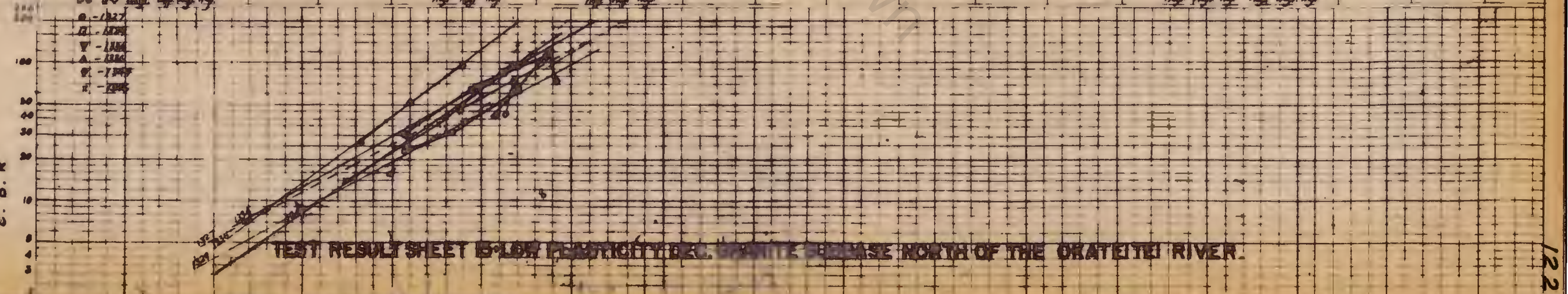
Area B

1) The gravel is covered in most [illegible] 2 [illegible] sand overburden [illegible] be removed

(Continued)

Visual Description		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Stabilized with/Ex mould								ex mould		ex mould									ex mould		
Sample No	IND/C.B.R.	1326 1327	1328 1329	1330 -	1331	1332	1333 1334	[illegible]	1335 1336	[illegible]	[illegible] -	[illegible] -	1337 -	1338	1341 -	[illegible] -	[illegible] 1344	1345 1346	[illegible]	[illegible]	[illegible]
Hole/depth below exist. grd level		1 0-20"	1 20"-40"	2 0-20"	3 0-10"	3 10"-48"	4 0-7"	4 0-7"	4 7"-[illegible]	4 [illegible]	5 0-13"	5 13"-37"	6 0-11"	6 11"-[illegible]"	7 0-12"	7 12"-[illegible]"	8 0-11"	8 [illegible]-36"	8 11"-36"	9 [illegible]-45"	10 [illegible]
P.R.A. classification (group index)		A1-b [0]	A2-4 [0]	A1-a [0]	A1-b [0]	A1-a [0]	A1-a [0]	A1-b [0]	A1-a [0]	A1-b (0)	A1-b [0]	A1-a [0]	A1-b [0]	A1-a [0]	A1-a [0]	A1-a [0]	A1-b [0]	A2-4 [0]	A1-b [0]	A1-a [0]	A1-[illegible]
screen analysis	- 1½" | 3/4"	99 97	100 95	96 91	97 93	97 87	100 96	100 100	95 85	100 100	97 95	87 83	91 84	94 90	97 [illegible]	98 92	99 97	100 96	100 100	98 86	[illegible]
	0.185" | - 0.078"	81 61	77 57	64 43	59 59	56 36	69 49	79 59	59 40	76 56	76 61	34 23	64 50	65 46	88 37	60 36	73 63	68 [illegible]	85 63	54 32	[illegible]
	0.0164" | - 0.0058/0.0081"	41 13/9	38 17/14	24 26	24 18/8	19 6/5	29 10/7	36 15/10	31 7/5	32 11/9	45 10/1	13 4/3	34 11/7	27 10/7	20 [illegible]	17 6/5	47 15/11	26 [illegible]	37 [illegible]	19 6/5	25 [illegible]
Soil mortar grading	coarse sand | C. fine sand	32 12	38 9	44 11	31 12	47 12	40 10	51 10	47 10	45 11	26 7	43 12	32 13	41 11	[illegible]	56 10	25 12	43 9	57 10	53 9	22 14
	M fine sand | F fine sand	15 26	11 22	12 19	15 26	11 17	12 23	12 22	11 19	10 17	16 14	11 19	8 25	11 21	13 24	8 14	16 31	9 20	10 20	9 15	13 24
	Silt | Clay	9 6	11 14	9 5	11 5	10 3	10 5	11 7	10 8	10 6	12 3	9 6	9 5	11 5	10 5	10 5	12 6	13 7	12 10	10 4	11 6
Atterberg limits	L.L. | P.I.	S P	21 7	19 2	S P	S P	S P	S P	S P	S P	S P	S P	S P	S P	S P	S P	N P	26 8	22 6	N P	[illegible]
	L.S.	1.0	3.5	1.0	<0.5	0.5	1.0	1.0	<0.5	<0.5	<0.5	1.0	<0.5	<0.5	0.5	<0.5	0.5	5.0	4.0	1.5	1.0
Opt moisture | Density at mod AASHO		6.7 132.6	6.1 132.0				6.6 130.6		6.4 129.0								5.2 134.7	6.3 131.8			
moisture content | Density/C.B.R. 90% 98%		126.0/30 6.5 119.2/10	125.[illegible]/[illegible] 6.1 118.8/7				[illegible]/[illegible] 6.6 [illegible]/[illegible]		123.6/124 6.4 [illegible]/6								[illegible]/[illegible] 5.4 121.2/13	123.2/[illegible] 6.6 118.7/6			
Density		123 [illegible] [illegible]	130 [illegible] [illegible]				[illegible] 1214 1257		1290 1240 1223								1339 1291 1306	1316 1276 1224			
C B R		43 77 46	64 31 24				114 65 34		96 51 27								122 76 48	97 36 14			
Swell		0.0 0.0 nil	nil nil nil				nil nil nil		nil nil nil								nil nil nil	nil nil nil			

C.B.R Density Diagrams



TEST RESULT SHEET 15: LOW PLASTICITY DEC. GRANITE SUBBASE NORTH OF THE ORATEITEI RIVER.

BORROW PIT INFORMATION	BORROW PIT Nº 862
Farm	Owner :
	Chainage :

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of Base	Min % of mod. AASHO Density required	Range of Opt. moist. content	Approx. Quantity yds ³
Area A Gravel - both layers	6" - 10" 10" - 18"	95% 90% (or 93%, depending on control test results)	6.2% - 8.7%	12,000
Area B :- Gravel - both layers	6" - 10" 10" - 18"	95% 90% (or 93%, depending on control test results)	6.4% - 8.3%	28,000

REMARKS

Area B (continued)

2.) The following holes are to be excluded as indicated on the diagram
Hole 12 High plasticity index
Hole 16 Unsampled probably plastic
Hole 24 - Awkward shape.

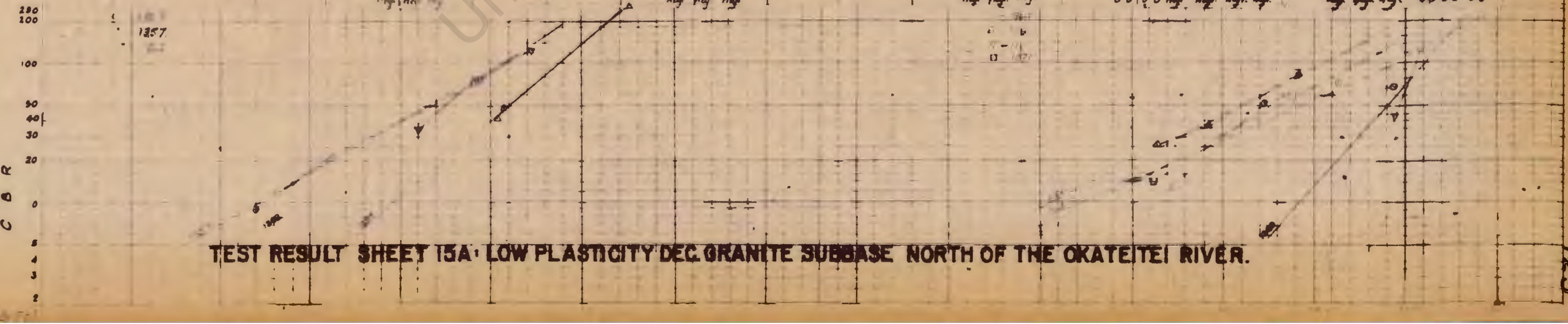
3) The gravel in the approved area consists of a thin variable layer of quartz pebbles overlying dec. granite. Both these materials are approved for use in the 6"-10" and 10"-18" layers compacted to a relative density of 95% and 90% (or 93%) respectively and will have to be worked together because of the thinness of the pebble layer. Due to the variation in Maximum Density (129.2 to 137.4 lbs/cu.ft.) care will have to be taken in ... a value [illegible]

Area A. / Area B.

	Area A.		Area B.						
Visual Description	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Stabilized with Ex mould					ex. mould			
Sample Nº IND/CBR	1349	1350 -	1351 -	1352 1353	1353 -	1354 -	1355 -	1356 1357
Hole/depth below exist. grd level	11 5"-14"	11 14"-30"	12 0-7"	12 7"-30"	12 7"-30"	13 0-9"	13 9"-20"	14 0-20"
PRA classification (group index)	A-1-a [0]	A-1-a [0]	A-1-b [0]	A-2-4 [0]	A-2-6 [5]	A-1-b [0]	A-1-a [0]	A-1-b [0]
Screen analysis 1½" - ¾"	93 79	99 95	100 98	100 94	100 100	99 92	98 85	100 90
0·83" - 0·078"	48 39	70 64	64 44	65 44	85 60	69 53	55 40	61 49
0·0164" - 0·0029/0·0021	30 10/8	26 12/10	33 13/11	30 13/11	38 19/16	41 14/12	27 11/8	37 13/10
Soil mortar grading: Coarse sand - C. fine sand	23 13	41 9	25 9	32 10	37 8	23 9	28 9	25 10
M. fine sand - F. fine sand	14 30	9 18	13 28	10 23	7 20	13 33	12 30	14 31
Silt - Clay	13 7	13 10	16 9	13 12	14 14	15 7	15 6	13 7
Atterberg Limits: L.L. - P.I.	21 P	20 9	[illegible]	25 10	29 12	5 P	14 3	5 P
L. SH.	<0·5	5·0	1·0	5·0	7·5	1·0	2·0	0·5
Opt moisture - Density at mod AASHO				7·0 129·8				130·5
Mould moisture content - Density/CBR 95% 90%				7·1 4/80 9/10				123·7 /85 /8
Density				125·5 122 117·0				[illegible]
C B R				[illegible]				8 4
Swell				neg neg neg				negl neg negl

	Area B.									
Visual Description	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Stabilized with Ex mould					ex. mould					ex. mould
Sample Nº IND/CBR	1358 -	1359 -	1360 -	1361 1362	1362 -	1363 1364	1365 1366	1367 -	1368 1369	1370 1371	1372 -
Hole/depth below exist. grd level	15 6"-16"	15 16"-31"	17 8"-12"	17 12"-20"	17 12-30	18 5"-17"	18 17"-26"	19 20-26	20 3"-10"	20 10"-30"	
PRA classification (group index)	A-1-b [0]	A-1-b [0]	A-1-a [0]	A-1-b [0]	A-1-b [0]	A-1-a [0]	A-1-a [0]	A-1-b [0]	A-2-a [0]	A-1-a [0]	A-1-b [0]
Screen analysis 1½" - ¾"	100 99	100 98	99 89	100 99	100 100	96 93	95 86	100 100	97 91	98 93	100 100
0·83" - 0·078"	76 55	74 52	57 44	78 60	81	71 49	69 46	87 59	51 35	68 65	79 61
0·0164" - 0·0029/0·0021	36 12/9	34 13/10	30 11/8	37 14/11	36 14/11	29 15	20 17	38 13/10	26 9/6	26 10/8	37 16/13
Soil mortar grading: Coarse sand - C. fine sand	35 11	34 10	32 12	38 11	40 9	41 12	47 11	36 11	26 11	42 10	59 10
M. fine sand - F. fine sand	12 26	12 24	13 26	11 22	11 22	11 20	9 18	13 22	18 31	10 21	10 20
Silt - Clay	11 5	12 6	11 6	12 6	10 11	10 6	10 5	10 8	12 6	12 5	13 8
Atterberg Limits: L.L. - P.I.	5 P	5 P	5 P	5 P	5 P	18 3	21 4	18 4	5 P	23 5	21 4
L. SH.	1·0	<0·5	0·5	<0·5	1·0	2·5	3·0	1·0	1·0	3·5	2·0
Opt moisture - Density at mod AASHO				132·3		6·1 134·4	8·5 129·2		[illegible]	7·2 128·5
Mould moisture content - Density/CBR 95% 90%				6· 125·7/95 190·/9		6·1 127·8/41 121·6/16	8·5 122·8/90 102/11		125·/30 125·/3	7·4 124·9/90 118·3/10
Density				132·3 129·2 126·0		134·4 127·3 122·3	129·8 124·2 121·4		130·0 125·9 120·0	134 128·5 121·3
C B R				24 76 33		70 53 13	86 36 26		214 123 48	76 60 14
Swell				negl negl negl		0·0 0·0 negl	negl negl negl		negl negl negl	0·0 0·0 0·0

C B R Density Diagrams



TEST RESULT SHEET 15A: LOW PLASTICITY DEC. GRANITE SUBBASE NORTH OF THE OKATEITEI RIVER.

BORROW PIT INFORMATION	BORROW PIT Nº 862
Farm	Owner : Chainage .

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of Base	Min % of mod. AASHO Density required	Range of Opt moist content	Approx. Quantity yds 3
Area A Gravel - both layers	4 - 0" 10" - 6"	98% 95% (or 93% depending on control test results)	5.2% - 6.7%	12 300
Area B - Gravel - both layers	4 - 10" 0" - 15"	98% 95% (or 93% depending on control test results)	4.4% - 6.3%	28 000

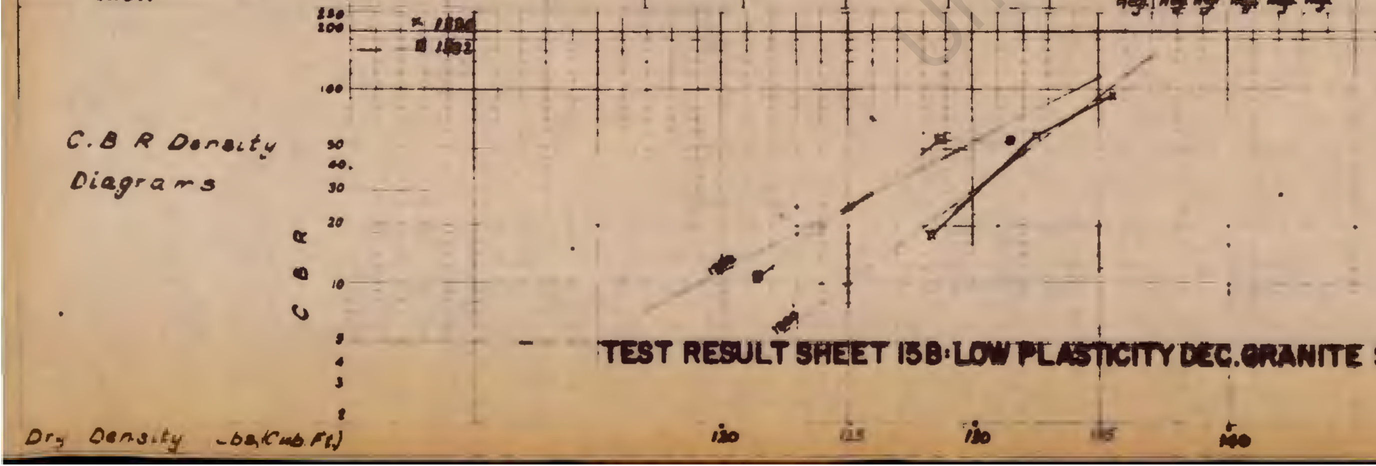
REMARKS

[illegible] road [illegible] work

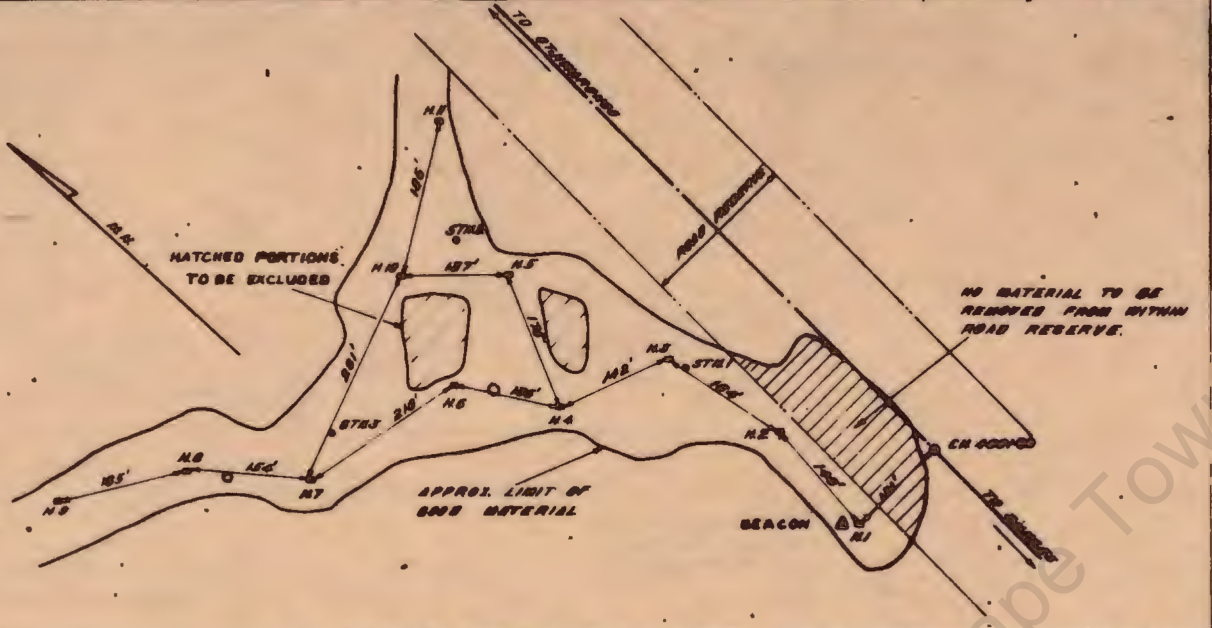
4) [illegible] is [illegible] adjacent [illegible] within the [illegible] areas are to be avoided

Area B.

Visual Description	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Stabilized with/Ex mould										ex mould					
Sample No IND	512	1375	1376	1365	1371	1372	1378	1379	1381	1382	1383	1384	1385	1386	1387
Sample No C.B.R								1380	1382						
Hole	21	21	22	23	23	24	24	25	26	26	27	27	28	28	29
depth below exist. grd level	3-7	7"-36"	7"-30"	2"-8"	8"-30"	3"-7"	7"-30"	10"-27"	10"-31"	10"-31"	6-2"	12"-32"	0-7"	9"-36"	9"-36"
P.R.A classification	A1-b	A2-6	A1-a	A1-a	A1-a	A1-b	A2-4	A1-b	A1-b	A1-b	A1-a	A1-b	A2-4	A1-b	A1-b
(group index)	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]	[0]
Screen analysis - 1½"	100	100	99	100	74	97	99	99	97	100	98	99	99	100	98
- 3/4"	94	97	96	84	82	94	93	92	90	100	89	96	98	96	95
- 0·185"	81	72	67	43	56	45	66	69	69	76	60	80	86	80	81
- 0·078"	70	51	45	33	39	47	40	55	52	58	42	59	76	62	59
- 0·0164"	48	30	27	24	21	35	25	37	32	34	28	36	52	55	34
- 0 0028/0 0021"	15/12	14/12	11/9	6/5	8/6	12/9	11/9	12/9	11/9	13/10	9/7	14/11	18/12	14/11	13/10
Soil mortar grading coarse sand	31	41	40	27	25	26	35	32	38	41	33	35	32	39	42
C fine sand	14	8	10	12	10	11	9	[illegible]	11	10	11	10	10	11	11
M fine sand	13	8	10	16	9	14	10	13	11	9	12	11	14	10	10
F fine sand	25	18	20	20	9	30	22	28	23	21	27	22	28	22	20
Silt	10	12	12	10	2	13	14	11	11	11	10	11	10	11	10
Clay	7	11	8	5	5	6	7	5	6	8	7	7	6	7	7
Atterberg Limits L.L.	5	21	22	5	5	5	24	5	5	5	5	5	5	22	21
P.I.	P	14	6	P	P	P	7	P	P	P	P	P	P	6	5
L. SN.	4.5	7.0	2.5	4.5	1.0	1.0	4.5	1.0	0.5	1.0	0.5	1.5	1.0	1.0	3.0
Opt moisture / Density at mod. AASHO								5.2 124.6	6.2 119.8						
Mould moisture content / Density/C.B.R								5.0 [illegible]	5.9 [illegible]						
Density								133.5 132.5 128.4	128.4 125.8 121.4						
C.B.R								94 59 15	57 58 11						
Swell								negl. negl. negl.	negl. negl. negl.						



TEST RESULT SHEET 15B: LOW PLASTICITY DEC. GRANITE SUBBASE NORTH OF THE OKATEITEI RIVER.



BORROW PIT INFORMATION

BORROW PIT Nº 87·2

Farm OHAKAUA No. 143

Owner : L STEENKAMP

Chainage : 4601·00

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of Base	Min. % of mod. AASHO Density required	Range of Opt. moist. content	Approx Quantity yds ³
Gravel	6" - 10" 10" - 18"	98 90	5·6 - 7·8 %	23,100

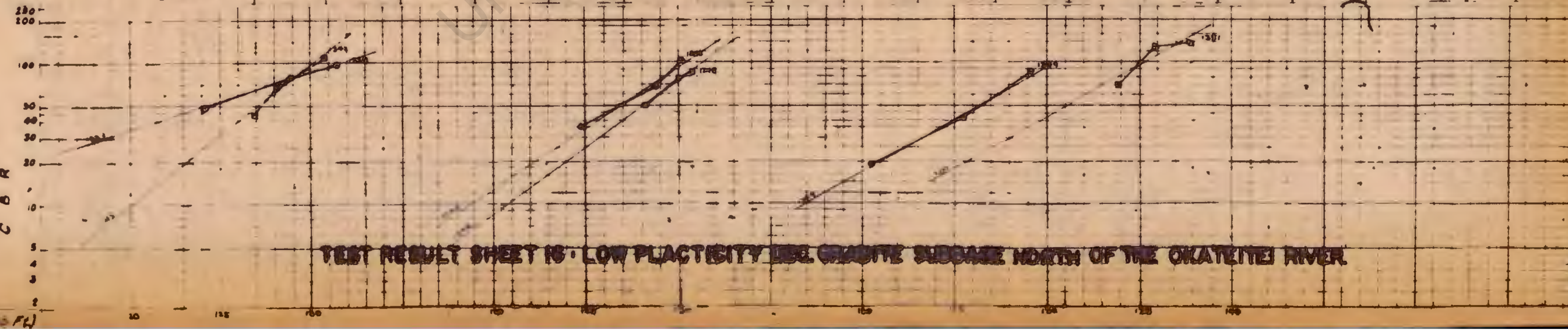
REMARKS

SHEET No 1

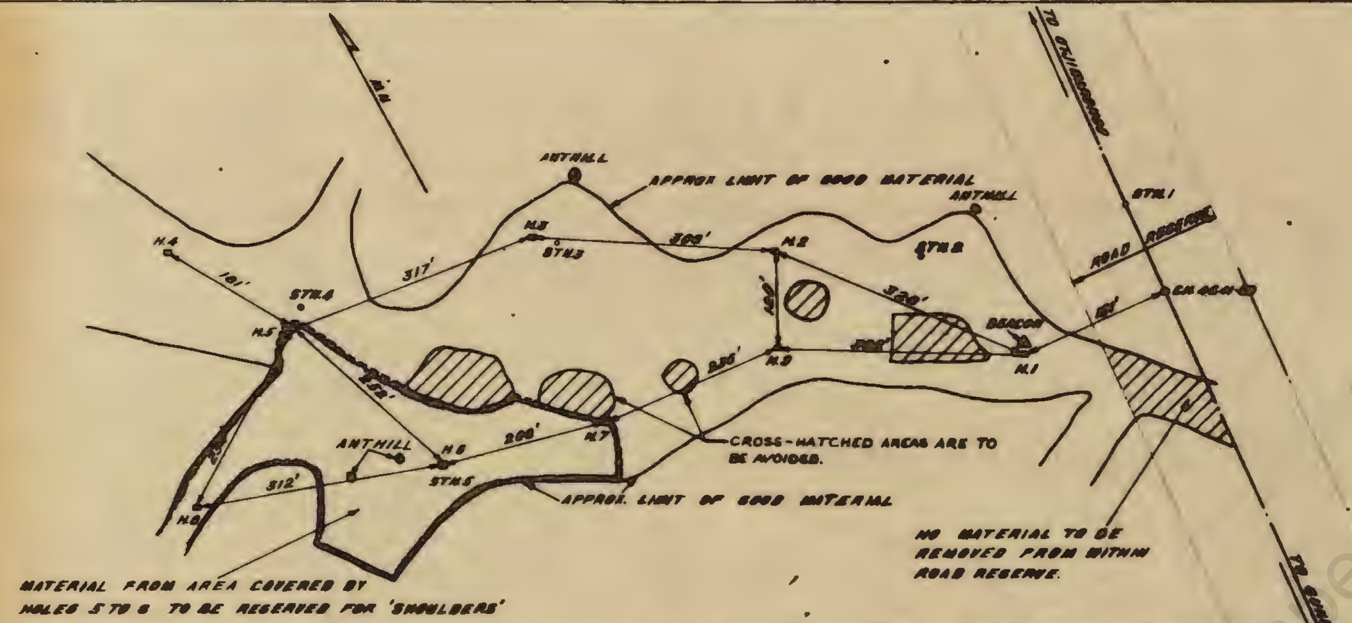
1. Where overburden is encountered, such as in the vicinity of holes 2, 3, 6 and 9, it is to be removed
2. The gravel is approved for the 6"-10" layer compacted to a min. relative density of 98 % and for the 10"-18" layer
3. The material underlying the approved gravel is either hard granite formation or plastic dec. granite. The latter must be avoided.
4. Hatched portions within the approved area are to be excluded.

Visual Description	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]
Stabilized with Ex mould			Ex mould				Ex mould		Ex mould						Ex mould		Ex mould			
Sample Nº IND/CBR	1338	1339 1339	1339	1340	1341	1342 1342	1342	1343 1343	1343	1344	1345	1346	1347	1348 1348	1348	1349 1349	1349	1350	1351 1351	1352
Hole/depth below exist. grd level	1 0"-9"	1 9"-36"	1 9"-36"	2 0"-15"	2 15"-37"	3 0"-23"	3 0"-23"	3 23"-34"	3 23"-34"	4 0"-14"	4 14"-48"	5 6"-35"	5 35"-67"	6 0"-14"	6 0"-14"	6 14"-41"	6 14"-41"	7 6"-29"	8 0"-29"	9 0"-6"
P R A classification (group index)	A1-a [0]	A1-a [0]		A1-b [0]	A1-a [0]	A1-b [0]		A2-4 [0]		A1-b [0]	A1-b [0]	A1-b [0]	A1-b [0]	A1-a [0]		A2-4 [0]		A2-4 [0]	A1-a [0]	A1-b [0]
Screen analysis 1½" | 3/4"	99 96	99 98	100	100 99	100 95	100 99	100	100 97	100	100 92	100 99	100 99	100	100	[illegible]	100	100	93 69	100 94	100
0 .25" | 0 .078"	61 40	33 21	58 30	92 78	68 40	73 80	94 81	68 62	80 65	78 59	77 50	87 81	90 55	88 73	74 74	[illegible] 86	[illegible] 69	36 26	60 36	98 80
0 .0164" | 0 .0029/0 .0021	29 9/6	13 6/5	22 10/8	42 13/9	29 9/6	44 15/10	46 15/10	28 7/6	27 9/8	44 13/9	31 11/8	26 10/8	32 12/9	40 16/11	[illegible] 15/11	35 10/12	[illegible] 17/16	12 8/7	23 8/6	80 15/11
Soil mortar grading: coarse sand | C. fine sand	37 15	30 13	43 10	38 16	40 13	42 13	41 15	52 12	51 12	33 12	36 13	44 13	42 11	32 12	38 12	40 9	40 9	44 10	37 11	37 13
M. fine sand | F. fine sand	17 26	10 19	9 18	10 22	16 20	16 20	14 21	9 14	9 14	12 26	12 21	12 18	11 20	15 24	16 26	8 17	8 20	9 16	12 31	15 21
Silt | Clay	10 5	16 7	12 9	6 8	6 7	6 8	6 6	7 6	6 5	9 5	7 9	8 6	10 6	10 5	8 6	8 10	9 12	10 9	9 9	7 7
Atterberg limits L.L. | P.I.	6 P	23 4	20 4	6 P	NP	NP	NP	20 4	14 5	NP	6 P	10 2	16 2	NP	NP	22 7	26 10	[illegible] 7	17 8	3 P
L. S.	<0.5	1.5	2.0	<0.5	0	0	0	2.0	[illegible]	0	<0.5	[illegible]	1.0	0	0	10.0	6.0	3.0	2.6	1.0
Opt moisture | Density at mod AASHO		6.3 130.6				6.9 130.7		6.7 130.0						6.3 130.0		5.7 129.9			5.6 137.7	
moisture content Density/C B R 95% 90%		6.1 120.0 23 118.3 10				6.6 130.0 25 117.8 6		6.4 122.8 18 117.0 7						6.1 123.9 20 117.2 6		6.8 125.0 20 117.0 10			6.6 130.0 30 125.0 15	
Density		134.8 130.0 130.3				130.7 129.2 120.8		130.8 127.6 124.7						130.7 130.0 128.2		129.8 128.5 120.5			137.7 138.8 129.7	
C. B. R		97 80 49				108 67 43		106 68 35						95 77 50		109 32 19			137 101 70	
Swell		0 0 0.1				0.1 0.1 0		0 0 0.1						0 0 0		0.1 0.1 0.2			0 0 9°	

C B R Density Diagrams



TEST RESULT SHEET 16 : LOW PLACTICITY DEC. GRANITE SUBGRADE NORTH OF THE OKATEITEI RIVER.



APPROX LIMIT OF GOOD MATERIAL

CROSS-HATCHED AREAS ARE TO BE AVOIDED.

APPROX. LIMIT OF GOOD MATERIAL

NO MATERIAL TO BE REMOVED FROM WITHIN ROAD RESERVE.

MATERIAL FROM AREA COVERED BY HOLES 5 TO 8 TO BE RESERVED FOR 'SHOULDERS'

BORROW PIT INFORMATION

BORROW PIT Nº 87·9

Farm : OHAKAUA No 143	Owner : L STEENKAMP
	Chainage : 4041·02

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of Base	Min. % of mod. AASHO Density required	[illegible]	Approx. Quantity yds³
Overburden	10" - 16"	95	6·1 - 7·3 %	14,100
Gravel	Shoulders (Holes 5 - 8)	95	8·1 - 8·2 %	6,000
	4" - 10" (Holes 1-4, and 9)	95	5·4 - 7·6 %	18,000

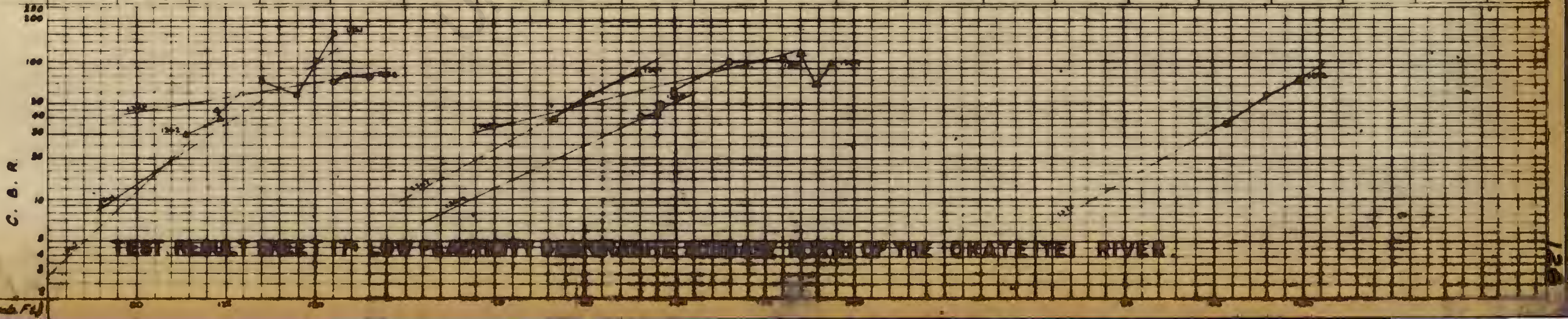
REMARKS

SHEET NO 1

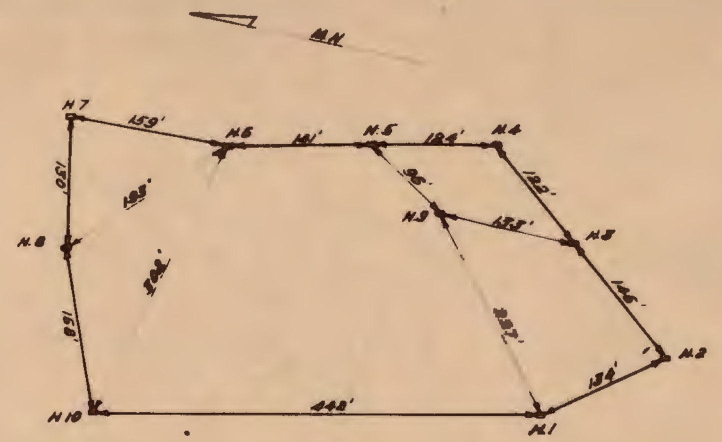
1. The overburden and gravel are to be worked separately.
2. The overburden is approved for use in the 10"-16" layer compacted to a min relative density of 95 %.
3. The gravel represented by holes 5 to 8 as indicated on the sketch, is to be reserved for use in the shoulders. The test results indicate a possible variation in max densities of from 130·6 to 138·6 lbs/cuft. The average max density used for control purposes should, therefore, be chosen with care.
4. The gravel represented by holes 1 to 4 and 9, as indicated on the sketch is approved for use in the 4"-10" layer.
5. Anthills within the approved area are to be avoided as also the hatched areas.
6. The underlying material is either (i) hard granite formation, or (ii) granite decomposed into relatively high plastic material. The latter must be avoided

Visual Description			[illegible]	dec grte pbls	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Stabilized with/Ex. mould				Ex Mould				Ex Mould						Ex Mould		Ex Mould			Ex Mould			
Sample Nº	IND/C.B.R.		1358	1358	1359	1360	1361	1361	1362	1363	1364	1365	1366	1366	1367	1367	1368	1369	1369	1370	1371	1372
Hole/depth below exist. grd			1 15"-34"	1 15"-34"	2 0"-19"	2 19"-35"	3 21"-46"	3 21"-46"	4 0"-10"	4 10"-29"	5 0"-17"	6 17"-47"	6 16"-25"	6 26"-25"	6 25"-39"	6 25"-39"	7 0"-19"	7 19"-40"	7 19"-40"	8 0"-22"	8 22"-36"	9 [illegible]
P.R.A classification (group index)			A1-b[0]		A2-4[0]	A1-a[0]	A1-a[0]		A2-4[0]	A1-b[0]	A2-4[0]	A1-a[0]	A1-a[0]		A2-4[0]		A2-4[0]	A1-a[0]		A1-a[0]	A1-a[0]	A2-[illegible][0]
Screen analysis	− 1½"	− ¾"	100 99	100	100 97	99 86	98 90	100	100	99 97	99	100 95	100 94	100	99 88	100	99	98 92	100	100	99 91	100
	− 0·185"	− 0·078"	79 53	84 64	92 84	54 39	62 42	76 49	96 82	86 55	99 84	62 41	61 48	78 62	89 59	83 69	95 80	76 61	78 49	78 83	68 61	93 66
	− 0·0164"	−0·00[illegible]/0·00[illegible]	27 10/8	36 12/11	56 15/11	27 8/6	25 7/5	20 9/7	57 14/9	34 9/7	55 10/11	27 10/8	29 9/8	37 10/11	82 8/6	33 11/9	69 18/12	37 11/9	31 12/10	29 10/8	19 7/6	66 21/17
Soil mortar grading	coarse sand	C. fine sand	49 11	45 11	31 12	31 15	40 15	46 13	31 14	36 14	30 15	34 12	44 13	40 12	52 10	53 13	27 11	34 11	34 11	45 10	59 11	36 11
	M. fine sand	F. fine sand	10 14	10 17	16 27	15 23	12 19	11 18	19 25	15 20	16 27	12 23	11 19	11 10	9 20	9 12	18 20	12 22	11 21	10 19	9 14	16 17
	Silt	Clay	9 6	9 8	8 5	9 7	9 4	9 6	8 3	6 5	9 4	11 8	10 7	10 9	9 9	7 6	9 5	12 9	8 13	10 6	9 6	9 7
Atterberg Limits	L.L.	P.I.	18 4	17 4	np	np	np	np	np	np	np	19 6	19 6	20 4	24 8	24 2	np	[illegible] 7	24 8	29 6	25 6	[illegible]
		L. SH.	3·0	3·0	0	0	0	0	0	0	0	3·5	3·0	2·5	3·0	1·5	0	3·5	3·5	2·5	2·5	0
Opt moisture	Density at mod. A.A.S.H.O		7·5 133·2				5·4 131·1		6·1 125·2		7·3 130·1		6·5 128·4		8·2 120·6			6·1 128·6				7·6 129·0
Mould moisture content	Density/C.B.R.		7·1 126·6/60 120·0/43				5·3 126·7/35 118·0/9		6·2 119·0/9 112·9/0		7·5 125·6/20 117·0/0		6·4 129·2/29 122·3/02		7·8 125·0/33 115·0/12			5·3 120·6 120·0				7·6 123·3/20 117·9/9
Density			133·2 126·6 118·1				131·1 127·0 128·9		134·8 126·6 122·8		129·3 120·1 120·2		136·1 133·1 129·9		123·0 125·4 123·0			128·6 134·1 137·8			129·8 130·0 126·6	
C.B.R.			78 58 31				161 73 58		65 39 30		80 42 41		105 79 63		83 59 39			95 107 69			78 57 36	
Swell			0 0 0				0 0 0		0 0 0		0·2 0·2 0		0·1 0·1 0·1		0 0 0			0 0 0			0 0 0	

C. B. R. Density Diagrams



TEST RESULT SHEET [illegible] NORTH OF THE [illegible] RIVER.



BORROW PIT INFORMATION | BORROW PIT Nº 310 A

Farm: Pinnacles Nº 310

Owner: G Doll

Chainage:

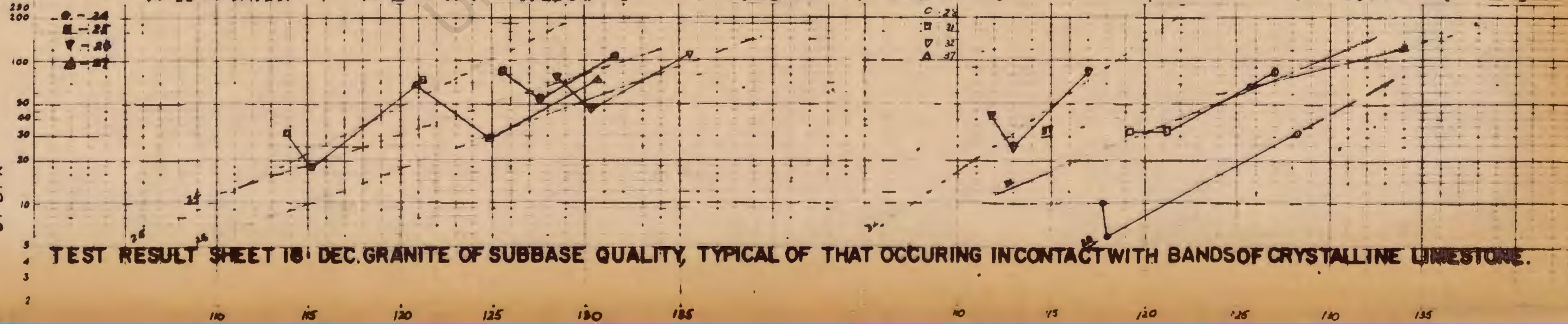
COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of base	Min % of mod. AASHO Density required	Range of Opt. moist content	Approx. Quantity yds 3

REMARKS

Visual Description		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	br.l.	[illegible]	br.l.	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
Stabilised with Ex mould					ex mould							ex mould		ex mould						ex mould	
Sample No	NO CBR	23.	24	25	26 -	26	27	28	29 -	30 -	30	31 -	32	32 -	33 -	34 -	35 -	36 -	37	37 -	38 -
Hole/depth below exist grd level		1 0	23	2 7"-25	-	3 4"-21"	3 21"-35	4 0-16"	4 16"-40"	5 0-18"	5 18"-36"		6 0-13"	6 0"-13"	6 13"-23"	7 0-12"	7 12"-21"	8 0-7"	8 7"-16"	8 7"-16"	9 13"-27"
PRA classification/group index		A- [illegible]	4.5	A2-4 [0]	A2-4 [0]	A1-a [0]	A1-a [0]	A1-a [0]	A2-4 [0]	A2-4 [0]	A2-4 [0]	A2-6 [0]	A1-a [0]	A1-a [0]	A1-a [0]	A2-4 [0]	A1-a [0]	A2-4 [0]	A1-a [0]	A1-a [0].	A1-a [0]
screen 1½	3/4	94	88.59	74.46	100		100,90	.98	96.81	100	94.74	100	76 48	100	17.19	00 97	96.83	81 70	73.56	100 95	87 84
analysis 0 85	0 078	5	38.2	33.28	64 40		70.47	95 91	54.40	97 94	51 40	70 54	37 33	66,55	51.48	46 26	41 24	50.41	34.27	40.30	65 53
0 0 64	.028 .002	8	18 3,3	24.8/6	39 16/8	4	25 7/5	82.23/8	35 11/9	85 23/9	36.11/9	44 18/6	29 7/4	40.12/9	26.8/6	20 6/4	12 8/3	35 11/8	23.7/5	22.8/6	45 13/10
Soil Coarse sand	C fine sand	8,2	33 2	14.12	22		51 12	10.13	12.13	10 13	15.12	19 12	12.9	28.10	14.10	23 8	50 2	15.7	15 8	26.7	15 11
mortar M fine sand	F fine sand	28 39	19.25	22.31	16 23		13.14	26.31	24.28	26.31	22.28	19.21	25 36	18.28	13.23	17 36	5 35	20.40	17.03	15.31	21.35
grading - Silt	Clay	2	9 2	3 8	1.16	1.4	7 3	13.7	14.9	12.8	13.10	11.18	11 7	11.5	10.4	12.4	4 2	16.2	14.3	13.8	12.6
Atterberg L L L	P I	s.p.	s.p.	[illegible] 7	24.9		s.p.	28.6	25.11	21 7	20.9	24.11	s.p	25 s.p.	s.p	22.7	25 6	s.p	20.5	26.6	24.6
limits	L SH	0.5	.05	5.0	3.5	0.5	5	3.0	6.0	.4.0	5.0	5.0	0.5	1.5	1.5	3.5	3 0	1.0	2.0	2.5	4.5
Opt moisture	Density at mod AASHO		6.7 130.5	9.9 123.7		5.7 137.1	6.4 141.3	7.3 138.3			9.2 127.1		11 138.6						6.9 132.0		
Mould moisture content	Density/CBR 95% 90%		6.7 117 3/24 124 0/85	9.9 117.3/32 9.9 111.1/12		5.5 123.1/26 130.4 15.6	6.1 112 2/- 134 0/-	6.7 115 5/4 121 0/8			8.8 114 3/15 12 8/36		8.9 106 8/8 112 8/30						7.0 118.0/61 125.4/85		
Density			114.7 127.5 125.5	128.2 105.1 118		135.5 123 125	107 119 129	112 119 117.8			127.0 118.2 119.2		117.0 110.0 111.9						136.0 125.8		
C B R			108 55 85	78 18 32		114 47 79	74 28 69	32 6 10			84 33 52		85 25 43						123 69		
Swell			0.0 0.0 0.0	0.1 0.2 0.1		0.0 0.0 0.0	0.0 0.0 0.0	0.9 0.9 0.8			0.1 0.1 0.1		0.1 0.0 0.1						0.0 0.0		

C.B.R Density Diagrams



TEST RESULT SHEET 18: DEC. GRANITE OF SUBBASE QUALITY, TYPICAL OF THAT OCCURING INCONTACT WITH BANDS OF CRYSTALLINE LIMESTONE.

BORROW PIT INFORMATION | BORROW PIT Nº 99·6

Farm PINNACLES No 310
Owner : G DOLL
Chainage : 5258·90

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of Base	Min. % of mod. AASHO Density required	Range of Opt. moist content	Approx. Quantity yds ³
Overburden (Holes 1-15 incl)	10" - 18"	90 (depending on control test results)	60 - 6.4 %	19,200
Gravel (Holes 1-15 incl)	4" - 10" Shoulders	98 95	56 - 7.6 %	63,000

REMARKS

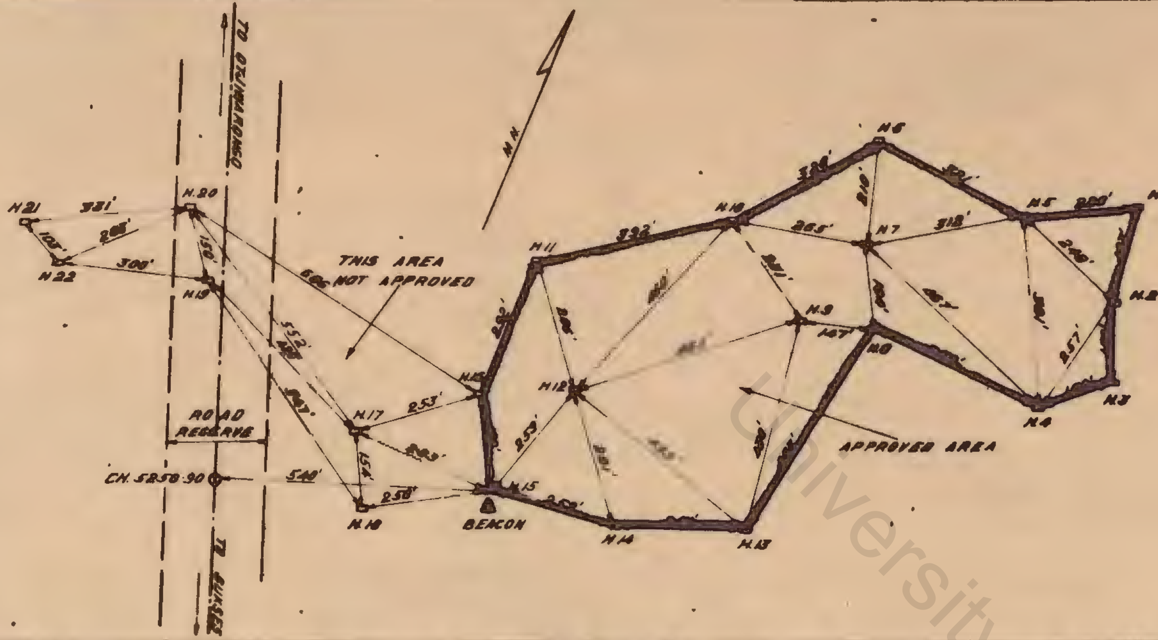
SHEET No. 1 of 3

1 The overburden is approved for use in the 10" - 18" layer compacted to a min relative density of 90 % depending on control test results

2 Only the overburden and gravel represented by holes 1 - 15 inclusive, and as indicated on the sketch is approved for use. That represented by holes 16 - 22 inclusive is NOT approved

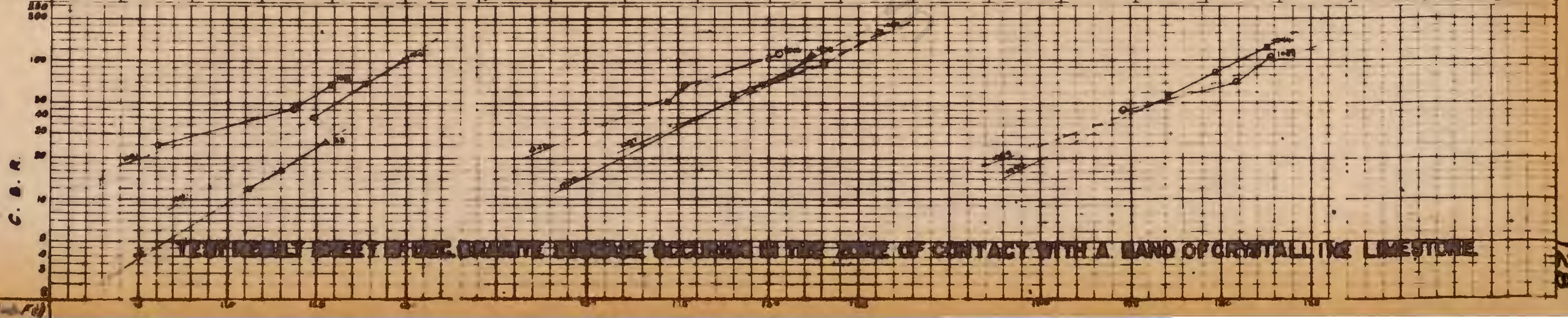
3 The gravel is approved for the 4" - 10" layer compacted to a min. relative density of 98 %. It can be worked as deep as practicable. The test results indicate a variation of the max density of from 128·8 to 34·3 lbs/cuft. The average max density used for control purposes should, therefore, be chosen with care.

Continued on SHEET No. 2



Visual Description	drc grvl pbls br sl.		br Sl	br. Sl grte pbls	br Sl grvl dcr pbls	dcr grte pbls.	Lt brown	brown Soil		dk br sl grte dk grte pbls	dk Sl grte pbls	dcr grte blks gry sl		dr grte pbls, br sl	dr grte blks, H br sl		dec grte pbls br sl		dec grte pbls, 14 br U	
Stabilized with / Ex mould		Ex Mould					Ex Mould		Ex Mould				Ex Mould			Ex Mould		Ex Mould		Ex Mould
Sample No IND/C.B.R.	98 108.	8	082	10[illegible]	1084	1541 154	1541	1542 1542	1542	1550 63	1086	1087 1087	1087	1088	1543 1543	1543	1089 1089	1089	1544 1544	1544
Hole/depth below exist. grd level	2" 30"	2 3	2 0-8	4 0"-24"	3 8"-28"	3 20"-47"	3 28"-47"	3 47"-72"	3 47"-72"	4 0"-7"	4 17"-36"	4 34"-56"	4 34"-56"	5 12"-46"	5 46"-72"	5 46"-72"	6 10"-30"	6 10"-30"	6 30"-65"	6 30"-65"
PRA classification (group index)	A2-4		A2 4 [0]	A1 b [0]	A1 b [0]	2 [illegible]		A 1-0 [0]		A2 4 [0]	A1 b [0]	A1 0 [0]		A2 4 [0]	A1 0 [0]		A1 0 [0]		A1 0 [0]	
Screen – 1½" – 3/4"	100 99	00	100	99 98	100	81 67	100	60 48	100	100	100 96	78 64	100	100 96	79 66	100	100 90	100	80 60	100
analysis – 0·185" – 0·078"	14 49	86 62	95 98	75 52	81 52	46 30	88 65	26 16	66 45	90 92	71 58	40 30	60 41	67 42	45 29	70 48	64 41	14 63	35 24	72 61
– 0·0164" – 0·0035/0·0021"	27 12/10	32 14 2	69 19/13	31 10/7	28 9/7	15 5/4	33 10/12	7 3/2	19 0/6	62 24/15	37 13/10	19 7/5	22 9/7	32 9/7	16 6/5	24 10/8	81 8/6	27 12/10	13 5/4	26 19/8
Soil Coarse sand C. fine sand	45 1	48 10	33 11	40 13	46 11	50 11	49 11	36 13	50 11	22 13	36 12	37 11	44 11	40 11	45 10	50 9	47 11	49 11	46 11	49 12
mortar M. fine sand F. fine sand	9 15	9 13	15 27	12 21	10 20	8	9 13	7 12	8 10	14 23	13 23	11 24	10 17	9 16	9 9	8 15	9 17	9 13	8 17	8 15
grading Silt Clay	12 8	11 9	9 5	10 4	9 4	16 5	10 8	8 4	7 6	11 6	12 4	10 7	10 8	11 5	10 7	10 8	10 6	10 8	11 7	9 7
Atterberg L.L. P.I.	22 7	20 7	5 P	17 2	30 5	23 9	23 7	23 4	5 P	5 P	19 5	6 P	5 P	21 8	21 6	22 6	21 6	20 4	20 3	5 P
Limits L. SH.	4·0	8·0	10·5	1·0	2·5	4·0	3·5	3·0	1·0	1·0	3·0	1·0	1·0	4·0	3·5	4·0	3·5	7·5	2·5	1·0
Opt moisture / Density at mod AASHO	6·2 127·6					7·5 129·9		7·0 130·6		6·0 131·6		6·0 136·3			7·1 132·4		6·2 132·7		6·7 132·5	
Mould moisture content / Density/CBR 98% 95%	6·4 121·7 [37] 114·0 [19]					7·5 123·3 [20] 117·0 [9]		7·7 123·9 [32] 117·4 [22]		6·0 125·0 [illegible] 119·3 [4]		6·4 129·4 [60] 122·7 [35]			7·1 125·0 [19] 119·1 [13]		5·0 126·8 [47] 119·4 [32]		6·7 125·8 [47] 119·2 [17]	
Density	125·8 122·6 116·1					129·9 126·6 120·8		130·5 125·6 124·5		128·5 126·0 121·2		136·3 [illegible] 129·0			132·4 [illegible] 128·0		132·7 130·8 126·5		132·5 129·6 127·2	
C.B.R.	68 46 25					103 69 40		112 66 51		27 15 12		162 98 68			114 82 57		107 71 45		115 83 56	
Swell	0·2 0 0					0 0 0		0 0 0		0 0 0		0 0 0			0 0 0		0 0 0		0 0·1 0·1	

C.B.R. Density Diagrams



[illegible] IN THE ZONE OF CONTACT WITH A BAND OF CRYSTALLINE LIMESTONE

BORROW PIT INFORMATION | BORROW PIT Nº 99·6

Farm : PINNACLES No 310

Owner : G DOLL

Chainage : 5258·90

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of Base	Min % of mod AASHO Density required	Range of Opt moist content	Approx Quantity yds 3
Overburden (Holes 1-18 incl)	10"- 16"	90 (depending on control test results)	6·0 - 6·4 %	19,200
Gravel (Holes 1-18 incl)	4" - 10" Shoulders	98 95	5·6 - 7·6 %	62,600

REMARKS

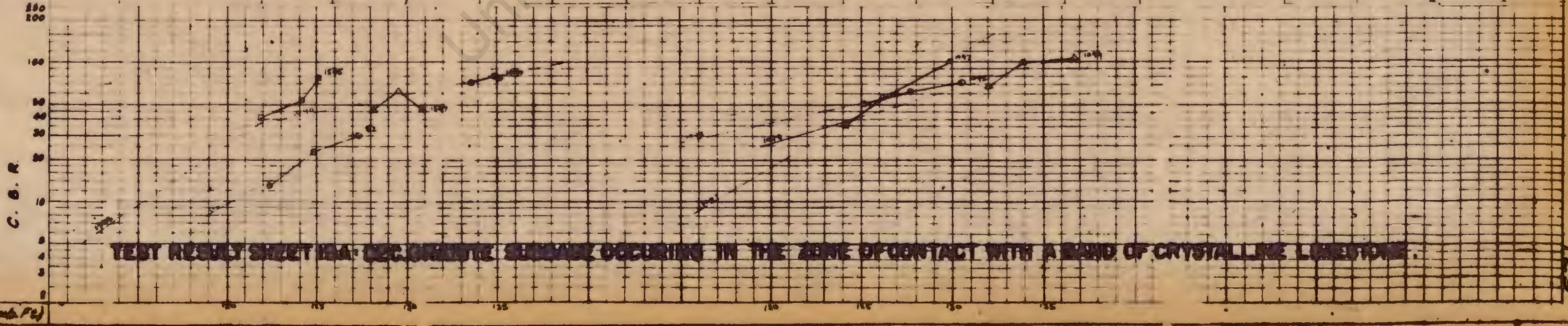
SHEET No.2 of 3

See SHEET No. 1

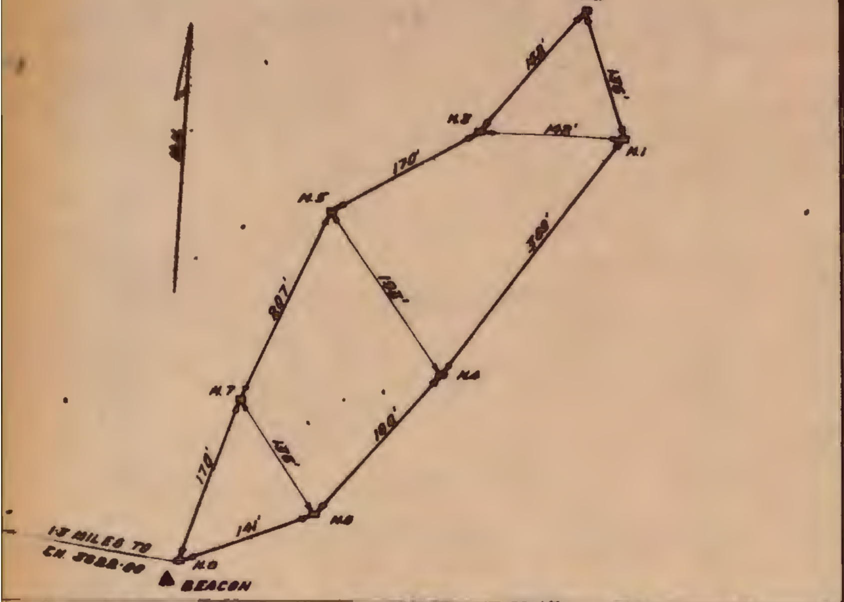
4. The gravel is also approved for the Shoulders.
5. Positions of holes 7, 9, 12, and 17, which are not boundary holes, have not been marked with a metal plate embedded in concrete in the usual way.

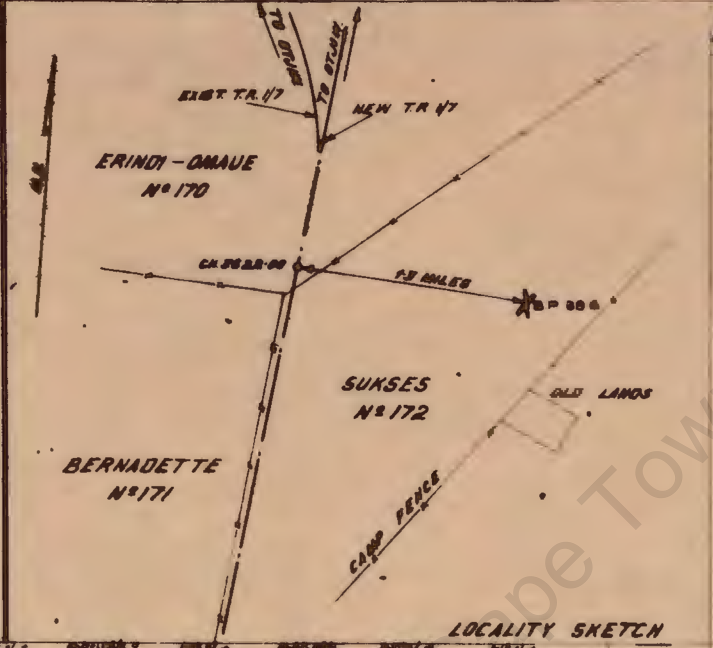
Visual Description	red br si, dec grte pels		dec grte pels H.br sdy si		dec grte pels br si	lt br si, dec grte pels	yel br to si, qtz dec grte pels	rd br si, dec grte, qtz pels		dec grte pels, br si	br si, dec grte, qtz pels		dec grte, qtz pels, br si		dec grte pels, br si	dec grte pels br si		qtz, dec grte pels br si	br si, qtz dec grte pels	
Stabilized with/Ex mould		Ex Mould		Ex Mould					Ex Mould					Ex Mould			Ex Mould			Ex Mould
Sample Nº IND/CBR	1090 1090	1090	1545 1545	1545	1091	1544	1549 62	1547 1607	1547	1548	1098	1098	1095 1095	1095	1096	1097 1097	1097	1098	1099 1099	1099
Hole/depth below exist. grd. level	7 16"-48"	7 16"-48"	7 48"-66"	7 48"-66"	8 1"-37"	8 37"-60"	9 6"-12"	9 12"-39"	9 12"-39"	9 39"-52"	10 11"-48"	11 10"-37"	12 16"-52"	12 16"-52"	13 4"-34"	14 8"-36"	14 8"-36"	15 11"-30"	16 9"-29"	16 9"-29"
PRA classification (group index)	A 1-b [0]		A 1-a [0]		A 2-4 [0]	A 1-b [0]	A 2-4 [0]	A 2-4 [0]	A 2-4 [0]	A 1-a [0]	A 1-b [0]	A 1-b [0]	A 2-4 [0]		A 1-a [0]	A 1-a [0]		A 1-a [0]	A 1-b [0]	
Screen analysis – 1½" / – 3/4"	99 99	100	99 90	100	95 87	100 94	100	99 98	99 98	96 89	100	100	99 97	100	100	100 99	100	96 90	100 93	100
– 0·183" / – 0·078"	85 58	88 66	60 35	76 46	63 44	70 52	87 91	87 59	87 59	64 32	88 63	80 66	70 45	86 63	78 44	62 42	74 51	65 49	73 57	78 65
0·0188" / – 0·0038/0·0021"	36 12/9	41 10/13	15 8/4	20 7/6	23 8/6	16 6/5	58 17/13	27 12/10	27 12/10	13 5/4	32 10/8	37 13/10	23 8/7	30 13/10	21 7/6	24 9/7	29 13,11	30 12/10	33 11/9	38 15/13
Soil mortar grading: coarse sand / C. fine sand	30 12	30 12	57 12	57 12	48 12	69 10	34 12	54 8	54 8	62 11	49 12	44 12	49 11	58 11	52 10	38 12	41 11	39 10	42 11	42 12
M. fine sand / F. fine sand	12 21	11 20	8 12	8 10	10 16	7 5	14 23	7 14	7 14	7 8	10 16	10 20	8 16	7 13	8 18	10 32	8 16	9 23	10 21	10 16
Silt / Clay	13 4	10 9	7 4	8 5	10 4	5 4	8 7	9 8	9 8	7 5	8 5	9 6	9 7	8 8	9 3	13 5	14 8	12 7	11 5	11 9
Atterberg Limits: L.L. / P.I.	19 4	17 4	n p	s p	27 7	23 5	6 p	22 8	23 8	25 8	26 3	21 3	21 7	28 7	20 4	23 6	22 5	19 5	17 3	17 4
L. SH	3.5	2.0	0	1.0	3.0	3.5	1.0	5.5	5.5	2.5	2.0	2.0	4.0	3.6	3.0	3.0	3.0	3.0	1.5	2.0
Opt. moisture / Density at mod AASHO	6.4 134.2		7.5 136.2				6.4 132.5	7.6 130.8					7.6 130.5			5.7 129.0			5.5 134.3	
Mould moisture content / Density/C.B.R. 100% 95% 90%	6.3 137 6|53 130 9|35		7.4 118 8|21 113 8,6				6.4 135 9|18 121,0	7.4 117.0					8.0 124.0 68 117 5,32			5.4 133.2 135 116 8,0			5.5 137 7 183 130 9,40	
Density	134.8 135.1 133.5		135.2 124.2 121.9				127.4 120.8 122.4	130.8 129.5 128.2					130.6 128.6 125.2			129.8 136.3 134.2			136.7 131.9 132.0	
C.B.R.	80 90 72		77 54 41				80 23 13	47 63 47					72 63 51			100 56 35			109 98 67	
Swell	0 0 0		0.2 0.2 0.1				[illegible] 0	0.2 0.2 0.2					0 0			0 0 0			0 0 0	

C. B. R. Density Diagrams



TEST RESULT SHEET 13A: DEC. GRANITE SUBGRADE OCCURING IN THE ZONE OF CONTACT WITH A BAND OF CRYSTALLINE LIMESTONE.





LOCALITY SKETCH

BORROW PIT INFORMATION BORROW PIT Nº 666.

Farm Sukses Nº 172
Owner · Mrs M J.E. Meyer.
Chainage 3622 00

COMPACTION REQUIREMENTS and QUANTITY

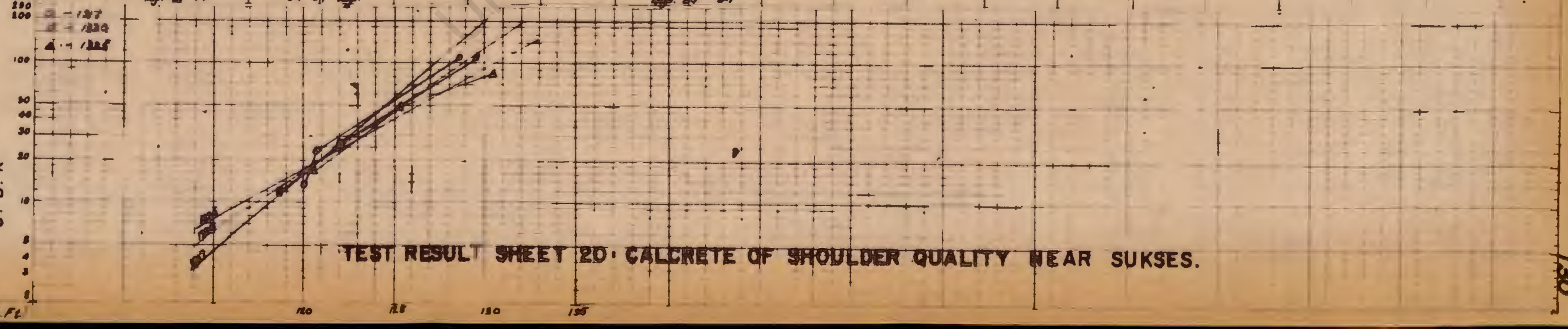
Material	Horizon measured from top of Base	Min % of mod. AASHO Density required	Range of Opt. moist content	Approx. Quantity yds 3
Gravel	Shoulders	95	83%	8,700

REMARKS

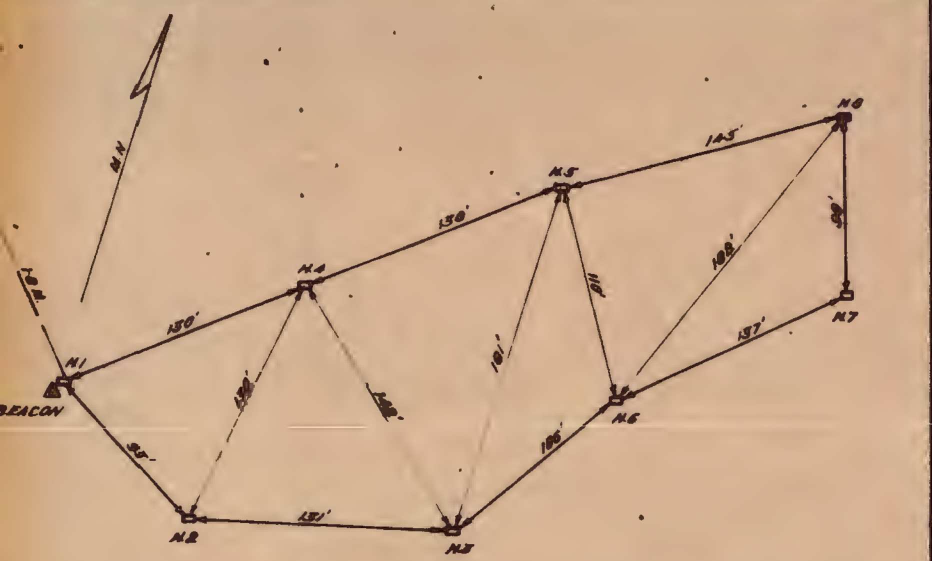
1. Remove all Overburden.
2. The gravel is approved for use in the shoulders
3. Any powdery limestone underlying the tested gravel is to be strictly avoided.
4. Any anthills within the approved area are to be avoided.

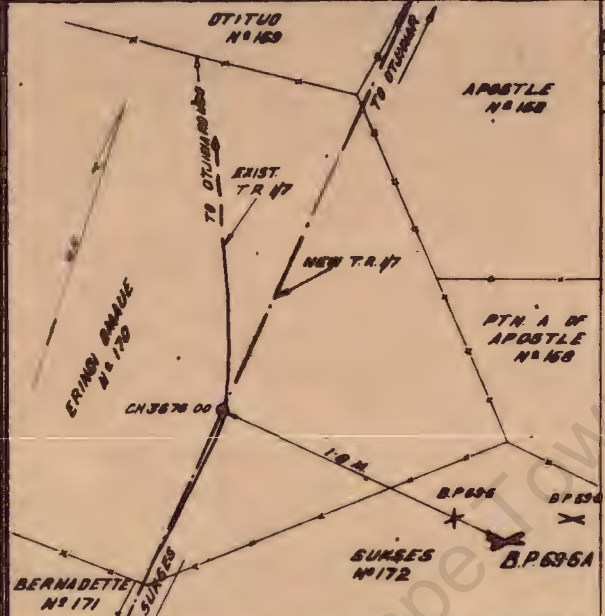
Visual Description	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Stabilized with/Ex mould					93 mould					ex mould
Sample Nº IND/C.B.R	1215 –	[illegible] 1217	1218 –	1219 1220	1220	1221 –	1222 –	1223 –	1224 1225	1225
Hole/depth below exist grd level	1 [illegible]	2 9'-08"	3 10'-08"	4 15'-01"	4 12'-3"	5 9'-00"	6 10'-01"	7 14'-08"	8 15'-07"	8 15'-07"
RA classification (group index)	A-2-4 [0]	A-2-4 [0]	A-2-4 [0]	A-2-6 [0]	A-2-4 [0]	A-2-4 [0]	A-2-4 [0]	A-2-4 [0]	A-2-4 [0]	A-2-4 [0]
Screen analysis – 1½ | – 3/4"	90 89	90 91	92 92	[illegible] 95	100 100	91 75	91 81	90 72	98 98	100 100
– 0·185" | – 0 078"	59 47	55 42	75 66	76 65	86 77	52 41	68 56	46 35	70 63	82 73
0 0164" | – 0 0088/0 0021	[illegible]	31 12/9	51 16/5	49 19/6	59 25/21	28 14/8	40 11/13	27 11/9	46 17/14	56 22/19
Soil mortar grading: coarse sand | C fine sand	25 14	25 13	23 10	25 13	24 12	22 12	29 11	23 18	37 13	25 13
M fine sand | F fine sand	14 25	13 26	19 27	13 27	11 26	12 25	11 25	12 26	13 24	12 26
Silt | Clay	14 8	13 10	13 7	14 8	13 14	13 6	16 8	16 10	14 9	13 13
Atterberg limits L.L. | P.I.	23 7	25 8	23 7	22 9	22 9	26 8	26 8	24 8	23 7	23 7
L SH	9·0	8·5	8·0	9·0	4·0	6·0	6·0	4·5	9·5	4·5
Opt moisture | Density at mod AASHO		8·3 128·6 128 27		8·3 129·5 128·1 31					8·8 129·8 128 11 35	
moisture content | Density/C B R		8·3 115 5/5		8·3 116·7 18					8·6 118·[illegible] 12	
Density		128·6 124·9 110·0		129·6 122·0 107·7					129·6 125·3 120·6	
C B R		114 20 12		81 27 12					86 50 17	
Swell		negl. 0·1 0·1		0·1 0·1 negl.					negl. 0·1 0·1	

C. B. R Density Diagrams



TEST RESULT SHEET 20 · CALCRETE OF SHOULDER QUALITY NEAR SUKSES.





LOCALITY SKETCH.

BORROW PIT INFORMATION

BORROW PIT Nº 69·6 A

Farm : Sukses Nº 172

Owner : Mrs M.J.E. Meyer

Chainage : 3676·00

COMPACTION REQUIREMENTS and QUANTITY

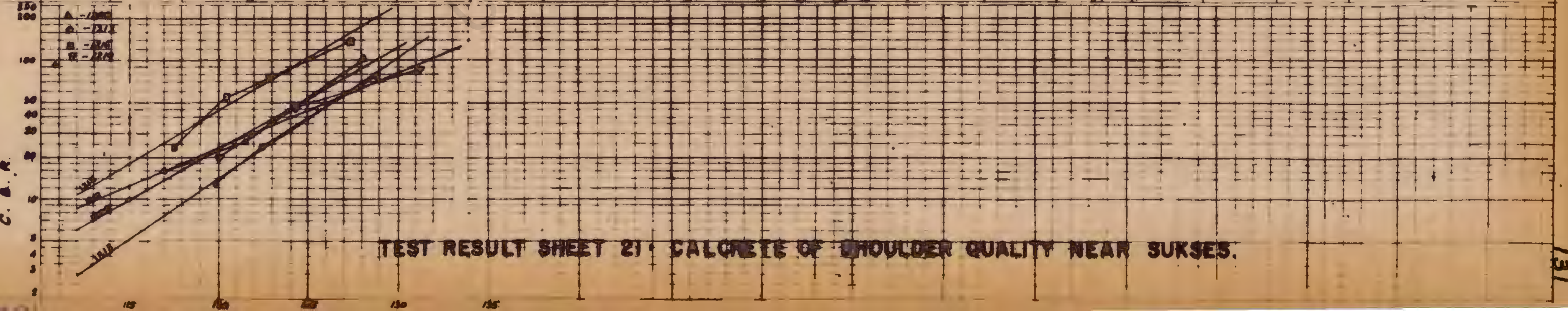
Material	Horizon measured from top of Base	Min % of mod AASHO Density required	Range of Opt. mould content	Approx. Quantity yds ³
Gravel	Shoulders	95	8·9 - 9·5%	2,700

REMARKS

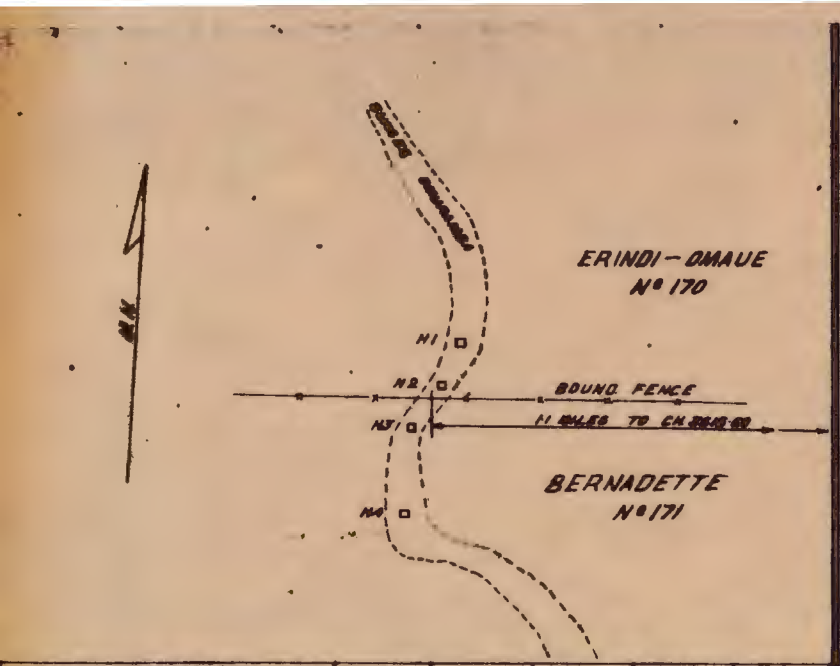
1. Remove all overburden
2. The gravel is approved for use in the shoulders. The PI of the gravel in hole 6 is slightly low, but this is considered to be a small pocket only.
3. Any powdery limestone underlying the tested gravel is to be strictly avoided.
4. Anthills within the approved area are to be avoided.

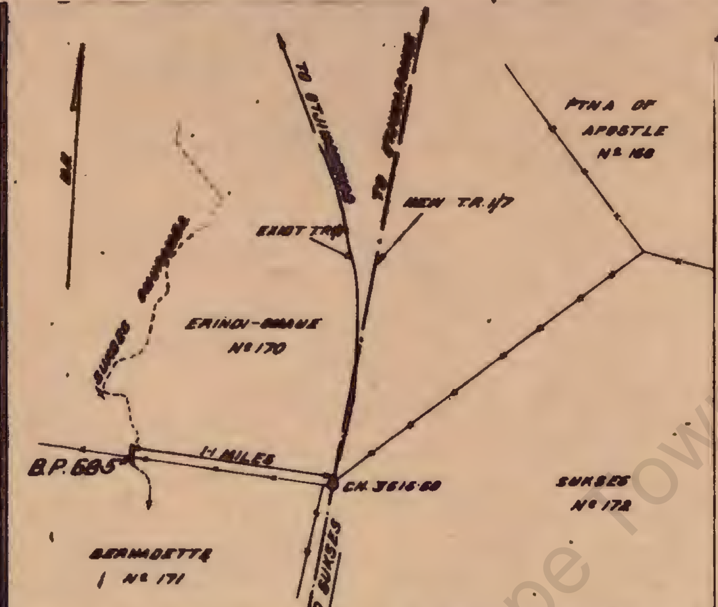
Visual Description		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	dk. br. sd.	[illegible]	[illegible]	[illegible]	[illegible]	br. sl.	[illegible]	[illegible]	[illegible]	[illegible]
Stabilized with/Ex mould				ex mould								ex mould				ex mould		
Sample Nº	IND/C.B.R	1204 –	1205 –	1206	1207 –	1208 –	1209 –	1210 –	1211 –	1212 1213	1214 –	1215	1216 –	1217 –	1218 –	1219	1220 –	1221 –
[illegible] depth below exist. grd. level		1 0"-18"	1 18"-40"	1 18"-40"	2 0"-16"	2 16"-40"	3 0"-9"	3 9"-20"	4 0"-36"	4 36"-68"	5 [illegible]	6 6"-[illegible]"	6 [illegible]	7 0"-[illegible]"	7 [illegible]"-40"	7 [illegible]"-40"	8 0"-20"	8 20"-[illegible]"
[illegible] classification (group index)		A-2-4 [0]	A-1-b [0]	A-2-4 [0]	A-2-4 [0]	A-2-4 [0]	A-2-4 [0]	A-1-b [0]	A-2-4 [0]	A-2-4 [0]	A-2-4 [0]	A-2-4 [0]	A-1-b [0]	A-2-4 [0]	A-2-4 [0]	A-2-4 [0]	A-2-4 [0]	A-1-b [0]
Screen analysis	- 1½" / - ¾"	100 98	78 70	100 100	100 98	98 93	100 98	100 98	100 96	98 88	[illegible] [illegible]	100 100	88 71	100 99	88 67	100 100	100 [illegible]	93 [illegible]
	- 0·189" / - 0·078"	86 81	54 47	86 70	81 78	66 55	91 89	67 68	90 87	71 65	37 32	62 84	49 41	[illegible] [illegible]	58 48	80 71	[illegible] 72	[illegible] [illegible]
	0·0164" / -0·0065/0·0021"	69 21/15	38 15/12	59 20/22	65 13/12	45 15/11	77 10/10	41 15/11	72 20/15	50 20/15	25 3/5	41 12/11	[illegible] [illegible]	69 12/10	38 [illegible]	68 19/15	60 17/12	42 13/10
Soil mortar grading	coarse sand / c. fine sand	15 15	19 12	20 11	16 [illegible]	19 16	20 16	26 13	17 18	17 18	[illegible] [illegible]	[illegible] 16	[illegible] 14	20 16	21 14	22 16	17 16	18 16
	M. fine sand / F. fine sand	17 34	14 28	12 26	18 34	16 30	18 34	15 27	18 30	16 29	17 29	[illegible] [illegible]	[illegible] 29	17 31	15 30	15 27	17 34	[illegible] [illegible]
	Silt / Clay	14 5	19 8	19 11	12 4	15 5	9 8	10 5	12 5	18 6	11 8	13 8	16 5	16 8	18 10	13 8	16 6	18 7
Atterberg limits	L.L.L. / P.I.	21 4	21 6	22 7	3 P	25 8	3 P	20 5	22 7	24 9	20 8	22 8	3 P	20 4	21 9	21 9	18 2	20 [illegible]
	L. Sh.	2·5	3·0	9·0	1·0	4·0	1·0	3·5	8·0	9·0	3·0	2·5	1·0	2·5	3·0	3·0	1·0	0·5
Opt. moisture / Density of mod. AASHO				8·9 128·1						9·0 129·9		9·4 127·3				8·9 130·1		
Mould moisture content / Density / C.B.R.				9·0 [illegible]/110						8·5 [illegible]/16		9·4 [illegible]/15				8·9 [illegible]/[illegible]		
Density				124·1 [illegible] 117·0						129·9 [illegible] [illegible]		127·3 [illegible] 117·7				130·1 130·1 [illegible]		
C.B.R				102 [illegible] [illegible]						72 [illegible] 19		[illegible] [illegible] 24				67 67 20		
Swell				0·1 0·1 0·1						0·0 0·1 0·1		negl. negl. negl.				0·1 0·0 0·0		

C. B. R. Density Diagrams



TEST RESULT SHEET 21 : CALCRETE OF SHOULDER QUALITY NEAR SUKSES.





LOCALITY SKETCH

BORROW PIT INFORMATION BORROW PIT Nº 685

Farm Erindi- Omaue No.170 Bernadette No. 171

Owner Mrs H.F. Behrens W von Oppen

Chainage 3616·60

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of Base.	Min % of mod. AASHO Density required	Range of Opt. mois. content	Approx. Quantity yds ³
Sand	Sand surface dressing			

REMARKS

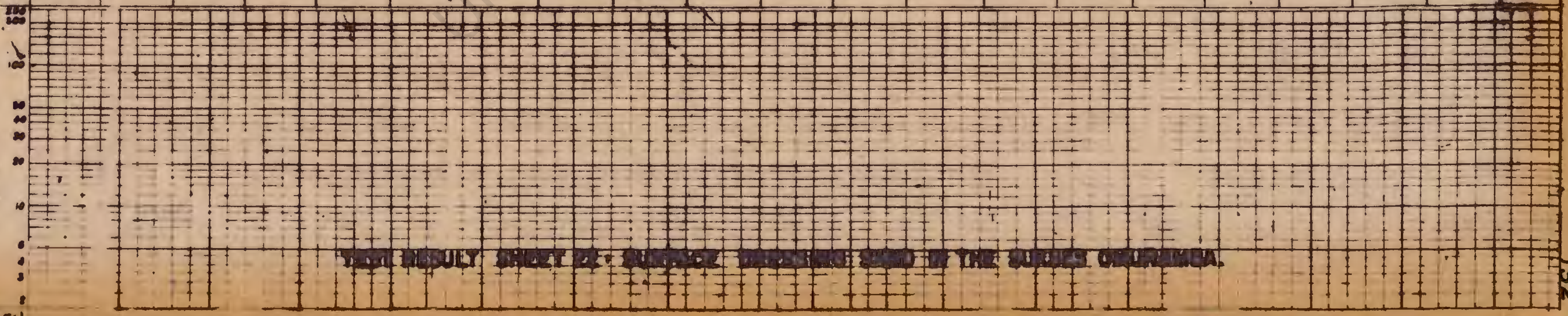
1. The screen analysis will most probably alter after the river has flowed. It will, therefore, be necessary to retest immediately prior to working the deposit to confirm suitability and whether or not screening is required.

2. Holes 1 and 4 should give a satisfactory screen analysis over the complete profile after the oversize sand has been removed by screening

3. The top layer of holes 2 & 3 is too fine. The underlying layer should be satisfactory after removal by screening of the oversize sand.

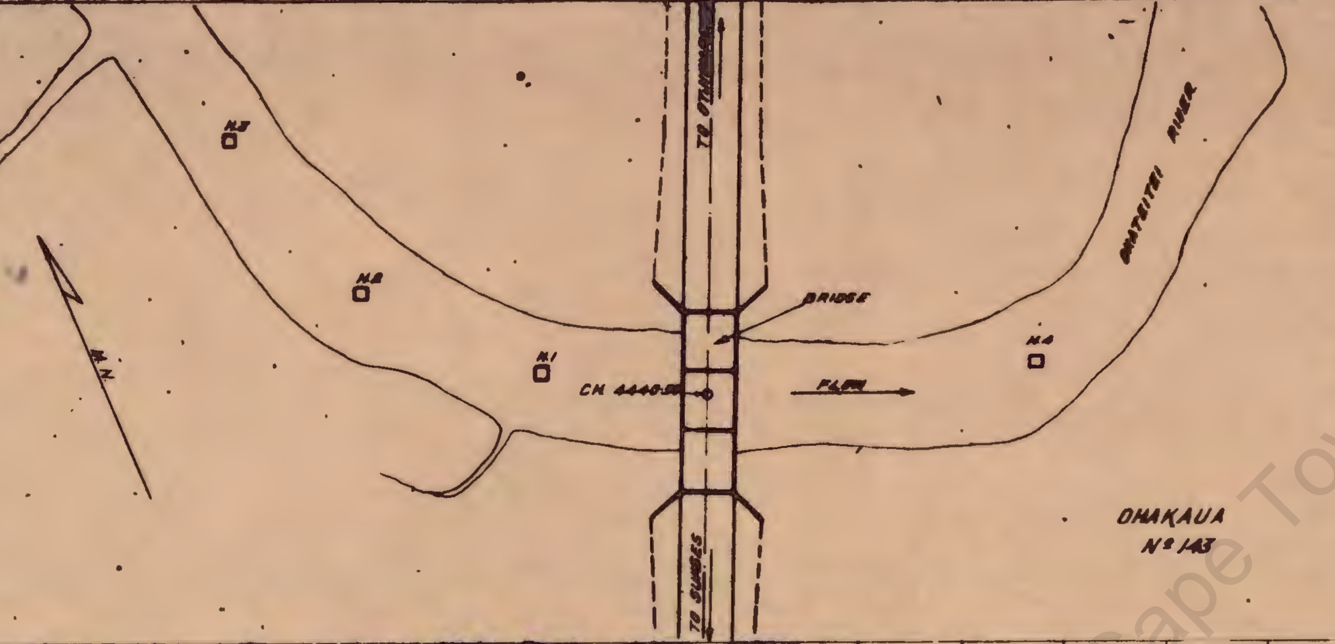
Visual Description			l.br grit sand	l.br grit sd	l.br grit sd	l.br grit sd	l.br grit sd	l.br grit sd	[illegible]	l.br grit sd
Stabilized with/Ex mould										
Sample Nº		IND/C.B.R.	620 –	[illegible] –	632 –	648 –	649 –	[illegible] –	625 –	657 –
Hole/depth below exist. grd level			1 0"-30"	1 30"-72"	2 0"-50"	2 30"-61"	3 0"-35"	3 35"-58"	4 0"-38"	4 38"-65"
P.R.A. classification (group index)										
Screen analysis	– 1½"	– 3/4"								
	– 0·188"	– 0·078"	96	95	98	96	96	96	96	99
	– 0·0164"	– 0·0053	14 1	9 0	31 3	16 1	28 1	15 1	10 1	18 1
Soil mortar grading	coarse sand	C. fine sand								
	M. fine sand	F. fine sand								
	Silt	Clay								
Atterberg Limits	L.L.	P.I.								
		L. SH.								
Opt. moisture	Density at mod. AASHO									
Mould moisture content	Density C.B.R.									
	Density									
	C. B. R.									
	Swell									

C.B.R. Density Diagrams



Dry Density (Lbs/Cu Ft)

TEST RESULT SHEET 22: SURFACE DRESSING SAND IN THE SUKSES OMURAMBA.



BORROW PIT INFORMATION

BORROW PIT Nº 84·1

Farm : Ohakaua No. 143

Owner : L Steenkamp

Chainage : 4440·50

COMPACTION REQUIREMENTS and QUANTITY

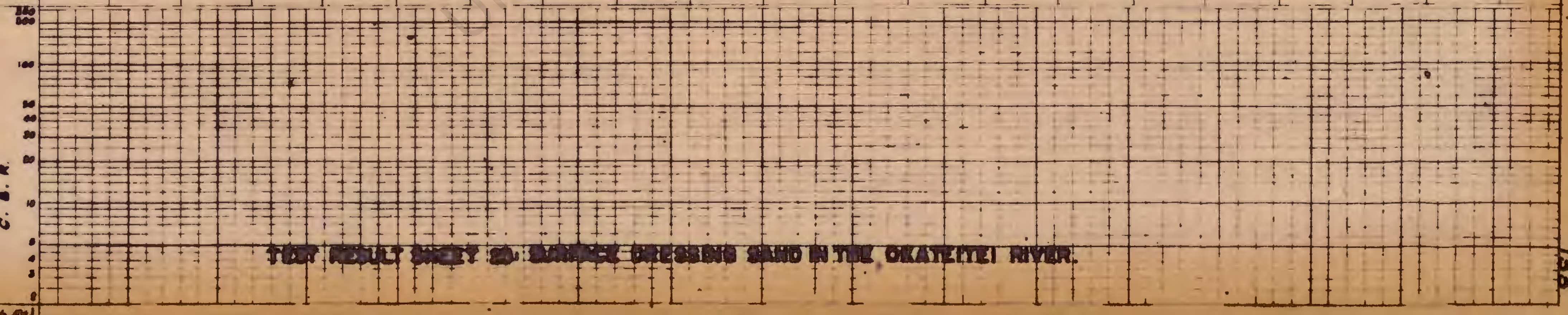
Material	Horizon measured from top of Base.	Min. % of mod. AASHO Density required	Range of Opt. moist. content	Approx. Quantity yds ³
Sand	Sand surface dressing			—

REMARKS

1. The screen analysis will most probably alter after the river has flowed. It will, therefore, be necessary to re-test immediately prior to working the deposit to confirm suitability and whether or not screening is required.
2. Sand as represented by hole 1, 0"-54"; and hole 3, 0"-18", is unsuitable.
3. Sand, as represented by hole 2, 0"-32", hole 3, 18" 42", and hole 4, 0"-40", should be suitable after screening out the oversize sand.

Visual Description		g/s	g/s, granite sand	[illegible]	[illegible]	[illegible]	[illegible]
Stabilized with / Ex mould							
Sample Nº	INC/C.B.R.	1195 -	[illegible] -	1200 -	[illegible] -	[illegible] -	[illegible] -
Hole / depth below exist. grd level		1 0"-54"	2 0"-32"	3 0"-18"	3 18"-27"	3 27"-42"	4 0"-40"
P R A classification (group index)							
Screen analysis	- 1½" / - 3/4"						
	- 0·185" / - 0·078"	95	92	67	99	95	89
	- 0·0164" / - 0·0030"	10 /	11 /	9 /	21 /	11 /	9 /
Soil mortar grading	coarse sand / C. fine sand						
	M. fine sand / F. fine sand						
	Silt / Clay						
Atterberg limits	L.L. / P.I.						
	/ L. SH.						
Opt. moisture / Density at mod. AASHO							
Mould moisture content / Density/C.B.R.							
Density							
C. B. R.							
Swell							

C. B. R. Density Diagrams



TEST RESULT SHEET 29: SURFACE DRESSING SAND IN THE OKATEITEI RIVER.

BORROW PIT INFORMATION

BORROW PIT No 102·1

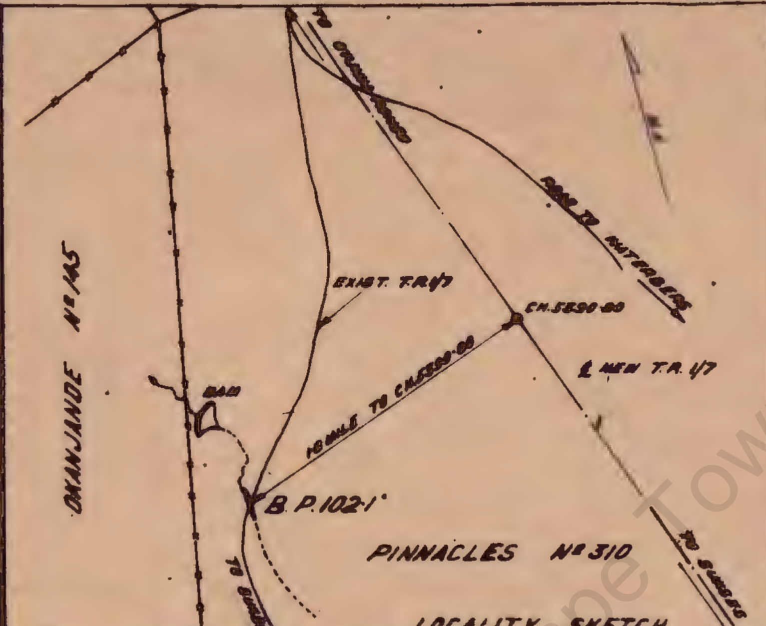
Farm : Pinnacles No 310.	Owner : G. Doll.
	Chainage : 5390·80.

COMPACTION REQUIREMENTS and QUANTITY

Material	Method of measurement from top of Base.	Min % of mod. AASHO Density required	Range of Opt. moist content	Approx. Quantity yds³
Sand.	Sand surface dressing.			

REMARKS

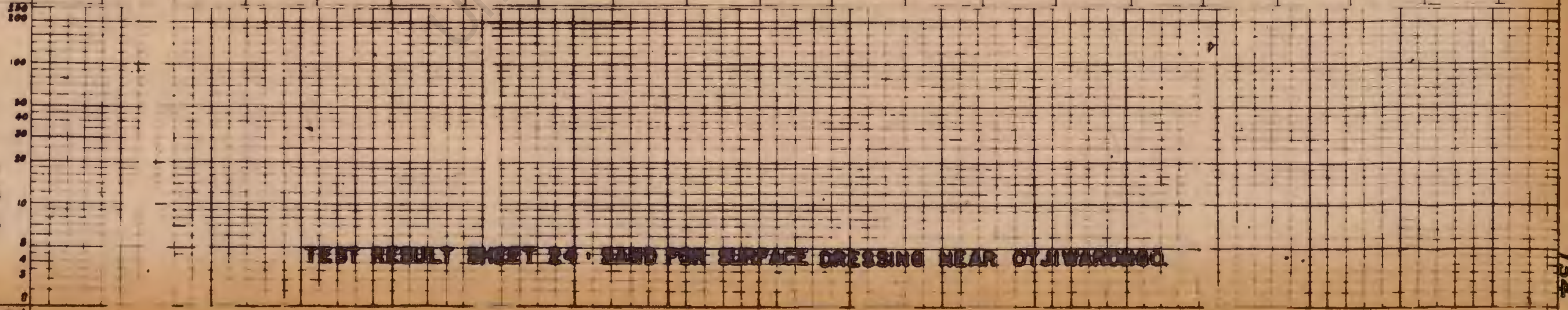
1. The screen analysis will most probably alter after the river has flowed. It will, therefore, be necessary to re-test immediately prior to working the deposit to confirm suitability and whether or not screening is required.
2. Holes 1-5 are too finely graded. Such sand should be avoided.
3. Holes 6-9 give satisfactory results. Screening may be necessary.
4. Clay is found immediately under the sand.



LOCALITY SKETCH

		1	2	3	4	5	6	7	8	9
Visual Description		[illegible] sand + [illegible]			[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
Stabilized with / Ex mould										
Sample No	IND/C.B.R.	[illegible] -			[illegible] -	[illegible] -	1301 -		[illegible] -	[illegible] -
Hole/depth below exist. grd level		1 0-24"	[illegible]	3 0-20"	4 0-24"	5 0-30"	6 0-20"	7 0-20"	8 0-24"	9 0-36"
P.R.A. classification (group index)										
Screen analysis	- 1½" / - 3/4"	100			100	100	100		100	100
	0·185" / - 0·078"	89			90	9[illegible]	9[illegible]		9[illegible]	100
	- 0·0164" / - 0·0029"	19 | 1			47 | 3	[illegible] | 4	18 | 3		21 | 3	22 | 2
Soil mortar grading	coarse sand / C. fine sand									
	M. fine sand / F. fine sand									
	Silt / Clay									
Atterberg Limits	L.L. / P.I.									
	L. SH.									
Opt moisture / Density at mod. AASHO										
Mould moisture content / Density / C.B.R.										
Density										
C.B.R.										
Swell										

C.B.R. Density Diagrams



TEST RESULT SHEET 24 : SAND FOR SURFACE DRESSING NEAR OTJIWARONGO.

BORROW PIT INFORMATION

BORROW PIT Nº 1-3

Farm Otjiwarongo Townlands Nº 18

Owner : Otjiwarongo Municipality

Chainage : 66·6

COMPACTION REQUIREMENTS and QUANTITY

Material		Horizon measured from top of Base	Min % of mod AASHO Density required	Range of Opt. moist content	Approx. Quantity yds ³
OVERBURDEN AREAS A,B&C		10" - 6"	95 %	8·5% - 11·0%	105,100
GRAVEL	AREA A	SHOULDERS	95 %	6·4% - 9·2%	29,700
	AREA B	4 -10"	98 %	6·5% - 8·0%	28,900
	AREA C	BASE: LIME STAB	98 %	8·7% - 9·1 %	68,700
		MECH PROCESSED	98 %	5·9% - 6·6 %	

REMARKS.

Sheet

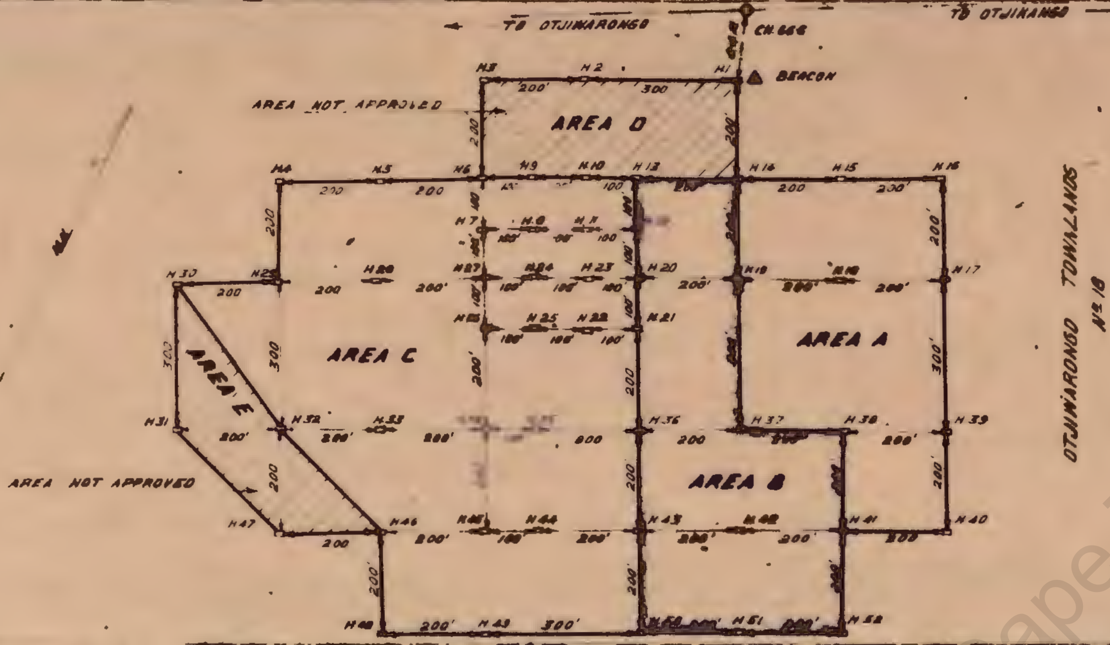
1 Areas D and are NOT approved
Areas A,B and C are approved for use as stipulated below

2 The overburden from areas A, B and C is approved for use in the 10"- 6" layer compacted to a minimum relative density of 95%.

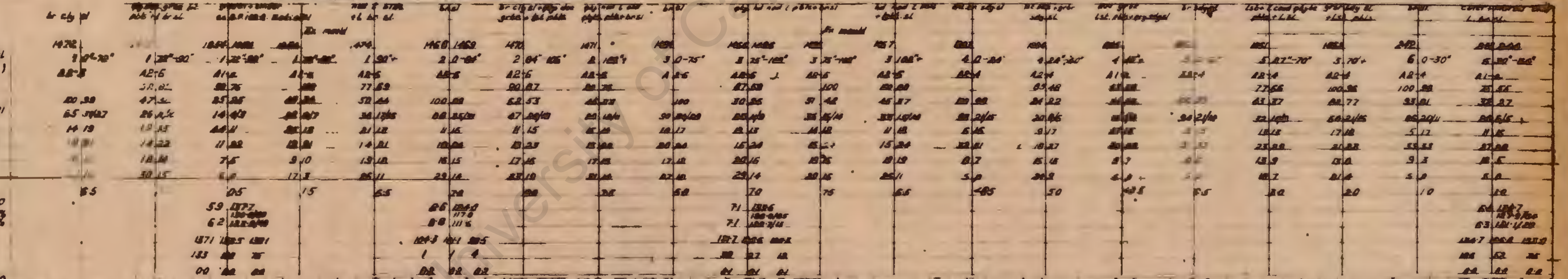
3 (a) The tested layer of gravel in area C is approved for use in the basecourse either stabilized with 3% Lime (Usakos or Stabilim), or mechanically processed as follows

(i) Screen the gravel through a ½" mesh screen to eliminate the fines,

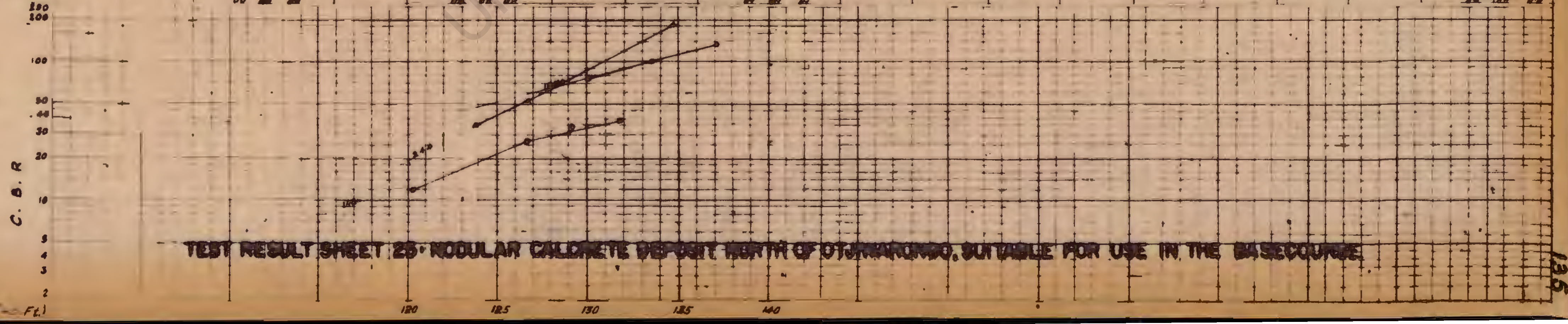
(cont. on sheet 2)



Visual Description
Stabilized with/Ex mould
Sample Nº IND C B R
Hole/depth below exist. grd level
P R A classification (group index)
screen analysis 1½" - ¾" 0·188" - 0·078" 0·0164" - 0·0029/0·0021
Soil mortar grading coarse sand C fine sand M fine sand F. fine sand Silt Clay
Atterberg Limits L L L P. I. L. SH.
Opt moisture Density at mod AASHO
Mould moisture content Density/C B R 95% 90%
Density
C B R
Swell



C. B. R Density Diagrams



TEST RESULT SHEET 25: NODULAR CALCRETE DEPOSIT NORTH OF OTJIWARONGO, SUITABLE FOR USE IN THE BASECOURSE.

BORROW PIT INFORMATION

BORROW PIT Nº 1·3

Farm Otjiwarongo Townlands Nº18
Owner · Otjiwarongo Municipalit
Chainage. 66·6

COMPACTION REQUIREMENTS and QUANTIT

Material	Horizon measured from top of Base	Min % of mod. AASHO Density required	Range of Opt moist content	Approx. Quantit yds 3

REMARKS (cont. from sheet 1)

Sheet 2

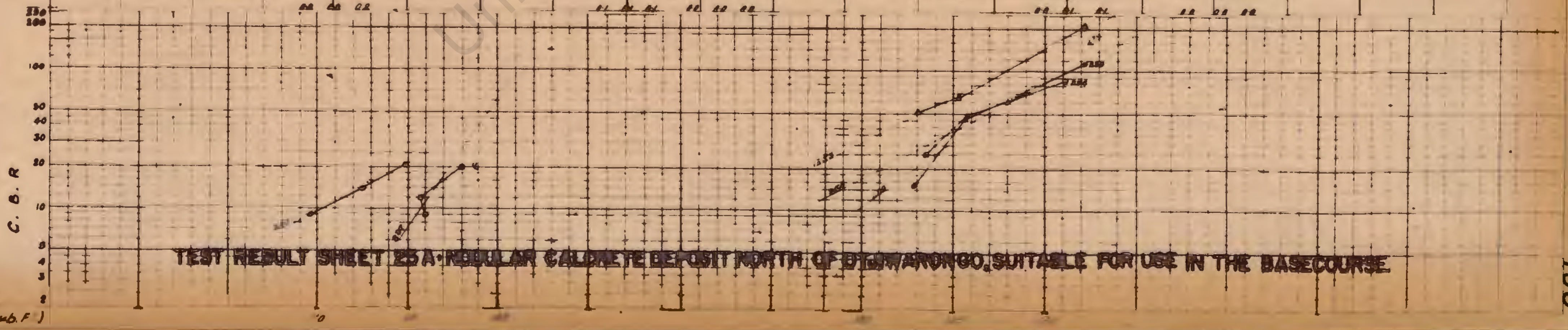
(ii) the plus ¾ inch aggregate is then to be lightly grid rolled to break down any pieces larger than 2" and to obtain a reasonably uniform grading.

(iii, a binder is to be added to the grid-rolled aggregate The ratio of 1 binder to 4 aggregate by weight should give a satisfactory However, this ratio is to be altered if control screen analyses of product of (ii) above indicate the desirability thereof. For the Sukses - Otjiwarongo road material from B.P. 102·8 (or a similar s should be used. For the Otjiwarongo - Otjikango section o from B.P's 6·9 and 11·6 (or a similar binder) should be used.

Visual Description
Stabilized with / Ex mould
Sample Nº IND/C.B.R.
Hole/depth below exist. grd. level
P R A classification (group index)
Screen analysis: - 1½" | - ¾"; 0·185" | - 0·078"; 0·0164" | -0 0029/0 0001"
Soil mortar grading: coarse sand | C fine sand; M fine sand | F fine sand; Silt | Clay
Atterberg Limits: L.L. | P.I.; L. SH
Opt moisture / Density at mod AASHO
Mould moisture content / Density/C.B.R. 95% 90%
Density
C.B.R.
Swell

cont. o

C. B. R Density Diagrams



TEST RESULT SHEET 25A: NODULAR CALCRETE DEPOSIT NORTH OF OTJIWARONGO, SUITABLE FOR USE IN THE BASECOURSE.

BORROW PIT INFORMATION

BORROW PIT Nº 13

Farm Otjiwarongo Townlands Nº18 | Owner : Otjiwarongo Municipality

Chainage . 66·6

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of Base	Min % of mod AASHO Density required	Range of Opt moist content	Approx Quantity yds ³

REMARKS (cont from sheet 2)

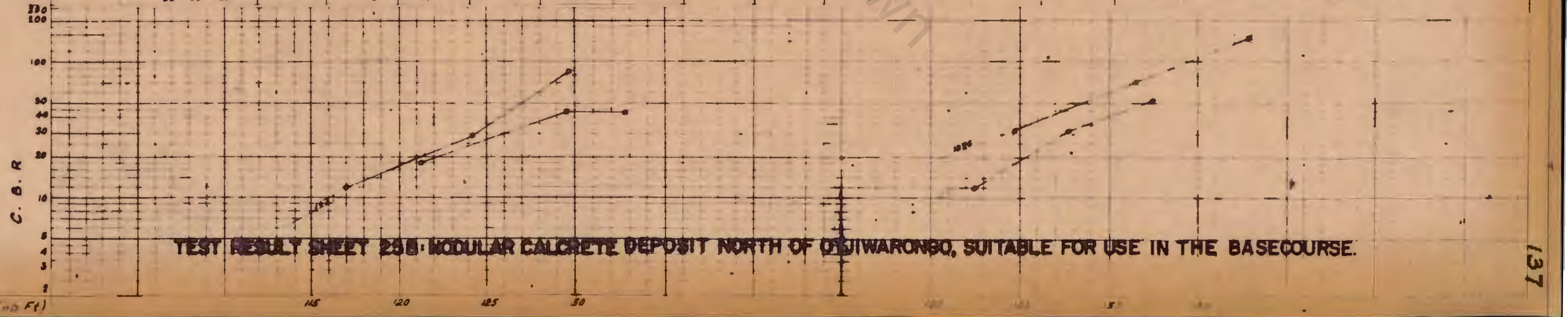
Sheet 3

[illegible] Visual exa[illegible] of [illegible] [illegible]roved grave[illegible] in conjunction with a s[illegible]dy [illegible] the [illegible]t resu'ts ha[illegible] led [illegible] [illegible]s'on tha[illegible] mo[illegible] of the [illegible] require only very light gr[illegible]d[illegible]r[illegible]ng In Fact too much grid-rol[illegible]ng [illegible] resu[illegible] in [illegible]ling [illegible] [illegible] [illegible] the basecourse whether [illegible] [illegible] s[illegible]ized, [illegible] re[illegible]g [illegible]du[illegible] [illegible] [illegible] [illegible] the case [illegible] proposed [illegible] stat[illegible] [illegible]d [illegible]se. [illegible] [illegible] name[illegible] ho[illegible] 25 was the grav[illegible] Found to be real[illegible] coarse [illegible] [illegible] [illegible]eris[illegible] [illegible] [illegible] [illegible] [illegible] int[illegible] kn[illegible] [illegible] [illegible] [illegible]varise[illegible] [illegible] [illegible] [illegible]rd.

cont on sheet 4.

Visual Description		br [illegible]	mod [illegible] calcrete mix [illegible] + [illegible] or sl		calc gravel [illegible] mix gl.	br sdy sl	nod [illegible] pbls +[illegible] sl	[illegible] pbls +[illegible]	[illegible]	[illegible] pbls [illegible]	[illegible]	br [illegible] sl	mod [illegible] pbls [illegible]		calc gravel [illegible] +[illegible]	br[illegible]	l calcrete and [illegible] gravels +[illegible]		gravel + [illegible] under [illegible] [illegible] 3		l [illegible] + [illegible] l [illegible]
Stabilized with/Ex mould				Ex mould										Ex mould				Ex mould		Ex mould	
Sample Nº	IND/CBR	1475	1476 1477	1477	1478	1495 1495a	1496	1497	[illegible]	1521	[illegible]	[illegible]	1524 1525	[illegible]	[illegible]	[illegible]	1499 1500	1500	1855 1856	1856	[illegible]
Hole/depth below exist. grd level		14 0-22	.14 22"-82"	14 22"-82"	14 82"+	15 0-66"	15 66"-94"	15 94"+	16 0-48"	16 48"-76"	[illegible] 76"+	[illegible]	17 46"-92"	[illegible]	17 92"+	18 0-39	18 39"-78"	18 39"-78"	18 39"-78"	18 39 78"	18 78"+
PRA classification (group index)		A2-4	A2-4	A2-4	A1-a	A2-4	A2-6	A2-6	A2-6	A2-6	A2-[illegible]	[illegible]	A2-4	A2 [illegible]	A2-4	A2-4	A2-6	A2-6	A1-a	A1-a	A2-4
Screen analysis	1½" | - 3/4"	100	95 78	100	100 92		99 85	100 94		93 77	[illegible] 93		82 61	[illegible]	100 94		92 8[illegible]	0	95 84	[illegible]	100
	0·185" | - 0·078"	96 94	41 32	65 51	63 43	100 99	37 28	51 40	100 97	47 37	[illegible]	100 96	34 27	59 43	58 37	[illegible]	[illegible] 3	[illegible]	35 25	47 [illegible]	90 84
	0·0164" | -0·0068/0·0081"	76 18/15	27 10/9	40 18/16	19 5/4	88 32/29	24 10/9	35 16/14	85 [illegible] 22	31 14/12	41 13/	85 25/9	24 10/8	25 5/14	27 11/10	66 24/9	[illegible] 4/12	42 13/17	20 6/4	[illegible] 9/7	69 24/20
Soil mortar grading	coarse sand | C fine sand	13 21	16 15	21 12	55 15	11 16	14 14	13 13	14 17	16 17	16 13	13 18	11 16	25 12	26 13	13 18	16 [illegible]	[illegible] 12	20 15	20 14	18 19
	M fine sand | F. fine sand	20 24	15 26	14 21	9 10	21 24	16 24	16 23	23 22	21 13	[illegible] 23	23 26	18 [illegible]	13 20	16 21	[illegible]	16 2[illegible]	15 21	19 32	14 26	19 20
	Silt | Clay	10 6	15 13	15 17	6 4	16 12	22 10	25 10	25 9	17 16	[illegible]	13 7	18 12	13 19	15 11	12 [illegible]	19 4	23 11	7 7	[illegible]	15 9
Atterberg limits	L L L | P.I.	8 p	23 8	22 7	s p	24 10	28 15	26 12	25 [illegible]	27 12	[illegible]	5 [illegible]	25 9	25 11	25 7	2[illegible] 4	[illegible]	25 10	s p	s [illegible]	2[illegible]
	L. SH.	10	50	35	1·5	4·0	6·5	6·5	4·5	6·0	[illegible] 5	[illegible]	5	6·0	[illegible]	[illegible]	4·5	0	<0·5	1·5	4
Opt moisture | Density at mod AASHO			7·7 1316			8·3 1291							7·1 133·8				6·4 132·4		6·0 13[illegible]9		
Mould moisture content | Density/CBR 90% 95%			75 125/37 118 3/13			8·2 1236 1181							7·6 127·8/28 120·1/28				6·6 125·9/28 119·4/8		6·0 3[illegible] [illegible]		
Density			129·6 124·2 117·0			113·5 11/9 108							132·8 129·5 [illegible]12				132·5 127·7 122·5		137·9 1[illegible]·5 124·7		
C B. R			86 20 12			3 2 1							43 44 18				53 32 12		53 71 32		
Swell			00 00 00			0 0· 01							00 00 00				0·1 0·1 0·1		00 00 00		

C. B. R Density Diagrams



TEST RESULT SHEET 25B: NODULAR CALCRETE DEPOSIT NORTH OF OTJIWARONGO, SUITABLE FOR USE IN THE BASECOURSE.

BORROW PIT INFORMATION

BORROW PIT Nº 13

Farm Otjiwarongo Townlands Nº18

Owner Otjiwarongo Municipality

Chainage 65.6

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of Base	Min % of mod AASHO Density required	Range of Opt moist content	Approx. Quantity yds³

REMARKS

[illegible]

A 10 [illegible]

[illegible] A [illegible]

[illegible] o [illegible] graded [illegible] ABSO [illegible] test results [illegible] is [illegible]

Visual Description

Sample Nº IND / C B R

Hole depth below exist. g.l. level

H R A classification (group index)

Sieve analysis: 1½" / 3/4" / 0.25 / 0.078" / 0.0164 / 0.0065/0.002

Soil mortar: Coarse sand / C fine sand / M fine sand / F fine sand / Silt / Clay

Atterberg limits: L L L / P I / L S

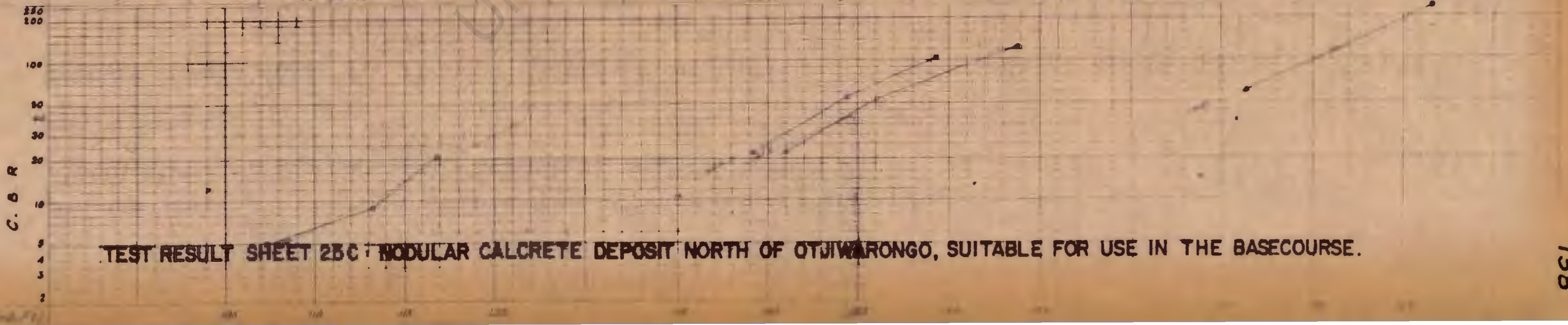
Opt moisture / Density at mod AASHO

Mould moisture content / Density C B R 95% 90%

Density

C B R

Swell



C.B R Density Diagrams

TEST RESULT SHEET 25C : NODULAR CALCRETE DEPOSIT NORTH OF OTJIWARONGO, SUITABLE FOR USE IN THE BASECOURSE.

BORROW PIT INFORMATION

BORROW PIT Nº 1·3

Farm : Otjiwarongo Townlands Nº 18

Owner : Otjiwarongo Municipality

Chainage : 66·6

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of Base	Min % of mod. AASHO Density required	Range of Opt. moist. content	Approx. Quantity yds ³
—				

REMARKS (cont. from sheet 4)

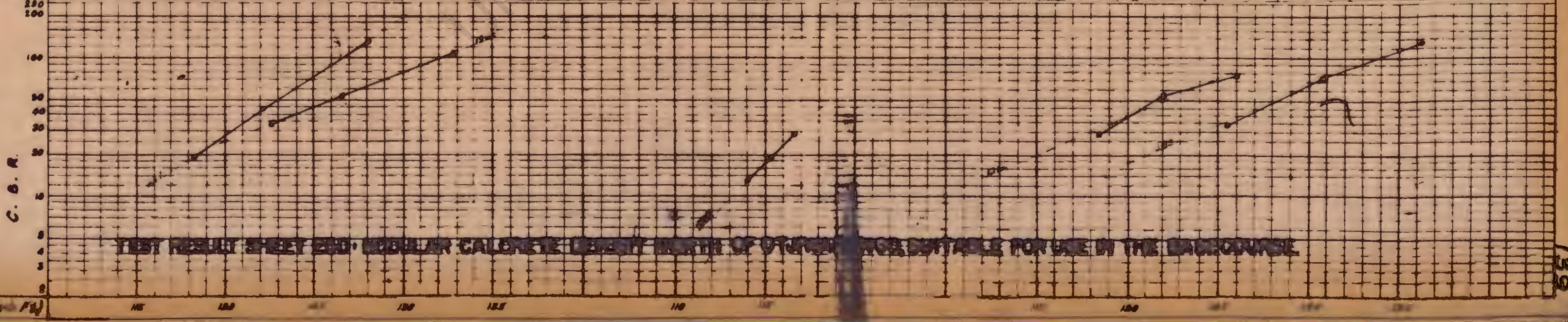
Sheet 5

spoiling the stock piles for their particular approved use. As the borrow pit will not be fully planned it will be advisable not to attempt stock piling the gravel to the full depth of the approved layer.

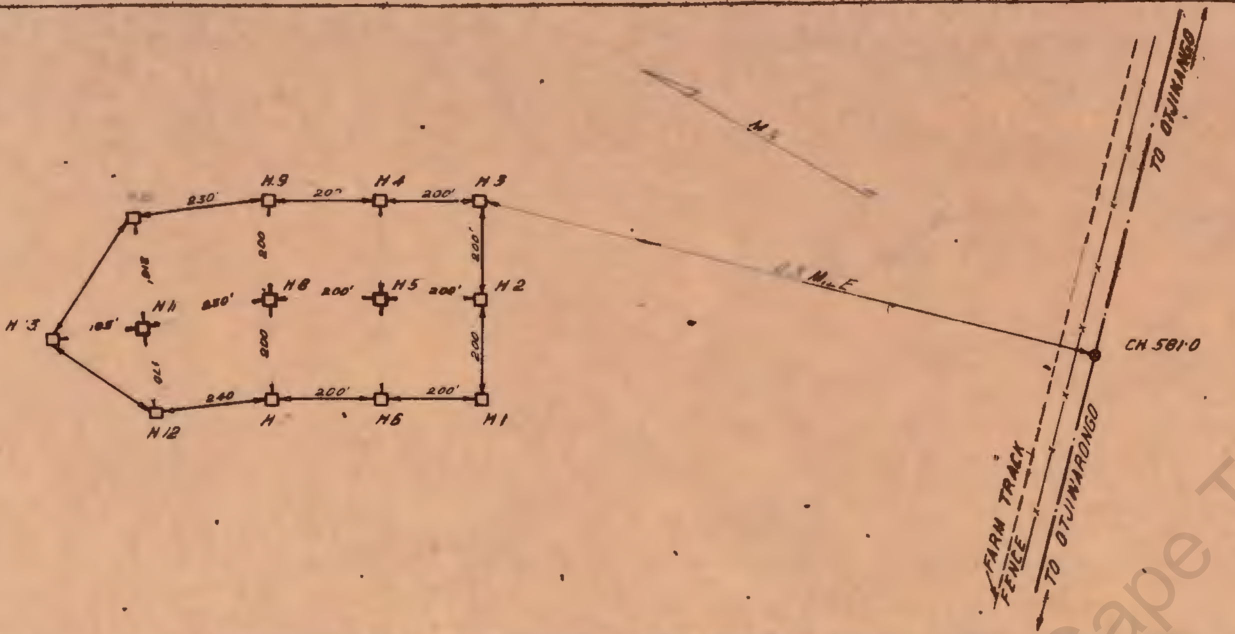
7 Anthills within the approved areas are to be avoided.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Visual Description		[illegible]	[illegible] + L [illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible] sdy sl	calc + qtz + [illegible] + grbe. sdy. sl.		[illegible] sdy sl	calc pbls + grav sdy sl		[illegible] sdy sl [illegible]
Stabilized with / Ex mould				Ex mould					Ex mould							Ex mould			Ex mould	
Sample Nº	IND / C.B.R.	265	266 267	267	268	264	1063	1064 1065	1066	1086	1086 1087	1088	1089	1907	1908 1909	1909	1910	1911 1912	1912	1913
Hole / depth below exist. grd. level		25 0-12"	26 12"-40"	26 12"-40"	27 0-35"	27 35"-72"	29 0-62"	28 12"-62"	28 12"-62"	28 62"+	29 0-16"	30 16"-58"	29 52"+	30 0-40"	30 40"-80"	30 40"-80"	31 0-24"	31 24"-46"	31 24"-46"	31 46"+
P R A classification (group index)		A2-4	A1-6	A1-6	A2-4	A1-6	A2-4	A1-a	A1-a	A1-a	A2-4	A1-b	A2-4	A2-4	A2-4	A2-4	A2-4	A1-6	A1-b	A2-4
Screen analysis	– 1½" / – 3/4"	100	93 82	100	100	97 86	100	85 82	100	69 51	100	87 75	91 86		94 70	100	100	95 82	100	80 70
	– 0·185" / – 0·078"	99 30	44 36	62 51	98 96	53 45	99 97	46 34	59 42	30 20	98 96	49 40	75 69	100 98	49 30	54 42	99 98	52 45	69 60	80 58
	– 0·0164" / – 0·0058/0·0021"	38 23/14	22 9/6	43 16/14	91 25/17	39 13/10	92 21/13	26 8/5	27 11/9	12 4/3	80 20/11	35 8/5	51 13/9	80 20/13	31 9/7	34 13/8	91 17/11	39 10/7	52 15/11	43 9/7
Soil mortar grading	Coarse sand / C fine sand	5 14	11 15	16 13	5 18	13 12	5 13	24 11	36 9	49 13	8 13	17 17	26 21	9 15	19 15	13 13	8 10	13 17	13 14	26 21
	M. fine sand / F. fine sand	39 37	26 31	28 24	20 30	21 31	31 30	21 27	13 21	18 17	31 38	26 27	20 21	38 33	22 25	15 27	34 30	27 28	26 28	28 19
	Silt / Clay	11 3	12 5	13 14	8 5	16 7	6 5	10 7	11 10	10 7	8 4	17 4	9 3	7 6	11 7	10 11	8 7	10 5	9 10	7 5
Atterberg Limits	L.L. / P.I.	6 p	25 6	20 3	20 2	21 4	8 p	20 5	20 3	20 4	6 p	20 3	8 p	5 p	21 8	19 7	5 p	5 p	5 p	20 7
	L. SH.	1·0	4·0	2·0	1·5	3·0	<0·5	3·0	2·0	2·5	<0·5	2·6	1·0	0·5	3·5	3·5	<0·5	<0·5	1·0	2·0
Opt moisture / Density at mod. AASHO			7·4 120·9					6·6 133·9			11·9 115·6				6·7 135·2			10·3 125·9		
Mould moisture content / Density / C.B.R. 95% 90%			8·0 122·1/103 117·8/10					7·4 [illegible]			11·1 108·0 106·8				6·5 133·5/53 128·7/26			10·3 118 ?/32 118·6/16		
Density			120·1 122·1 110·3					132·9 129·6 122·6			116·6 113·3 [illegible]				136·2 129·9 125·4			126·0 122·6 110·4		
C.B.R.			137 44 19					112 53 30			29 12 13				130 75 30			78 55 28		
Swell			0·0 0·0 0·1					0·0 0·0 0·0			0·0 0·0 0·0				0·0 0·0 0·0			0·0 0·0 0·0		

C. B. R. Density Diagrams



TEST RESULT SHEET 2.3.0: NODULAR CALCRETE [illegible] NORTH OF OTJIWARONGO, SUITABLE FOR USE IN THE BASECOURSE



BORROW PIT INFORMATION

BORROW PIT. Nº 11·0

Farm Drukwerk Nº 13

Owner : P. Genis

Chainage. 581 0

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of base	Min % of mod. AASHO Density required	Range of Opt moist content	Approx Quantity yds ³
Overburden Hole 2 + similar	10"–16"	95	± 7·8 %	48,000
Hole 8 + similar	Below 16"	90	± 8·7 %	
Screen nat gravel + binder	Base	98	5·0%–6·0%	23,000

REMARKS

Sheet 1

1 The overburden similar to that represented by hole 8 is of poor quality and should be kept below 16 inches from the top of the basecourse. Sand similar to that from hole 2 may be used in the 10"–16" layer compacted to a minimum relative density of 95 %.

2 The tested layer of gravel is approved for use in the basecourse mechanically processed as follows.

(i) Screen the gravel through a 3/16th inch mesh to remove the fines

(ii) The aggregate retained on the 3/16th inch mesh is then to be sufficiently grid rolled on the road to break down any pieces larger than 2" and to obtain a reasonably consistent grading

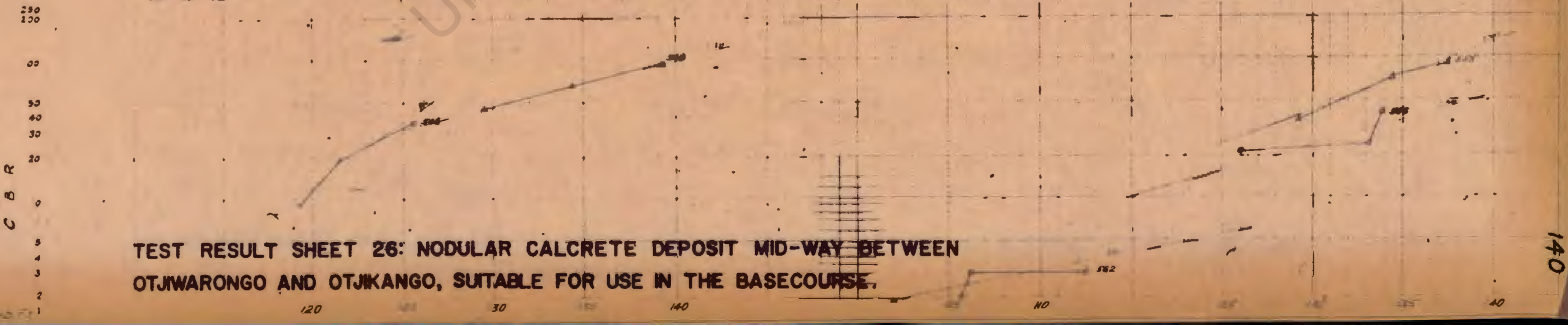
(iii) A binder is to be added to the grid rolled aggregate. The ratio of 1 bind

(cont on sheet 2.

Visual Description of	calcr+gly pbls+l br sl	rd br sdy si	calcr+gly pbls+br sl		calcr+gly pbls+br sl		mdl calcr+gly+br sl	rd br sl	mdl calcr pbls+l br sl	rd br sl	gly+calcr pbls+br sl			calcr+gly pbls+br sl	calcr+gly pbls+rd br sl	rd br sl	calcr+gly pbls+l br sl	calcr+gly pbls+br sl	calcr+gly pbls+l br sl
Stabilized with ex mould				Ex mould	molasses binder 4:1 ratio	Ex mould						Ex mould	molasses binder 4:1 ratio						
Sample No	544	545 546	547	548	548 548	548 549	550	551	552	553	554	556	555 555	557	560	561 562	563	564	565
Hole, depth below exist grd level	1 51"–75"	2 0"–40"	2 40"–65"	2 40"–65"	2 40"–65"	2 40"–65"	3 45"–65"	4 0"–45"	4 45"–69"	5 0"–48"	5 48"–72"	5 48"–72"	5 48"–72"	8 55"–75"	7 55"–75"	9 0"–63"	8 63"–80"	9 55"–75"	10 50"–74"
PR classification (group index)	A2-6	A2-4	A2-4	A2-4	A2-4	A2-4	A1-b	A2-4	A2-4	A2-4	A2-6	A2-6	A2-6	A2-6	A2-6	A2-4	A2-4	A2-4	A1-a
Sieve 1½ | 3/4	84 59		79 62	100	100	100	86 65		86 69		88 82	100	100	84 75	77 59	100	68 50	77 61	80 51
0 85 | 0 078	37 28	100 99	35 25	63 48	26 22	35 26	48 45	100 98	47 38	100 98	55 29	74 47	28 19	58 38	45 33	97 88	43 29	38 25	31 21
analysis 0 0 54 | 0 0029 0 002	25 10/8	83 28/15	21 7/5	35 14/12	17 5/4	18 7/4	37 13/9	80 28/22	31 12/9	83 31/24	25 11/9	40 18/15	14 4/3	33 13/10	28 11/9	74 28/22	24 9/7	21 9/7	16 6/5
Soil coarse sand | C fine sand	14 13	16 17	16 16	19 16	25 16	31 12	18 14	18 14	18 12	15 15	14 12	15 12	27 13	13 13	15 13	16 13	17 15	16 11	24 13
mortar M fine sand | F fine sand	16 30	20 31	19 28	17 24	16 26	13 24	16 32	17 28	12 35	29	12 35	15 25	16 30	10 31	16 29	14 32	16 25	12 33	15 26
grading Silt | Clay	19 8	11 5	13 8	11 13	7 12	9 9	15 5	14 8	17 8	16 8	21 8	16 15	9 5	20 5	20 7	21 4	[illegible] 7	10 9	19 [illegible]
Atterberg LL | PI	28 11	S.P	20 8	22 9	S.P	15 1	20 6	21 7	25 [illegible]	23 10	30 15	31 15	S.P	27 11	27 10	26 10	[illegible]	24 9	26 6
limits L Sh	6·5	0·5	4·0	4·0	0·5	0·5	4·0	4·0	5·0	5·0	7·5	7·5	1·0	6·6	7·0	5·5	[illegible]	8·8	4·0
Opt moisture Density at mod AASHO		7·8 131·0			6·0 139·1	5·4 139·6						7·0 133·0	5·0 130·5			6·7 124·3			
Field moisture content Density-CBR 95% 98%		7·9 124·5, 33 7·9, 8			6·0 132·1/58 125·2/32	5·4 132·6 125·6						7·6 127·3/18 120·3/10	5·1 132·5/55 125·6/26			6·6 118·1/5 111·8/3·5			
Density		125·5 121·5 121			139·1 134·4 129·6	139·6 136·7 125·7						133·0 [illegible] 128·0	137·5 130·5 128·2			124 125·1 125·7			
C B R		35 19 5			94 64 45	19 22 32						41 25 21	90 74 56			3 3 2			
Swell		0·2 0·2 0·2			0·0 0·0 0·0	0·0 0·0 0·0						0·1 0·1 0·1	0·1 0·1 0·1			0·3 0·2 0·3			

C B R Density

Diagrams



TEST RESULT SHEET 26: NODULAR CALCRETE DEPOSIT MID-WAY BETWEEN OTJIWARONGO AND OTJIKANGO, SUITABLE FOR USE IN THE BASECOURSE.

Dry Density lbs/cu ft

BORROW PIT INFORMATION

BORROW PIT Nº 11·0

Farm : Druhwerk Nº 13

Owner : P Gems

Chainage : 581·0

COMPACTION REQUIREMENTS and QUANTIT

Material	Horizon measured from top of base	Min % of mod. AASHO Density required	Range of Opt moist content	Approx. Quantity yds ³
Overburden Hole 2 + similar	10"–16"	95	± 7 8 %	48,000
Hole 8 + similar	Below 16"	90	± 8·7 %	
Screen mat. gravel + binder	Base	98	50%–60%	23,000

REMARKS (cont. from sheet 1

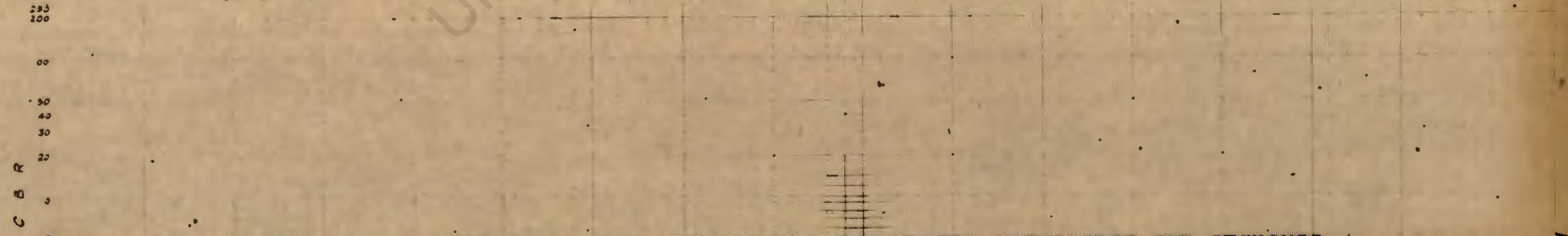
Sheet 2

to 4 aggregate by weight should give a satisfactory mix. However, this ratio is to be altered if control screen analyses of the grid-rolled aggregate indicate the desirability thereof. A suitable binder can be obtained from B.P. № 6.
a) The grid-rolled aggregate and binder are to be thoroughly mixed while dry so as to ensure a uniform mix

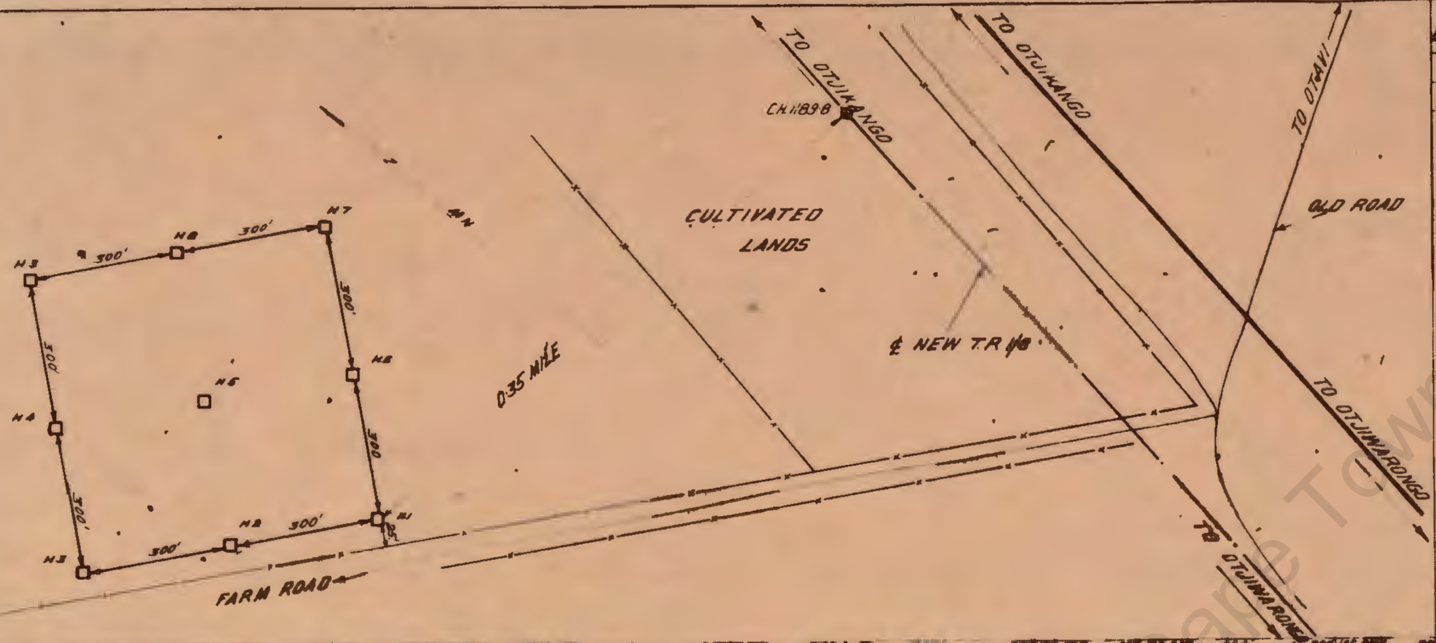
3. Immediately underlying the tested and approved layer of gravel similar material occurs, but in places this may be replaced by either calcrete bank or boulders. A certain amount of expansion with depth should, however, be possible

Visual Description		[illegible]	[illegible]		[illegible]	[illegible]	BINDER
Stabilized with				Ex mould			
Sample Nº	VD CBR	650	651	652	653	654	566
Hole/Depth below exist grd level		H 0"-42"	H 42"-65"	H 42"-66"	12 45"-68"	13 48"-78"	
PR classification (group index)		A2-4	A2-6	A2-6	A2-4	A2-4	A2-4
Screen analysis	1½ | ¾		66 54	100	68 58	81 40	
	0 83 | 0 078	100 87	39 28	60 43	43 29	32 28	100 97
	0 0 64 | 0 0029 0 002	81 31/25	23 19/7	34 16/13	23 9/7	24 10/8	71 20/14
Soil mortar grading	coarse sand | C fine sand	16 14	18 12	21 12	21 13	14 12	27 13
	M fine sand | F fine sand	16 28	15 29	13 25	15 27	15 30	11 35
	Silt | Clay	18 8	19 7	17 12	18 8	21 8	18 4
Atterberg limits	LL | P	23 9	27 12	20 12	24 9	20 10	6 p
	L S	4·5	6·5	6·5	5·0	6·0	40·5
Opt moisture Density at mod AASHO				7·0 130·2			
Mould moisture content Density CBR 95% 90%				7·0 131 3 124 4			
Density				130·2 130·5 127·2			
C B R				29 36 26			
Swell				0·1 0·1			

C B R Density Diagrams



TEST RESULT SHEET 26A: NODULAR CALCRETE DEPOSIT MID-WAY BETWEEN OTJIWARONGO AND OTJIKANGO, SUITABLE FOR USE IN THE BASECOURSE.



BORROW PIT INFORMATION

BORROW PIT Nº 22.6

Farm Brunnental Nº 7

Owner : F.J. Mouton

Chainage : 1189.8

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of base	Min. % of mod. AASHO Density required	Range of Opt. moist. content	Approx. Quantity yds ³
Overburden	10"-16" except hole 4 and similar material	95	8.4%-9.7%	36,000
Screen net gravel Gravel+binder	Base	98	5.9%-7.8%	42,200

REMARKS

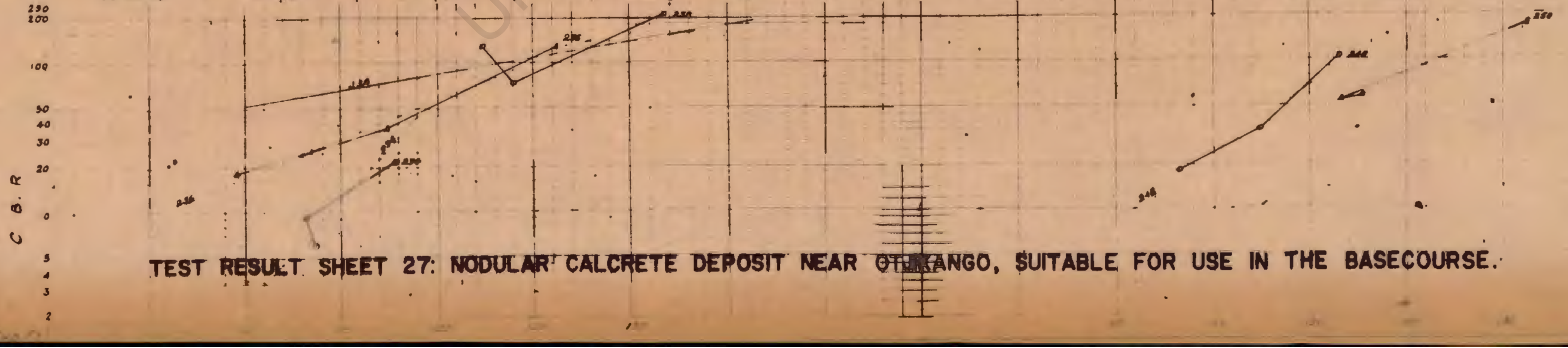
Sheet 1

1. The overburden from hole 4 and similarly plastic soil is NOT approved for use and must be removed from the borrow pit area. The overburden as represented by the remaining eight holes is approved for use in the 10"-16" layer compacted to a minimum relative density of 95%
2. The tested layer of gravel is approved for use in the basecourse mechanically processed as follows:
   (i) Screen the gravel through a 3/16th inch mesh to remove the fines.
   (ii) The aggregate retained on the 3/16th inch mesh is then to be sufficient grid-rolled on the road to break down any pieces larger than 2" and to obtain a reasonably consistent grading
   iii) A binder is to be added to the grid-rolled aggregate. The ratio of 1 bi

(cont. on sheet 2.

Visual Description		br sl	nod lst pble + lt gr br cly sl	nod lst pble + lt gry cly sl			nod lst pble + lt gr br sl	br sl	nod lst pble + lt cly sl	nod lst pble + lt cly sl	br sl	nod lst pble + lt gr br cly sl	nod lst pble + lt cl sl	br sl	nod lst pble + lt gr br cly sl				nod lst pble + gr br cly sl	br sl	nod lst pble + lt gr br sl
Stabilized with/Ex mould				Ex mould	3/16" material + binder 4:1 ratio	Ex mould										Ex mould	3/16" material + binder 4:1 ratio	Ex mould			
Sample Nº	IND/CBR	233 234	235	236 236	237	238 238	239	240	241	242	243	244	245	246	247	248 248	249	250 250	251	252	253
Hole/depth below exist grd level		1 0"-34"	1 34"-74"	1 34"-74"	1		1 74"+	2 0"-35"	2 35"-85"	2 85"+	3 0"-52"	3 52"-76"	3 76"+	4 0"-57"	4 57"-81"	4 57"-81"	4 57"-81"	4 57"-81"	4 81"+	5 0"-34"	5 34"-70"
P R A classification (group index)		A2-4	A2-7	A2-7			A2-7	A2-4	A2-7	A2-7	A2-4	A2-7	A2-7	A2-6	A2-7	A2-7	A2-7	A2-7	A2-7	A2-4	A2-6
screen analysis	1½" / 3/4		89 69	100	100	100	84 69		74 53	96 81		71 55	97 81		93 72	100	100	100	75 61		76 63
	0.0 83" / 0.078	100	41 34	46 38	29 29	42 37	43 36	100 99	34 23	52 42	100	36 25	47 39	100 [illegible]	35 32	53 44	26 25	33 29	35 30	100	39 33
	0.0164" / -0.0029 0.0021	85 26/17	30 10/9	31 13/11	22 7/4	27 9/6	30 18/9	85 26/15	26 10/9	34 15/12	87 30/19	26 8/8	33 14/11	[illegible]	28 12/9	37 17/15	19 5/5	20 6/4	26 11/10	86 26/17	29 11/10
Soil mortar grading	coarse sand / C fine sand	15 11	12 11	18 9	24 14	27 13	17 9	14 15	10 9	19 9	13 11	18 10	18 10	13 11	12 11	16 10	25 14	20 12	12 11	14 15	12 12
	M. fine sand / F fine sand	22 35	19 33	14 32	19 30	16 27	15 34	22 35	16 32	15 33	21 36	20 35	17 36	18 34	20 32	14 30	17 31	16 30	22 31	21 35	23 30
	Silt / Clay	12 5	-25-	-27-	9 4	12 5	-25-	10 6	-31-	-28-	11 8	-33-	-37-	[illegible]	-25-	18 12	9 4	11 3	-24-	13 4	-23-
Atterberg limits	L.L. / P.I.	19 4	41 18	30 16	S P	S P	42 14	19 2	53 31	63 28	25 9	49 15	46 16	31 [illegible]	50 23	59 25	S P	19 2	70 34	20 6	40 15
	L SH	15	8.5	7.0	4.5	4.6	8.5	1.5	11.5	13.0	3.5	10	10	[illegible]	12.0	12.5	1.0	1.5	14	2.0	9.0
Opt moisture / Density at mod AASHO		9.7 125.1		7.7 128.1		7.0 131.0										10.6 123.0		7.3 131.6			
Mould moisture content / Density CBR 95% 90%		9.6 118.8/40 112.6/6		7.7 119.8/55 118.6/26		7.0 128.2/109 118.6/60										10.5 114.0/19 110.7/9		7.3 125.8 120.4			
Density		117.5 113.1 115.6		126.1 117.8 108.6		131.0 124.0 122.3										121.5 117.5 113.2		131.4 126.6 122.7			
C B R		22 8 6		131 37 10		209 73 120										105 35 10		176 65 59			
Swell		0.0 0.0 0.0		0.0 0.0 0.0		0.0 0.0 0.0										0.0 0.0 0.0		0.0 0.0 0.0			

C.B.R Density Diagrams



TEST RESULT SHEET 27: NODULAR CALCRETE DEPOSIT NEAR OTJIKANGO, SUITABLE FOR USE IN THE BASECOURSE.

BORROW PIT INFORMATION | BORROW PIT Nº 226

Farm Brunnental Nº 7

Owner : F.J. Mouton .
Chainage . 1189 B

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of base	Min % of mod AASHO Density required	Range of Opt moist content	Approx Quantity yds 3
Overburden	10"-16" except hole 4 and similar material	95	8·4%-9·7%	36,000
Screen not gravel Gravel+binder	Base	98	6·9%-7·8%	42,200

REMARKS (contd from sheet 1)

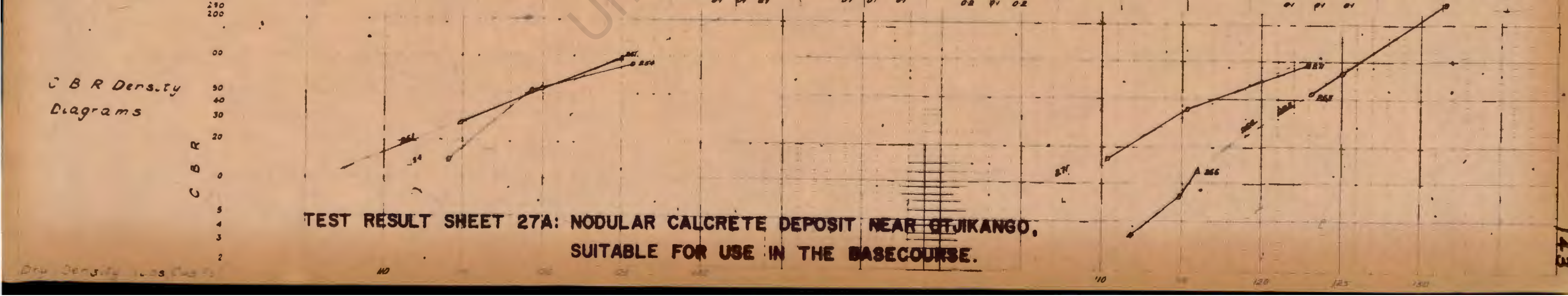
Sheet 2

to 4 aggregate by weight should give a satisfactory mix. However, this ratio is to altered if control screen analyses of the grid-rolled aggregate. indicate the desirability thereof A suitable binder can be obtained from either B.P 20·4 A or B.P 21·0 B

(iv) The grid-rolled aggregate and binder are to be thoroughly mixed while dry so to ensure a uniform mix

3 The material immediately underlying the tested and approved layer of grave is similar in quality and a certain amount of expansion with depth should be possible

Visual Description																			Binder B.P 20·4A
Stabilized with Ex mould	Ex mould							Ex mould		Ex mould							Ex mould		
Sample No / No CBR	254 254	255	256	257	258	259	260	261 261	262	263 263	264	265 266	267	268	269	270	271 271	272	275
Hole/ depth below exist gra level	5 34"-70"	5 70"+	6 0"-34"	6 34"-94"	6 94"+	7 0"-34"	7 34"-80"	7 30"-80"	7 34"-80"	7 34"-80"	7 80"+	8 0"-32"	8 32"-50"	8 50"+	9 0"-32"	9 32"-60"	9 32"-80"	9 80"+	4 0"-116"
P R A classification 'group index'	A2-6	A2-6	A2-4	A2-6	A2-4	A2-4	A2-6	A2-6	A2-6	A2-6	A2-6	A2-4	A2-6	A2-6	A2-4	A2-7	A2-7	A2-7	
Screen analysis 1½ | 3/4	100	71 43		79 61	88 68		87 58	100	100	100	88 67		88 48	65 50		82 68	100	88 67	
0 .85 | 0 .078	54 47	23 18	100	33 27	43 35	100	33 26	46 38	31 29	42 36	68 55	100	23 19	30 26	100 86	38 31	50 40	34 30	100
0 0 54 | 0 .0029 0 002	39 13/10	16 6/4	88 27/17	23 8/7	28 9/6	88 24/15	20 7/5	31 13/10	22 7/4	26 8/5	40 15/10	86 28/17	17 6/4	23 9/6	84 26/17	27 11/8	38 14/12	23 10/8	74 20/8
Soil mortar grading: Coarse sand | C fine sand	16 12	16 11	12 12	15 13	20 12	12 18	23 13	19 10	24 13	25 13	27 15	14 13	11 15	12 15	15 11	13 10	20 10	16 11	26 14
M fine sand | F fine sand	17 34	17 33	19 39	23 30	20 30	26 28	22 24	15 29	16 33	16 28	30 23	21 34	26 27	27 28	10 39	15 36	12 29	20 20	19 30
Silt | Clay	21	17 6	14 4	19 -	13	-16-	-18-	27 -	11 3	11 4	-17-	15 3	-21-	-19-	13 4	-26-	-20-	-17-	7 4
Atterberg limits LL | P	36 12	35 11	19 5	36 11	32 7	21 6	34 11	34 12	9 P	5 P	33 11	22 5	30 14	34 11	22 5	46 18	60 19	60 26	5 P
L SH	7·0	7·0	1·5	6·5	4·0	2·0	6·5	5·5	-2·5	0·5	6·0	2·5	7·0	6·0	2·0	9·5	11·5	12·5	<·05
Opt moisture Density at mod AASHO	9·4 125·7							8·5 126·0		6·9 131·0		9·4 124·7					9·1 122·0		
Moulding moisture content Density CBR 95% 93%	9·1 119·4/83 115·1/16							8·9 119·5/52 113·2/23		6·5 125·2/100 118·6/23		8·9 118·5/25 112·2/14					8·1 115·6/45 110·6/19		
Density	125·7 118·4 114·0							125·0 120·0 114·0		131·6 125·0 123·1		116·0 114·9 111·0					122·9 115·3 110·3		
C B R	88 52 14							94 53 28		290 122 57		13 9 4					95 42 16		
Swell	0·0 0·1 0·1							0·1 0·1 0·1		0·1 0·1 0·1		0·2 0·1 0·2					0·1 0·1 0·1		



TEST RESULT SHEET 27A: NODULAR CALCRETE DEPOSIT NEAR OTJIKANGO, SUITABLE FOR USE IN THE BASECOURSE.

BORROW PIT INFORMATION

BORROW PIT Nº 21

Farm Schwerborn Nº 6

Owner H.W.F Goedecke

Chainage. 1112·0

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of base	Min % of mod. AASHO Density required	Range of Opt moist content	Approx. Quant. yds ³
Natural & screened net gravel mixed in equal parts	Base	98	50% 6·9%	20,000

REMARKS

Sheet 1.

1 Remove all overburden from the approved areas.

2. Three typical areas (A, B & C) in the deposit have been tested. Hole 11 has been excluded from the demarcated area C, due to the depth of sand overburden and the fineness of the gravel. The tested layer of gravel in the marked areas is approved for use in the basecourse mechanically processed as follows:

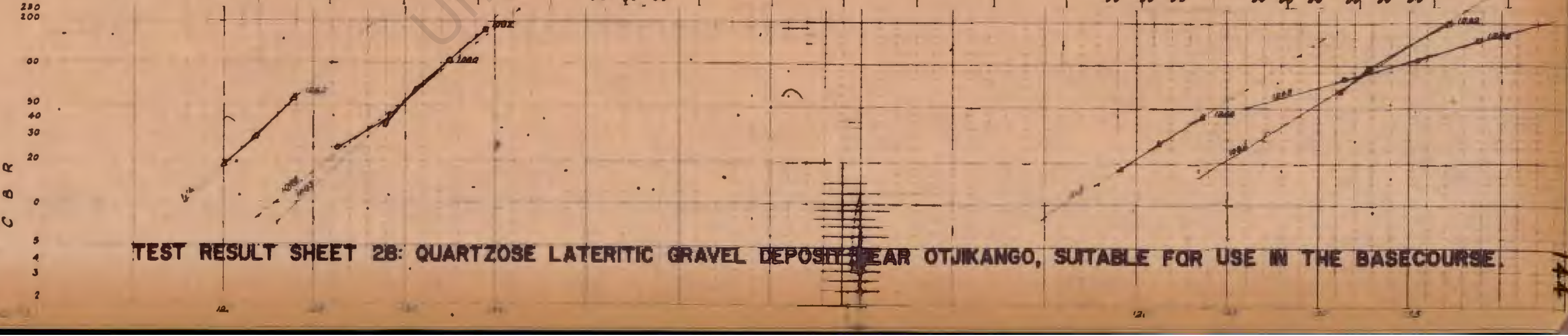
(i) Screen 50% of the gravel to be used through a ½ inch mesh to remove the fines.

(ii) Thoroughly mix on the road the screened out aggregate with the natural gravel in the ratio 1:1.

(cont on sheet 2)

Visual Description	qtz. lat. [illegible] comb. qtz. pbls + l. sdyal	sec. grte qtz. feldsp. pbls + l. sdyal	sec. comb. qtz. pbls. + r. br.	[illegible] sdy. al.	sec. comb. qtz. feldsp. pbls + br. sl	[illegible] sdy. al	[illegible] lim qtz. pbls + [illegible]	[illegible]	qtz. feldsp.	sec. comb. qtz. pbls + l. br. sdyal	sec. grte lat. comb. qtz. pbls lats + r. br. sdyal	lat. comb. qtz. [illegible] pbls + r. br. sdyal	qtz. feldspar. [illegible] r. br. sdyal	qtz. feldspar. [illegible]	lat. comb. qtz. + qtz. pbls. + l. sdy. sl.	[illegible]	l. br. sdy. + lat. comb. qtz. [illegible]	[illegible] sdy. al.	[illegible] comb. qtz. pbls + br. sdyal.	sec. grte + qtz. + lat. pbls + r. br. sdyal
Stabilized with Ex mould				Ex mould				Ex mould							Ex mould				
Sample Nº | NO CBR	1085	1086	1078	1080 1089	1081	1081 1262	1082	1083 1083	1059	1037	1029	1030	1031	1081	1082 1092	1088	1065 1066	1036 1268	1087
Hole/Depth below exist grd level	1 84"-96"	1 96"+	2 00"-66"	2 00"-66"	2 66"+	3 0-77"	3 77"-100"	3 77"-100"	3 100"+	4 98"-110"	4 110"+	5 84"-96"	5 96"+	6 98"-100"	6 96"-100"	6 100"+	7 0"-72"	7 72"-84"	7 84"+
PRA classification (group index)	A1-0	A1-6	A1-0	A1-0	A2-4	A2-4	A1-0	A1-0	A1-3	A1-3	A1-6	A1-0	A1-6	A1-0	A1-0	A1-6	A2-4	A1-0	A1-0
Screen analysis 1½ | 3/4	91 82	92 87	60 57	100	48 34		94 93	100	87 80	71 64	97 97	88 70	91 74	86 76	100	100 90	100	96 76	100 98
0 83 | 0 078	44 34	63 56	35 24	61 41	15 8	100 93	61 40	77 62	62 46	44 39	85 72	40 29	51 34	46 35	65 47	70 61	99 90	35 30	47 33
0 0 6A | 0 0028, 0 002	24 5/4	39 7/5	16 4/3	24 7/5	4 12/1	74 18/13	30 14/5	35 10/9	28 7/5	29 6/4	32 9/12	21 8/5	25 8/5	26 6/4	29 7/5	30 8/6	77 20/13	22 6/5	20 20
Soil mortar grading: coarse sand | C fine sand	30 25	30 22	30 21	42 10	50 11	25 15	30 15	39 15	39 17	26 17	55 15	29 19	25 26	30 18	30 17	45 [illegible]	21 17	25 10	20 20
fine sand | F fine sand	17 20	17 22	14 17	12 14	8 15	19 20	14 22	18 10	13 20	19 20	9 12	18 26	15 21	17 22	15 20	15 10	10 29	10 25	17 24
Silt | Clay	5 5	4 5	10 4	7 7	7 6	7 6	6 5	8 6	7 4	6 4	5 6	5 4	5 5	6 6	6 4	6 4	8 8	8 0	5 10
Atterberg limits L L L | P.I.	n.p.	n.p.	n.p.	19 3	22 7	5 p	n.p.	9 p.	n.p.	5 p.	24 5	n.p.	n.p.	n.p.	n.p.	n.p.	6 p.	8 p	10 8
L SH.	0·5	0	<0·5	1·5	3·0	0·5	<0·5	1·0	<0·5	<0·5	3·5	0	0	<0·5	<0·5	<0·5	0·5	0·5	1·0
Opt moisture | Density at mod AASHO				5·3 135·2		6·9 128·5		5·8 124·9							6·9 137·1		7·4 127·7	6·8 130·8	
Mould moisture content | Density/CBR 95% 90%				5·9 128·4/40 12·7/7·5		6·9 122·1/53 115·7/6		5·9 128 2/32 121·4/5							7·0 130·2/58 123·4/15		8·0 131·3/20 [illegible]	6·6 137·3/82 134·2/45	
Density				132·5 129·2 126·3		123·9 121·8 120·0		134·5 130·0 129·0							137·1 133·6 131·2		123·7 [illegible] [illegible]	[illegible] 135·5 131·4	
C B R				105 43 25		58 30 19		176 64 37							200 57 66		45 20 10	157 100 82	
Swell				-0·1 -0·1 0·0		0·0 0·0 0·0		0·0 0·0 0·0							0·0 0·0 0·0		0·0 0·0 0·0	0·0 0·0 0·0	

C B R Density Diagrams



TEST RESULT SHEET 28: QUARTZOSE LATERITIC GRAVEL DEPOSIT NEAR OTJIKANGO, SUITABLE FOR USE IN THE BASECOURSE.

BORROW PIT INFORMATION

BORROW PIT. Nº 21·1

Farm Schwerborn Nº 6

Owner : H.W.F. Goedecke

Chainage : 1112·0

COMPACTION REQUIREMENTS and QUANTIT

Material	Horizon measured from top of base	Min % of mod. AASHO Density required	Range of Opt. moist. content	Approx. Quanti yds 3
Natural & screened not gravel mixed in equal parts	Base	98	5·0% – 6·9%	20,000

REMARKS (cont from sheet 1.)

Sheet 2.

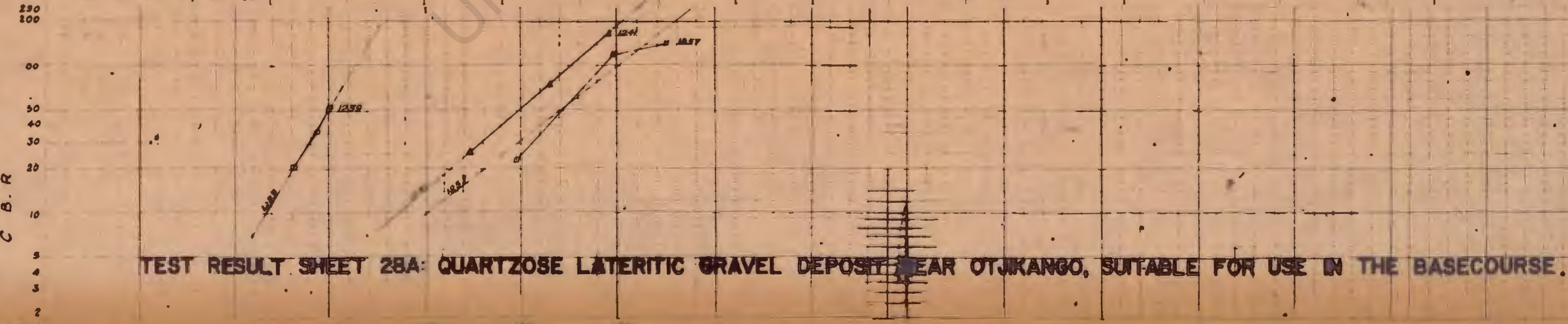
(iii) The aggregate tends to break down quite easily so it is unlikely that grid-rolling will be necessary.

(iv) Add water to bring the mixture to Optimum Moisture Content and com

3. In certain places immediately underlying the tested and approved lay of gravel, weathered granite is encountered which tends to be more finely graded. Such finely graded gravel must be avoided. Control testing should aim at ensuring a satisfactory grading.

Visual Description			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Stabilized with Ex mould														Ex mould			
Sample Nº		ND CBR	1238 1239	1240 1241	[illegible]	[illegible]	1246	1247	1248	1249	1250	1255	1256	1257 1257	1258	1259	1260
Hole/depth below exist grd level			6 0"-69"	6 69"-92"	6 92"-105"	9 0"-94"	9 94"-105"	9 105"-108"	10 108"-120"	10 120"-150"	11 108"-116"	11 116"-123"	12 98"-116"	12 98"-116"	12 116"+	13 81"-90"	13 90"-100"
PRA classification (group index)			A2-4	A1-a	A1-a	A2-4	A1-a	A1-b	A1-a	A1-b	A1-b	A1-b	A1-a	A1-a	A1-b	A1-b	A1-b
Screen analysis	1½	3/4		93 76	75 49		79 56	100	95 65	100	100 90	89 87	84 73	100	100 96	97 90	100 96
	0·185	0·078	100 99	42 29	25 16	100 99	35 27	97 75	53 43	98 81	79 61	77 65	35 25	58 42	62 45	51 42	74 53
	0·0164	0·0029, 0·0021	74 15/13	20 5/3	18 3/2	74 15/10	19 4/2	42 3/5	25 6/4	37 9/7	39 9/6	30 9/7	16 5/3	29 8/6	29 7/5	31 8/6	30 9/7
Soil mortar grading	coarse sand	C fine sand	25 16	31 19	44 16	25 16	30 20	45 19	42 16	54 14	36 16	54 14	31 20	31 10	36 15	26 15	43 15
	M fine sand	F fine sand	21 20	16 21	12 15	20 26	18 23	13 16	14 18	11 13	15 23	9 13	14 22	15 23	15 25	17 27	11 10
	Silt	Clay	5 5	6 5	7 4	7 3	6 3	4 4	6 4	4 4	6 4	6 4	7 6	7 6	6 4	10 5	7 6
Atterberg Limits	LL	PI.	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.	n.p.
		L SH.	0	<0·5	<0·5	<0·5	<0·5	<0·5	<0·5	<0·5	0·5	<0·5	[illegible]	<0·5	0·5	<0·5	[illegible]
Opt moisture	Density at mod AASHO		7·6 120·4	5·4 135·7										5·0 140·3			
Mould moisture content	Density, CBR	95% 90%	7·7 114·4 108·4	5·5 128·9/40 122·1/7										4·5 133·3/65 125·3/13			
Density			128·5 113·3 108·1	134·6 110·5 127·4										137·5 134·9 128·8			
C B R			52 38 21	163 74 26										141 110 82			
Swell			0·0 0·0 0·0	0·0 0·0 0·0										0·0 0·0 0·0			

C.B.R Density Diagrams



TEST RESULT SHEET 28A: QUARTZOSE LATERITIC GRAVEL DEPOSIT NEAR OTJIKANGO, SUITABLE FOR USE IN THE BASECOURSE.

BORROW PIT INFORMATION BORROW PIT Nº 69

Farm NEVADA NO 15
Owner M PENDERIS
Chainage 362 0

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of base	Min % of mod AASHO Density required	Range of Opt moist content	Approx Quantity yds ³
Overburden	0 - 6 Binder for Base ex BP 3	90%	5 0% - 6 9%	57,300
Gravel	4 - 0	98%	5 4% - 7 3%	47,200

REMARKS

Sheet 1

1. The Overburden is approved for use in the 10"-16" layer and in all layers below this. It may also be used as a binder for screened out base gravel from BP 13
2. The gravel is approved for use in the Subbase layer (4"-10") compacted to a minimum relative density of 98% Test results indicate a possible variation in Maximum Density between 129·4 lb/ft³ to 137 6 lb/ft³ Such a variation will require care in the application of compaction control
3. Expansion with depth seems a feasible proposition for the borrow pit Up to the depths tested the deeper gravel does not appear to increase in PI unduly. It is similar in nature but coarser and tougher to work. If expansion to the full workable depth is undertaken hole 6 and surrounding area should be excluded
4. Any anthills within the approved area should be avoided

Visual Description	br sdy sl	dec grte pble + l br sl	dec grte pble + br sl	dec grte pble + l. br. sl	rdsh br sdy sl	qz + dec grte pble + rd br sl	dec grte pble + l br. sl	br. sdy. sl	qz + dec grte pble + rd br. sl
Stabilized with Ex mould			Ex mould						
Sample No	574 1575	1576	577 15.7	1578	1579	1580	1581	1582	1583
Depth below exist grd level	1 0-36"	1 36"-60	1 36-60"	1 60+	2 0"-30	2 30"-60"	2 60"+	3 0"- 8"	3 18"-58"
Classification group index	A2-4	A1-b	A1-b	A1-a	A2-4	A-1a	A1-a	A2-4	A2-4
1½ 3/4	100	98 98		91 84	100	96 91	90 80		78 68
Analysis 0 85 0 078	97 90	79 48	88 59	62 39	97 91	78 47	47 26	99 94	48 32
0 0 64 0 029 0 002	63 16 12	27 10/8	30 21/17	20 7/5	65 20/13	29 10/7	13 5/4	66 18/12	20 7/6
Coarse sand C fine sand	30 14	44 12	49 0	49 12	28 13	38 13	30 11	29 16	37 3
Medium fine sand F fine sand	14 29	9 19	8 18	10 16	15 30	12 21	9 15	12 30	14 18
Silt Clay	8 5	9 7	8 10	7 6	9 5	12 4	10 5	9 4	12 6
Atterberg LL PI	8 p	20 8	20 7	20 3	S p	19 6	24 6	S p	23 9
limits LS	<0 5	3 5	3 5	1 5	<0 5	3 0	4 0	<0 5	5 0
Moisture Density at mod AASHO	5·8 [illegible]		6·3 131·5						
Opt moisture content Density : 98% 90%	5 8 125·2 138 118·6		5·3 124·9/4 118·5						
Density	[illegible] 121 [illegible]		122						
C B R	16		24						
Swell	[illegible]		0						

Visual Description	qz + dec grte pble + rd br. sl	dec. grte + rd br. sl	br sdy sl	dec grte pble + rd. br. sdy. sl	rdsh br sl + dec. grte. pble	rd br sdy sl	rdsh br sdy sl + dec grte pble	rdsh br sdy sl + dec grte pble	l br sdy sl + dec. grte. pble	br sdy sl	qz + dec grte pble + br sl
Stabilized with Ex mould	Ex mould							Ex mould			
Sample No	1584 1584	1585	1586 1587	1588	1589	1590	1591	1592 1592	1593	1594	1595
Depth below exist grd level	3 18"-58"	3 58"+	4 0"-42"	4 42"-55"	4 55"+	5 0"-42"	5 42"-62"	5 42"-62"	5 62"+	6 0"-18"	6 18"-40"
Classification group index	A2-4	A2-4	A2-4	A1-b	A1-b	A2-4	A1-b	A1-b	A1-b	A2-4	A2-4
1½ 3/4	100	99 92		00							98 90
Analysis 0 85 0 078	70 53	52 35	99 93	91 56	85 51	99 92	87 53	94 71	89 58	99 19	55 33
0 0 64 0 029 0 002	29 11/9	22 9/7	65 19/13	33 10/8	28 10/7	69 22/16	33 11/8	46 15/12	20 6/5	67 9/12	21 8/7
Coarse sand C fine sand	46 10	37 11	30 11	41 14	45 11	26 11	38 13	35 12	66 11	26 2	36 14
Medium fine sand F fine sand	8 19	10 31	14 32	10 21	9 20	13 33	10 24	11 24	6 9	15 34	9 20
Silt Clay	11 6	13 8	9 4	9 5	10 5	11 6	11 4	12 6	5 3	8 5	11 10
Atterberg LL PI	20 5	20 8	S p	S p	19 6	S p	8 p	17 5	S p	n p	22 9
limits LS	3 5	4 0	0 5	<0 5	3 5	<0 5	1 5	2 5	1 5	0	3 5
Moisture Density at mod AASHO	6·3 131·1		5·6 132·0					6·1 132·9			
Opt moisture content Density : 98% 90%	5·9 124·5/ 118·0/6		5·9 125·4/50 118·6/12					5·8 126·3/42 119·6/10			
Density	130·6 126·6 124		124·0 121·9 12[illegible]·9					132·0 129·5 126·4			
C B R	122 43 25		36 28 10					137·0 71 35			
Swell	00 0		0·0 00					0 0 00			

C B R Density Diagrams

TEST RESULT SHEET 29: TYPICAL SUBBASE GRANITE BETWEEN OTJIWARONGO AND OTJIKANGO.

BORROW PIT INFORMATION

BORROW PIT Nº 69

Farm NEVADA NO 15

Owner : M PENDERIS

Chainage : 3620

COMPACTION REQUIREMENTS and QUANTI

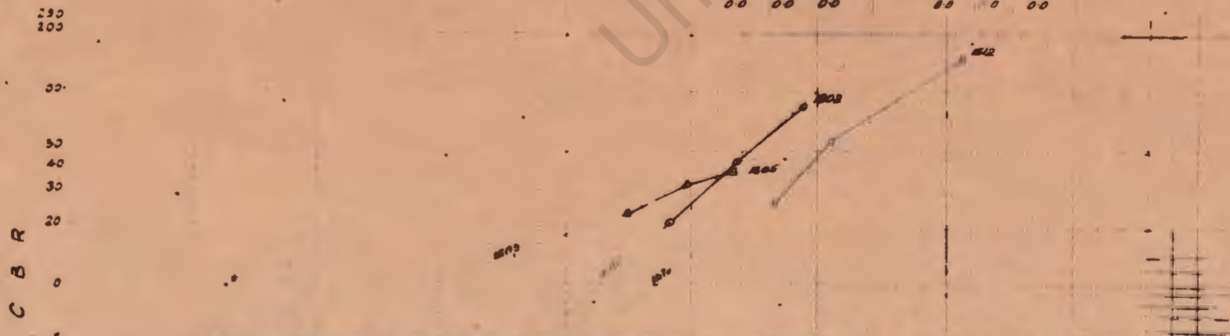
Material	Horizon measured from top of base	Min % of mod AASHO Density required	Range of Opt moist content	Approx. Quantity yds 3
Overburden	10"-16" Binder for Base ex BP 1-3	90%	5.0% - 6.9%	57,300
Gravel	4"-10"	98%	5.4% - 7.3%	47,200

REMARKS

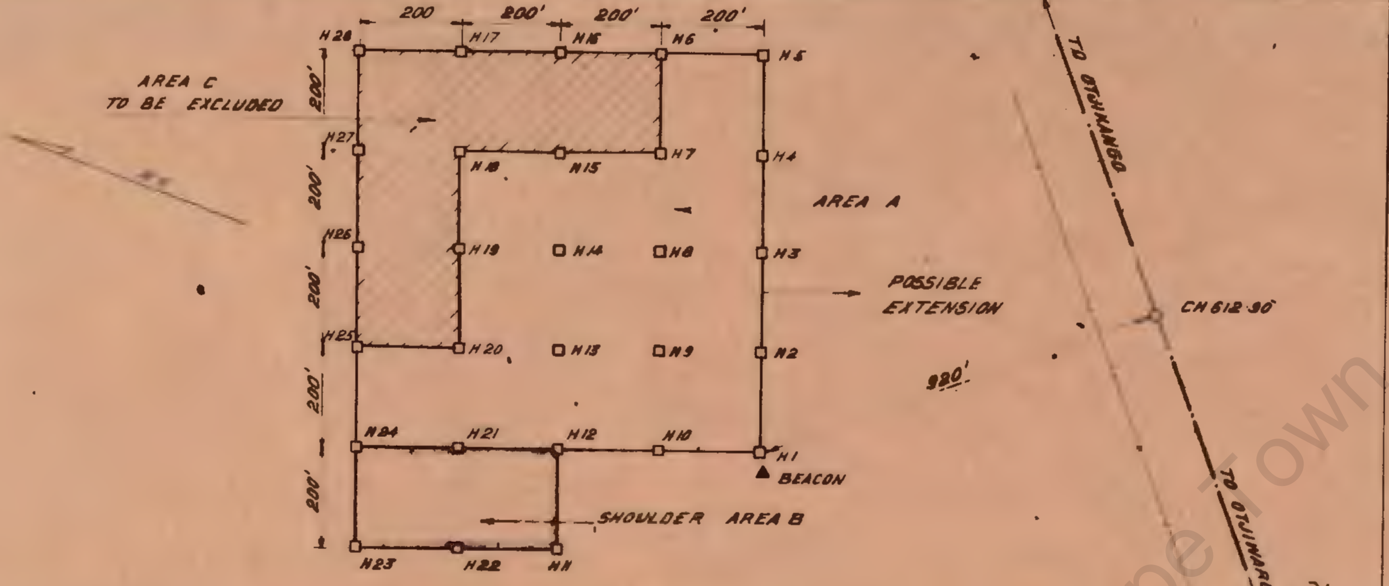
Sheet 2

Visual Description	dec grte (deep) + r br si	br sdy si	dec grte str of mica pble + rd br sdy si	dec grte pble + l br sdy si	rd br sdy si	rd br sdy si + dec grte + qz pble	rd br sdy si + dec grte + qz pble	l br sdy si + dec grte pble	br sdy si	rd br sdy si + dec grte pble	l br sdy si + dec grte pble	br sdy si	rdsh br sdy si + qz + dec grte pble	br sdy si	dec grte + qz pble + rd br sdy si	dec grte + qz pble + rd br sdy si	dec grte pble + l br sdy si	br sdy si	br si + dec grte + qz pble	br si + dec grte (ironox) pble
Stabilized with Ex mould							Ex mould									Ex mould				
Sample No / No CBR	1596	1597	1598	1599	1600	1601	1602 / 1602	1603	1604 / 1605	1606	1607	1608	1609	1610	1611	1612 / 1612	1613	1614	1615	1616
Hole; depth below exist grd lev.	6 40"+	7 0"-8"	7 18-32"	7 32"+	8 0"-35"	8 35"-48"	8 35"-48"	8 48"+	9 0"-30"	9 30"-50"	9 50"+	10 0"-18"	10 18"-32"	11 0"-28"	11 28"-50"	11 28"-50"	11 50"+	12 0"-52"	12 52"-64"	12 64"+
PRA classification (group index)	A2-6	A2-4	A -a	A1-a	A2-4	A1-b	A1-b	A1-b	A2-4	A1-b	A1-b	A2-4	A1-b	A2-4	A1-a	A1-a	A1-a	A2-4	A2-4	A2-4
Screen 1½ | ¾	100		97	94		99 96							99 98				100		100 98	100
analysis 0.25 | 0.078	65 40	89 85	65 40	53 30	100 95	85 54	94 74	80 51	99 92	88 54	86 53	96 87	78 56	99 92	82 47	92 61	88 41	100 95	80 53	82 57
0 0 64 | 0.0029 0.002	28 10/8	60 16/11	23 7 5	13 5/4	68 19/11	33 9/6	47 14/12	22 7/5	64 19/11	31 11/8	27 9/7	63 18/12	40 12/8	67 19/11	30 9/7	48 16/12	20 7/5	68 21/14	35 13/10	27 11/8
Soil coarse sand | C fine sand	42 10	30 12	42 2	57 0	28 12	39 14	37 13	57 12	30 11	44 11	49 12	28 11	29 15	27 10	36 13	21 14	52 9	28 9	34 11	53 9
Mortar M fine sand | F fine sand	8 19	16 28	2 21	8 13	17 31	14 21	12 23	9 12	16 31	0 2	9 17	15 32	15 27	18 34	12 25	16 30	9 18	16 32	11 25	8 16
Grading Silt | Clay	15 6	10 4	0 3	9 3	9 3	9 3	9 6	7 3	9 3	11 3	9 4	9 5	9 5	7 4	10 4	12 7	9 3	10 5	8 11	6 8
Atterberg LL | PI	29 14	5 p	S p	5 p	5 p	5 p	S p	n p	S p	S p	S p	S p	S p	8 p	S p	5 p	6 p	S p	19 8	20 9
Limits | L S	6 5	<0 5	1 5	1 0	<0 5	<0 5	0 5	0 ·	<0 5	<0 5	<0 5	<0·5	<0 5	<0 5	0 5	<0 5	<0 5	<0 5	3 0	3 0
Opt moisture and Density at mod AASHO							7.5 129.4		6.9 130							6.0 135.6				
Mould moisture content Density 98% 95%							7.3 122.8/15 116.6/5		6.8 125.6/28 117.1/15							6.0 128.4/35 122.4/12				
Density							129.4 126.0 124.4		5·8 126·9 122·5							135.6 130.5 128.2				
C B R							86 45 21		40 35 25							148 56 27				
Swell							0.0 0.0 0.0		0.0 0 0.0							0.0 0.0 0.0				

C B R Density Diagrams



TEST RESULT SHEET 29A: TYPICAL SUBBASE GRANITE BETWEEN OTJIWARONGO AND OTJIKANGO.



BORROW PIT INFORMATION

BORROW PIT Nº 11

Farm : DRUKWERK NO 13

Owner : P GENIS.

Chainage : 612 90

COMPACTION REQUIREMENTS and QUANT

Material	Horizon measured from top of base	Min % of mod AASHO Density required	Range of Opt. moist content	Approx Qua yds 3
Overburden	10" - 16" (Binder for Base ex B.P. 1-3	90%	6.4% - 7.4%	74,100
Gravel	4" - 10" (Area A) Shoulders (Area B)	98% 95% .	4.9% - 7.7% 6.2% - 7.6%	28,500 8,400

REMARKS

Sheet 1

1 Area C is not approved

2. The Overburden from Areas A and B is approved for use in the 10"-16" la and in all layers below this It may also be used as a binder for screened out Base gravel from borrow pits 13 and 110

3 The tested gravel from Area A is approved for use in the subbase layer (4"-10") compacted to a minimum relative density of 98%

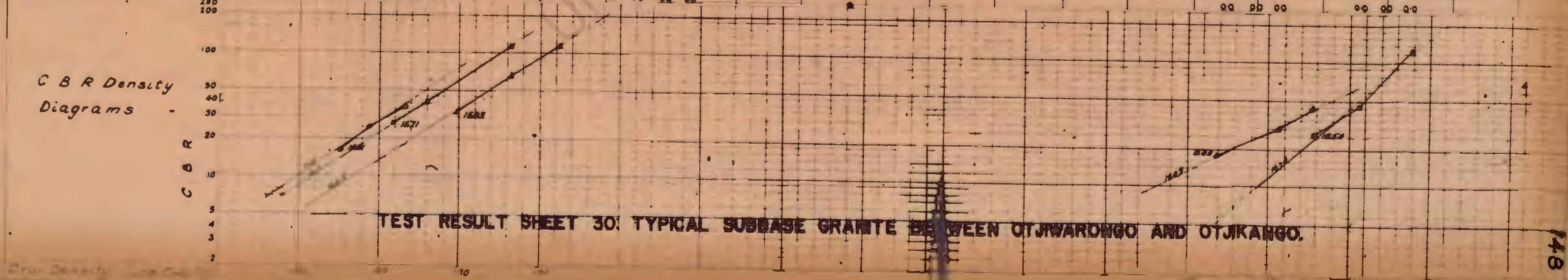
4. The tested gravel from Area B is only approved for use in the Shou

5 The Plasticity Index of the gravel may increase suddenly below the tested a approved layer. The CBR characteristics may also deteriorate rapidly a indicated by Sample 1679, depth 40"+, from hole 10 in Area A. Materia similar to this is not approved for use in the 4"-10" layer. Caution sho therefore, be exercised when working this borrow pit The approved layer can

(cont on sheet 2.)

Visual Description	rd br sdy sl.	rd br sdy sl +dec grt+qz pbls	rd br sdy sl +dec grts+qz pbls	br sl+dec grt pbls	rd br sdy sl.	rd br sdy sl.+ dec grts pbls	rd br sdy sl+ dec grts pbls	br sdy sl.+ dec grts pbls	[illegible]	qz +dec grts pbls +rdsh br sl.
Stabilized with, Ex mould			Ex mould				Ex mould			
Sample Nº ND/CBR	1680 1681	1682	1683 1683	1684	[illegible]	1670	[illegible] 1671	1672	[illegible]	1667
Hole/depth below exist. grd level	1 0"-60"	1 80"-94"	1 60"-94"	1 94"+	2 0"-48"	2 48"-66"	2 48"-66"	2 66"+	3 0"-34"	3 34"-46"
PRA classification (group index)	A2-4	A1-b	A1-b	A1-b	A2-4	A1-b	A1-b	A1-b	A2-4	A1-a
screen analysis 1½ | -3/4		100	100	100		100	100	100		96 99
0 85" | 0 078	100 96	92 57	97 68	67 52	100 95	84 53	95 74	96 67	100 98	84 36
0 0 66" | 0 0029, 0 0021	74 23/14	37 12/9	45 18/12	32 11/8	69 19/12	33 9/7	47 16/11	32 10/8	72 20/13	26 9/6
Soil mortar grading: coarse sand | C. fine sand	22 13	35 13	34 14	38 11	28 12	37 15	37 15	52 12	24 13	20 15
fine sand | F. fine sand	16 34	12 24	12 23	13 24	19 29	14 22	12 22	9 15	19 30	13 27
Silt | Clay	11 4	12 4	10 7	11 3	7 5	8 4	9 6	8 4	9 5	11 6
Atterberg Limits L L L | P	S p	S p	16 3	17 6	S p	S p	16 3	S p	S p	S p
L SH.	<0 5	<0 5	2.0	2 0	<0.5	1 0	1 5	1.5	1 0	1 0
Opt moisture/Density at mod AASHO	6 4 132.1		6 1 126.4				6.1 133.3			
Mould moisture content/Density CBR 95% 90%	123.2/20 6 2 118.2/8		123.6/32 6.0 122.8/3				123.6/32 6 1 120.6/8			
Density	126.6 124.4 122.7		126.2 126.2 129.8				133 3 128.0 125.9			
C B R	37 28 16		119 67 34				118 41 27			
Swel	0 0 0 0 0 0		0 0 0 0 0 0				0 0 0 0 0 0			

Visual Description	dec grts pbls + l br sdy. sl.	rd br sdy sl	dec grts +qz pbls + lt br sl.	qz +dec grts pbls + rdsh br. sl.	rdsh br sdy sl.	qz +dec grts pbls +rdsh br. sdy. sl	dec grts pbls + l. br. sl.	rd br sdy. sl.	l br sdy sl.+dec. grts pbls	dec grts pbls l. br sdy.
Stabilized with, Ex mould										
Sample Nº ND/CBR	1668	[illegible]	1657	[illegible]	1652	1653 1654	[illegible]	1648 1649	1650	1651
Hole/depth below exist. grd level	3 46"+	4 0"-48"	4 48"-66"	4 66"+	5 0"-32"	5 32"-56"	5 56"+	6 0"-60"	6 60"-70"	6 70"+
PRA classification (group index)	A1-a	A2-4	A2-4	A2-4	A2-4	A1-b	A2-6	A2-4	A1-b	A1-a
screen analysis 1½ | -3/4	100 98		96 92	81 65	100	100	100		100	100
0 85" | 0 078	57 30	100 96	51 85	32 20	99 94	90 46	66 37	100 96	89 55	64 34
0 0 66" | 0 0029, 0 0021	17 6/4	75 33/15	23 8/6	13 5/4	72 12/13	31 10/7	20 7/6	73 23/16	38 13/9	18 5/4
Soil mortar grading: coarse sand | C. fine sand	59 12	22 14	34 15	35 13	23 14	33 15	46 11	23 15	31 12	48 14
fine sand | F. fine sand	9 13	17 31	11 29	11 23	20 30	15 22	10 17	18 29	15 27	11 16
Silt | Clay	8 3	12 4	13 4	13 5	10 3	11 4	11 5	11 6	12 3	9 2
Atterberg Limits L L L | P	S p	6 p	20 9	21 9	5 p	5 p	26 13	5 p	5 p	5 p
L SH.	1 6	1 0	3 0	3.5	<0.5	1 0	4.5	<0 5	<0 5	<0
Opt moisture/Density at mod AASHO						4.9 135.6		7 0 132.6		
Mould moisture content/Density CBR 95% 90%						128.0/22 5.3 122 0/5		128.0/32 7 2 118 5/18		
Density						133.9 130.6 127.9		127 7 129.6 121.9		
C B R						129 46 27		45 30 16		
Swel						0.0 0.0 0.0		0.0 0.0 0.0		



TEST RESULT SHEET 30: TYPICAL SUBBASE GRANITE BETWEEN OTJIWARONGO AND OTJIKANGO.

BORROW PIT INFORMATION

BORROW PIT Nº 11·6

Farm : DRUKWERK NO 13

Owner : P. GENIS.

Chainage : 612 30

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of base	Min % of mod. AASHO Density required	Range of Opt. moist. content	Approx. Quantity yds 3
Overburden	10" - 16" (Binder for Base ex BP 1 3)	90%	6·4% - 7·4%	74,100
Gravel	4" - 10"(Area A) Shoulders (Area B)	98% 95%	4·9% - 7·7% 6·6% - 7·6%	26,500 6,400

REMARKS (cont. from sheet 1)

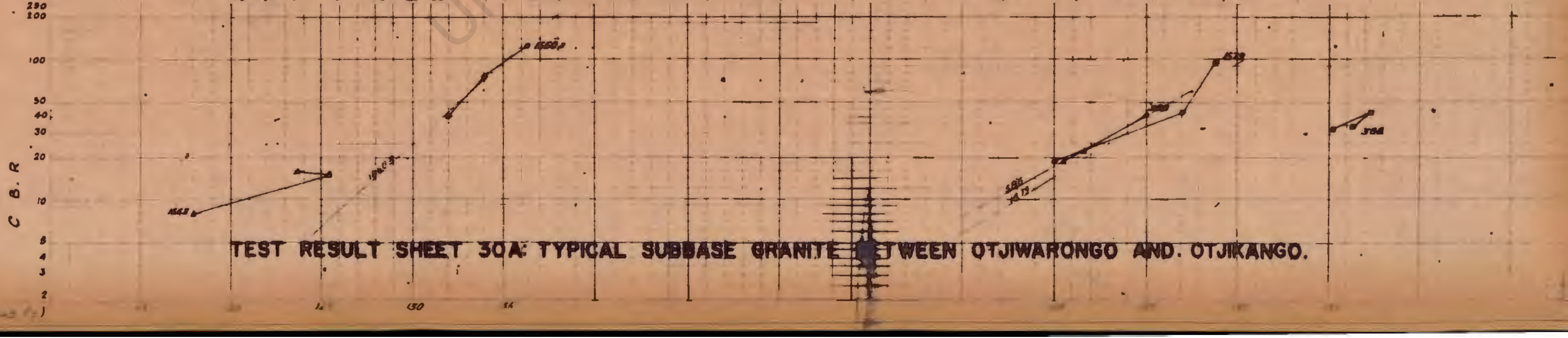
Sheet 2

normally be readily distinguished from the underlying material and only the former should be used.

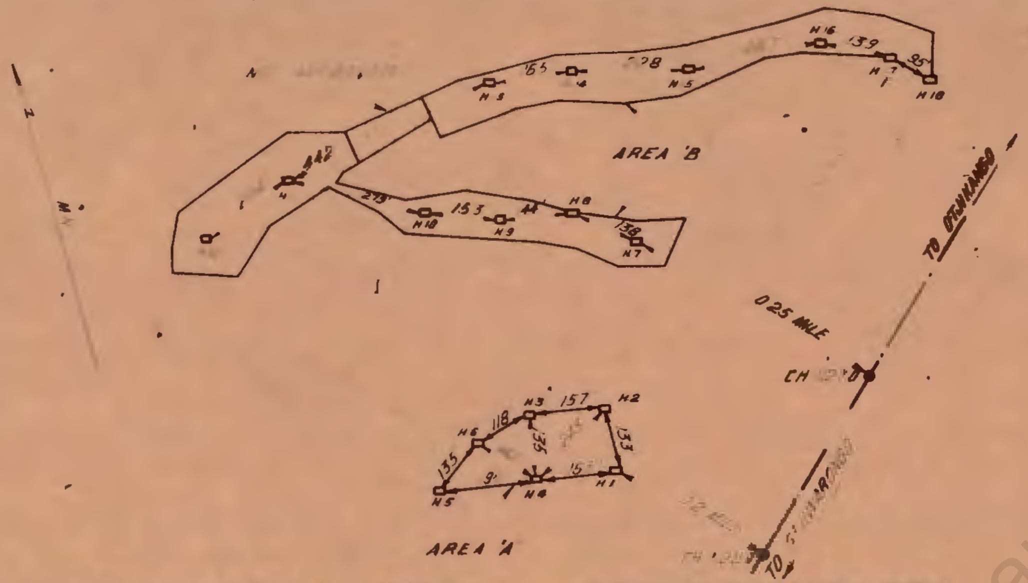
6 Anthills within the approved area should be avoided

Visual Description	rd br sdy si	qz+dec grte pbls+l.br sdy.si.	qz+dec grte pbls+l.br sdy.si.	dec grte+qz pbls. l.br si	dk br sdy si	qz+dec grte pbls+rd br si	dec grte (fresh) pbls+rd br si	rd br sdy si	dec grte rd pbls+rd br sdy si.	dec grte pbls+l.br. sdy si	rd br sdy si.	rd br sdy si + qz+dec grte pbls.	dec grte pbls l. br si	f br sdy si.	qz+dec grte pbls+r.br. si.	qz dec grte pbls+r.br. si.	f br sdy. si.	dec grte pbls+r.br. si.	f br si dec grte pbls	f br sdy si
Stabilized with Ex mould			Ex mould																	
Sample Nº IND;C.B.R	1659	1660	1660a 1660b	1661	1662 1663	1664	1665	1673	1674	1675	1676	1677	1678 1679	385 386	387	388 388	389	390	391	392
Hole/depth below exist. grd level	7 0"-34"	7 34"-66"	7 34"-66"	7 66"+	8 0"-48"	8 48"-57"	8 57"+	9 0"-36"	9 36"-54"	9 54"+	10 0"-42"	10 42"-60"	10 60"+	11 0"-40"	11 40"-66"	11 40"-66"	12 0"-36"	12 36"-60"	12 60"+	13 0"-36"
P.R.A. classification (group index)	A2-4	A1-a	A1-a	A1-a	A2-4	A2-4	A2-4	A2-4	A1-b	A1-a	A2-4	A1-b	A2-4	A2-4	A1-a	A1-a	A2-4	A1-b	A1-b	A2-4
Screen analysis 1½" - 3/4		99 96	100	100		96 84	91 78	—	100 99	100	—	100 99	98 96	100	98 96	100	100	100 97	100	100 99
0 83" · 0·078	100 94	81 41	87 53	71 45	100 98	48 29	46 34	100 94	82 48	68 41	100 94	88 61	73 44	97 89	74 38	79 58	98 91	72 50	78 63	97 92
0 0164" -0 0088; 0 0021	70 20/12	28 9/7	34 12/8	22 8/6	74 25/17	21 8/6	24 9/7	72 18/11	34 12/8	15 5/4	72 21/13	44 12/9	24 6/7	69 12/14	29 9/7	30 10/8	71 21/15	38 10/8	34 11/8	72 21/18
Soil mortar coarse sand / C. fine sand	26 15	32 17	35 14	51 13	22 14	28 13	29 12	24 16	29 16	63 9	24 16	28 10	46 11	22 18	38 18	42 11	20 12	36 13	36 11	22 13
M. fine sand / F. fine sand	17 30	13 23	13 22	8 15	15 31	12 28	12 27	17 31	14 25	8 10	15 31	16 30	9 19	18 28	15 26	11 19	17 33	13 22	13 24	17 32
grading Silt / Clay	9 3	11 4	10 6	9 4	14 4	15 3	15 5	8 4	12 4	7 3	9 5	11 5	9 6	9 7	11 7	7 10	10 8	10 6	8 8	10 6
Atterberg LL / PI	S P	S P	S p	20 6	S p	20 9	22 9	5 p	n p	S p	S p	9 p	19 8	9 p	20 6	19 4	S p	20 5	20 4	9 p
limits L SH.	<0·5	1 0	1·8	2 5	1 0	3 5	4 0	1 5	0	1·0	<0·5	<0·5	3 0	<0 5	5	2 5	<0 5	2 5	1 5	1 0
Opt moisture / Density at mod AASHO			6 1 137·3		6·5 134·8								6 3 129 3	6 7 130·9		6·8 137 7				
Mould moisture content / Density/CBR 95% 90%			6 1 130·4/27 125·6/4		6·5 127·0 121·1								6 2 122·8/24 116·4/8	7·1 124·3/36 117·7/12		6 6 130·9 125·9				
Density			136 3 134 0 131·7		123·6 125·5 118 0								128·9 127·0 119·9	125 0 121·8 120 5		136·3 137·3 135 3				
C B R			126 74 49		16 15 8								96 44 19	42 22 19		34 44 33				
Swell			-0·06 -0·1 -0·1		0 0 0 0 0 0								0 0 0 0 0 0	0 0 0 0 0 0		-0·1 0 0 0 0				

C B R Density Diagrams



TEST RESULT SHEET 30A: TYPICAL SUBBASE GRANITE BETWEEN OTJIWARONGO AND OTJIKANGO.



BORROW PIT INFORMATION

BORROW PIT Nº 21·3

Farm : BRUNNENTAL NO 7

Owner : F J MOUTON

Chainage : ·1127·0

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of base	Min % of mod AASHO Density required	Range of Opt moist content	Approx Quantity yds ³
Overburden	10" - 16"	95% or 90% depending on control test results	6 4% - 8 0%	15,700
Gravel	4" -10"	98%	5 0% - 7 2%	22,500

REMARKS

Sheet 1

1 The sand overburden is approved for use in the 10" - 16" layer compacted to a minimum relative density of either 90% or 95% depending on control test results

2 The overburden from area B gives good CBR results at 0·1 inch penetration, but these tend to deteriorate with increase in penetration. For this reason its use in the 4" - 0 layer is not recommended. The overburden from area A is not particularly well graded, and that from area B is only slightly better in this respect. As more suitably graded binders are available, this overburden is also not recommended for addition to the screened out calcrete aggregate from B P 22 6 for ultimate use in the base course

(cont on sheet 2)

	dec grte (pgtite) + q3 pble + br sdy si	dec grte (pgtite) + q3 pble + br sdy s	br sdy si	dec grte + q3 pble + br si	br sdy s	dec grte pble + rd br s	dec grte pble + br s
Visual description							
Stabilized with Ex mould		Ex mould					
Sample No / VD CBR	2 4	2 5 21 5	2036 2 7	2118	2 9	2120 2121	2122
Hole, depth below exist grd level	1 14 - 56	4'-56	2 0'-23	2 23 -59	3 0 -24	3 24 - 48	4 10"-52"
PR classification group index	A -a	A -1	A -b	A2-4	A2-4	A2-4	A1-a
Screen 1½ / 3 4	99 93	100	100	100	100	00	00, 94
analysis 0 85 / 0 78	60 35	79 52	99 94	78 48	97 93	81 46	60 36
0 0 64 / 0 0029 0 002	25 64	28 9/7	82 18/11	3 97	78 20/11	29 0,8	21 7 5
Soil coarse sand / C fine sand	29 1	47 0	13 2	33, 14	13 11	37 0	41 9
mortar M fine sand / F fine sand	19 29	3 8	23,40	18 21	25 39	15 2	3 23
grading Silt / Clay	6 6	5 7	7 5	8 8	7 5	8 9	7 7
Atterberg LL L / P	5 pl	9 3	5 p	21 8	5 pl	21 9	17 3
limits / L Sh	<0 5	2 0	<0 5	3 5	<0 5	3 5	·5
Opt moisture density at mod AASHO		0 275 121·1/17	90 1236 117 6			61 135 0 128 3/58	
Field moisture content Density CBR 95% 90%		51 114·6/6	79 111 4			59 121·5/11	
Density		1275 2 8	1236 12·4 1236			133·7 129 3 125 9	
CBR		59 17 0	57 37 31			65 41 20	
Swell		00 00 00	00 00 00			00 00 00	

	dec grte + q3 pble br sdy sl	dec grte + q3 pble br sdy s	br sdy s	dec grte (pgtite) pble + br sdy si	dec grte pble + rd br si	dec grte pble + rd br si	dec grte pble + rd br si
Visual description							
Stabilized with Ex mould		Ex mould				Ex mould	
Sample No / VD CBR	2123	2124 2124	2125	2126	39	140 140	141 42
Hole, depth below exist grd level	5 0 - 35'	5 10"-35	6 0"-17'	8 7'-46'	7 34'-80"	7 34'-80'	8 30"-62"
PR classification group index	A1-a	A1-a	A2-4	A1-a	A2-4	A2-4	A2-6
Screen 1½ / 3 4	100	100	100	00	100	100	100
analysis 0 85 / 0 78	79 50	85 59	98 88	69 42	84 47	98 62	82 48
0 0 64 / 0 0029 0 002	27 8/6	32 8/7	72 8/8	25 7,5	28 9/7	32 12/10	28 10/8
Soil coarse sand / C fine sand	45 8	46 9	16 9	40 10	47 11	48 10	47 10
mortar M fine sand / F fine sand	2 22	12 21	22 40	15 23	11 16	9 18	10 16
grading Silt / Clay	7 6	6 6	7 4	7 5	8 7	7 9	10 7
Atterberg LL L / P	8 pl	5 pl	n pl	5 p	22 10	21 8	28 13
limits / L Sh	<0·5	0 6	0	<0 5	4·0	4 0	6 0
Opt moisture density at mod AASHO		57 128 9 122·5/17				65 133·1 128·4/30	72 132 3 128 8/34
Field moisture content Density CBR 95% 90%		56 116·0/5				6·4 128·8/12	72 119 0/22
Density		127 8 123 0 121 8				133 0 130·3 126 0	132 2 130 3 126 4
CBR		59 82 12				93 40 34	46 62 30
Swell		00 00 00				00 00 00	00 00 00

	rd br sdy	rd br si + dec grte pble	rd br si + dec grte pble	dec grte + q3 pble + rd br si	rd br si + dec grte pble	rd br si + dec grte pble
Visual description						
Stabilized with Ex mould			Ex mould			Ex mould
Sample No / VD CBR	143 144	145	146 146	147 148	149	150 150
Hole, depth below exist grd level	9 0'-24	9 24'-57	9 24'-57	10 16"-46"	11 20'-53"	11 20"-53"
PR classification group index	A2-4	A2-4	A2-4	A2-4	A2-4	A2-4
Screen 1½ / 3 4	100	100	100	97 96	100	100
analysis 0 85 / 0 78	99 85	88 52	93 86	74 48	[illegible]	92 62
0 0 64 / 0 0029 0 002	71 19/13	32 12/8	37 15/12	35 14/11	31 11/8	34 12/7
Soil coarse sand / C fine sand	20 13	38 11	44 10	27 10	41 10	46 10
mortar M fine sand / F fine sand	22 30	12 21	11 17	14 25	13 19	11 21
grading Silt / Clay	8 7	12 6	9 9	6 8	9 8	7 5
Atterberg LL L / P	5 p	23 10	24 9	22 8	22 8	21 7
limits / L Sh	<0 5	4 5	5 0	4 0	3 0	4 0
Opt moisture density at mod AASHO	67 130 9 124·4		67 132 9 128·3/35	68 138 6 131 6/55		56 135 0 128·3/50
Field moisture content Density CBR 95% 90%	65 117 8		67 118·6/17	65 124 7/22		56 121·5/20
Density	125 9 121 8 123 1		132 9 129 6 123 0	138 5 130 5 128 2		135 0 127·7 124 0
CBR	43 22 24		67 40 23	41 47 17		25 48 26
Swell	00 0 0		00 00 01	00 0 00		00 00 00

TEST RESULT SHEET 31: SUBBASE GRANITE IN CONTACT WITH A BAND OF CRYSTALLINE LIMESTONE NEAR OTJIKANGO.

BORROW PIT INFORMATION

BORROW PIT Nº 21 3

Farm BRUNNENTAL NO 7

Owner : F J MOUTON

Chainage

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of base	Min % of mod AASHO Density required	Range of Opt moist content	Approx. Quantity yds 3
Overburden	10" -16	95% or 90% depending on contra test results	6% -8 0%.	15,700
Gravel	4 - 10'	98%	5 0% -7 2%.	22,500

REMARKS (cont from sheet 1

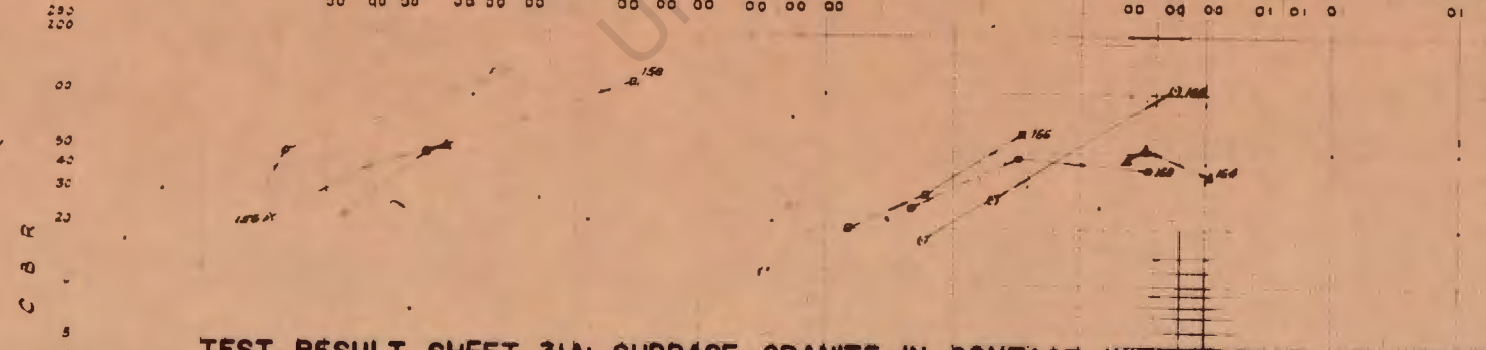
Sheet 2

3 The gravel is approved for use in the 4'-10 layer compacted to a minimum relative density of 98%. Test results indicate a possible variation in Maximum Density between 127 5 and 138 5 lb/ft³ Such a variation will require care in the application of compaction control The Plasticity Index will also need careful control in this regard initial stockpiling should be done well within the demarcated boundaries so as to avoid any possible admixing of unapproved inferior gravel

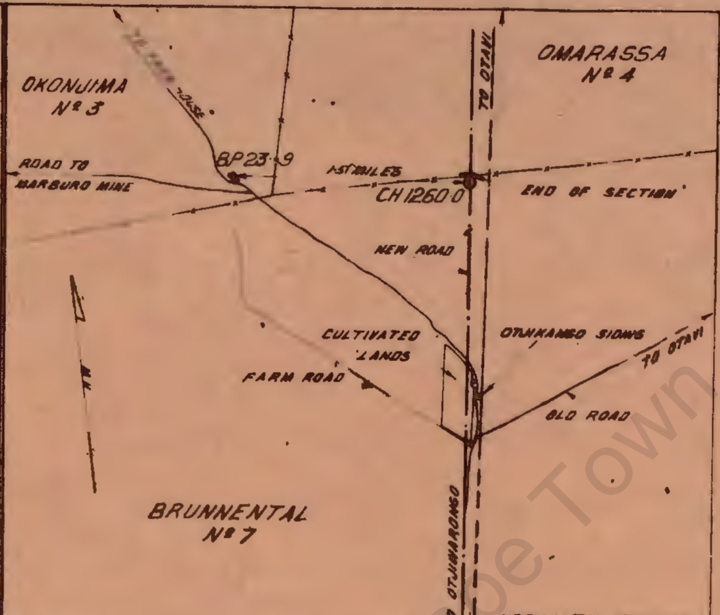
4 Tough dec granite bank underlies the tested and approved layer of granite It may be workable to a depth greater than that tested Provided that the PI's do not become greater than 10 below the tested depth expansion in this direction may prove feasible

[illegible]	br sdy & dec grte pbls	dec grte pbls + br sl	dec grte pbls + br s	rd br sdy sl	dec grte pbls + rd br sl	dec grte pbls + rd br s	dec grte pbls + rd br sl.	rdsh br sl + dec grte pbls	dec grte pbls + rd. br sl	dec grte + qz pbls + rd br sl	dec grte + qz pbls + rd br sl	br sdy sl	dec grte + qz pbls + rd/br sl	dec grte + qz pbls + rd br sl
Stabilised with Ex mould			Ex mould			Ex mould					Ex mould			Ex mould
Sample No No CBR	151	53	154 154	155 56	157	158 158	159 160	61	162	163	164 164	165 166	167	168 68
Hole [illegible] depth below ground level	12 0 - 14	12 14"-50	12 14"-50'	3 0 -27"	13 27 -54'	3 27"-54"	4 20'-68'	15 36"-72"	16 29"-56"	17 34"-72"	17 34"-72"	18 0"-30'	8 30"-69"	18 30"-69'
PRA classification group index	A2-4	A1-a	A +a	A2-4	A8-4	A2-4	A2-6	A1-b	A1-a	A2-4	A2-4	A2-4	A -b	A1-b
Sieve 1/2 3 4		98	00					100	100	100 94	100	100	00 97	10
analysis [illegible] 0 078	95 8	57 34	75 52	98 90	83 48	86 51	81 49	84 54	80 50	67 42	79 54	97 92	81 49	86 62
[illegible] 0 64 [illegible] 29 0 002	65 17 0	7 5/4	26 9,7	73 20/11	34 12/10	36 3,	29 12/10	31 11/8	29 10/8	28 10/8	35 14/11	73 16/13	35 11/9	44 16/13
Soil coarse sand C fine sand	20 9	50 12	50 3	19 12	29 11	30 11	42 9	43 11	42 11	34 11	35 11	20 12	29 13	29 12
mortar M fine sand F fine sand	23 36	2 5	0 14	22 35	6 23	5 22	11 17	19 17	12 20	14 22	13 20	23 30	17 23	15 24
grading Silt Clay	6 4	7 4	6 7	5 7	2 9	9 13	12 9	11 5	11 4	13 6	9 12	9 6	2 6	10 10
Atterberg LL P	n p	22 4	25.5	5 .p	2 8	23 10	27 11	20 5	20 6	20 7	21 8	6 p	19 6	18 5
limits L S	0	2 5	3 0	<0 5	4 0	4 5	6 0	3 0	3 0	3 5	4 0	<0 5	3 0	2 5
Opt moisture Density at mod AASHO			65 131 2 124 6/32	72 3 9 128 3/32		55 137 3 130 4/50	70 132 7 [illegible] 1/36				63 135 1 128 5	64 129 7 123 2/30		51 133 9 127 2/32
and moisture content Density CBR 95% 90%			65 118 1/18	70 118 7, 4		55 125 6/13	70 119 4/25				63 121 6	66 116 7/10		5 120 3/8
Density			3 2 233 22 6	29 9 266 22 6		37 3 29 0 125 7	32 7 127 6 23 3				135 1 132 5 131 7	127 5 23 8 120 9		133 8 126 4 123 7
C B R			0 48 3	52 4 21		3 47 22	42 47 26				39 52 46	63 30 20		07 29 7
Swe.			30 00 00	00 00 00		00 00 00	00 00 00				00 00 00	01 01 0		01 01 01

C B R Density Diagrams



TEST RESULT SHEET 31A: SUBBASE GRANITE IN CONTACT WITH A BAND OF CRYSTALLINE LIMESTONE NEAR OTJIKANGO.



LOCALITY SKETCH

BORROW PIT INFORMATION

BORROW PIT Nº 23 9

Farm : OKONJIMA NO 3.

Owner : I. DE WET LE ROUX

Chainage : 1260

COMPACTION REQUIREMENTS and QUANTITY

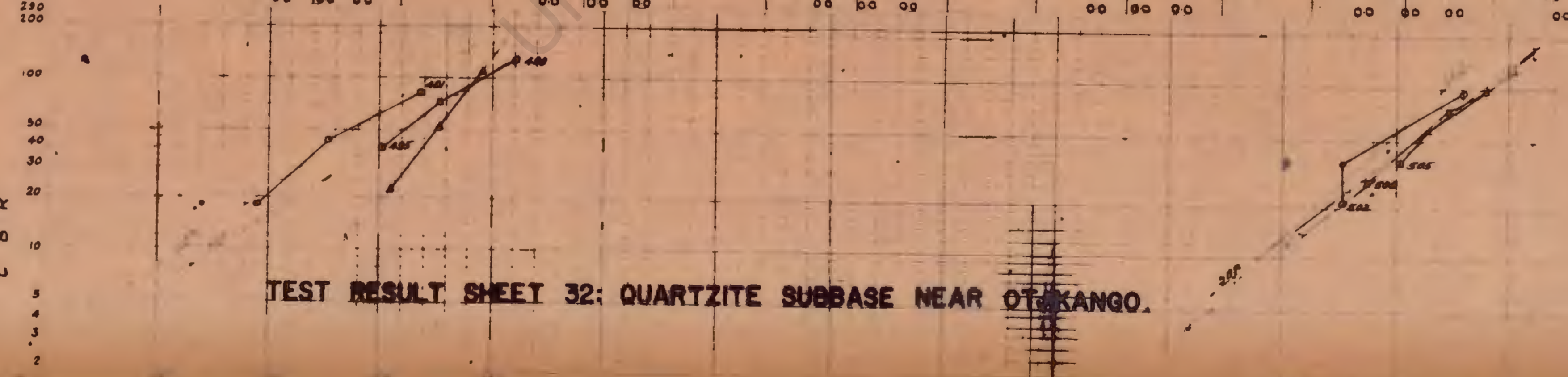
Material	Horizon measured from top of base.	Min. % of mod. AASHO Density required	Range of Opt moist content	Approx. Quantity yds 3
Gravel	4" - 10"	98	6.2 - 7.5%	14,500

REMARKS

1. There is no sand overburden apart from a little around hole 4
2. Numerous hard quartzite boulders are strewn over the borrow pit area These and small quantity of sand overburden around hole 4 should be removed when clearing the site of bush.
3. Holes 1 and 2 are excluded from the approved area as shown on the sketch on account of hard quartzite outcrops in the intervening area represented by these holes. The gravel in the remaining tested area is approved for use in the 4"-10" layer compacted to a minimum relative density of 98%. The profile generally consists of a layer of quartzite gravel of variable thickness overlying soft weathered quartzite formation. The layer of gravel which is often thin, and the weathered quartzite are to be stock-piled together
4. Provided that the quality of the quartzite does not deteriorate below the tested layer, it can be worked to as deep as is practicable.

Visual Description	f qzte bdls +br dec. sdy si	f qzte bdls+br dec sdy. si.	f qzte bdls+br dec sdy. si.	f qzte bdls+br sdy. si.	[illegible] sdy. si.	f qzte bdls +br dec sdy si.	[illegible] br. si.	f qzte bdls +rdsh dec. br. sdy si	f qzte bdls+br dec sdy si.	f qzte bdls+br dec. sdy si	f qzte bdls+br dec sdy si	f qzte bdls+br dec sdy si.	f qzte +f.z bdls + dec rdsh br sdy si	[illegible] dec. sdy. si.	f qzte bdls+br dec sdy si	f qzte bdls+br dec. sdy si	f qzte f qz bdls +br dec sdy si.	f qzte bdls+br dec sdy si.
Stabilized with Ex mould																		
Sample Nº ND/CBR	489	490	491 481	492	493	494 495	496	497	498 499	499	500	501 502	503	504	505 505	506	507 508	509
Hole/depth below exist. grd level	1 0"-24"	2 0"-18"	2 0"-18"	3 0"-24"	3 24"+	4 0"-36"	4 36"+	5 0"-24"	6 0"-21"	6 0 -21"	7 0"-30"	8 0"-18"	9 0"-44"	10 12"-34"	10 0"-34"	11 0"-20"	12 0"-26"	12 26"+
PRA classification (group index)	A1-a	A1-a	A1-a	A1-a	A1-b	A1-b	A1-a	A1-a	A1-a	A1-a	A1-a	A1-a	A1-a	A1-b	A1-b	A1-a	A1-b	A1-b
screen analysis 1½" | -3/4	64 40	49 34	100	79 68	98 93	77 65	71 60	65 52	39 27	100	75 55	60 46	48 36	81 69	100	76 58	72 56	74 57
0.185" | 0.078	23 18	20 16	64 53	29 24	68 49	52 47	36 29	31 23	16 13	64 81	33 27	26 19	27 22	54 46	61 52	38 32	41 37	42 36
0.0164" | -0.0029, 0.0021	15 5/3	13 3/2	44 12/8	22 5/3	42 16/11	42 11/7	28 8/6	19 6/3	11 3/2	39 12/8	23 8/3	16 4/3	20 8/3	44 11/8	43 12/8	26 8/5	34 9/8	32 9/8
Soil mortar grading coarse sand | C fine sand	17 7	19 11	17 10	6 9	14 8	11 14	14 13	17 10	15 8	84 9	15 12	16 11	9 14	9 11	12 11	14 9	8 13	11 17
M fine sand | F fine sand	17 41	20 37	21 36	24 45	17 26	24 37	19 34	19 39	18 42	18 36	20 41	21 38	24 39	24 44	23 39	21 40	24 41	25 32
Silt | Clay	12 6	9 4	10 3	10 3	18 8	10 4	13 7	12 3	41 4	9 6	9 3	11 3	6 6	9 4	10 6	18 4	9 5	8 T
Atterberg Limits LL | PI	5 p	S p	S p	4 p	20 3	6 p	18 3	9 p	S p	S p	9 p	S p	S p	8 p	8 p	S P	8 p	S p
LSH	1.0	<0.5	<0.5	3.5	2.5	0.5	2.5	0.5	<0.5	<0.5	<0.5	0.8	<0.5	<0.8	<0.5	<0.8	<0.5	0.5
Opt moisture | Density at mod AASHO			6.7 127.0			6.2 130.9			7.2 131.0			7.4 127.8			7.5 130.3		8.0 129.1	
Mould moisture content | Density/CBR 95% 90%			6.7 120.7/26 114.3/6			6.9 124.4/15 117.8			7.2 124.5/37 117.9/10			7.4 121.6/20 116.1/5			7.2 123.8/29 117.3/5		7.9 122.6/24 116.8/6	
Density			128.9 122.8 116.6			129.6 127.6 125.5			131.0 127.8 125.1			128.0 122.8 123.6			130.3 128.4 125.1		129.0 127.3 123.7	
CBR			81 44 16			110 52 23			127 71 40			95 37 21			128 59 37		98 78 29	
Swell			0.0 0.0 0.0			0.0 0.0 0.0			0.0 0.0 0.0			0.0 0.0 0.0			0.0 0.0 0.0		0.0 0.0 0.0	

C.B.R Density Diagrams



TEST RESULT SHEET 32: QUARTZITE SUBBASE NEAR OTJIKANGO.

BORROW PIT INFORMATION	BORROW PIT Nº
Farm :	Owner :
	Chainage :

COMPACTION REQUIREMENTS and QUANTITY

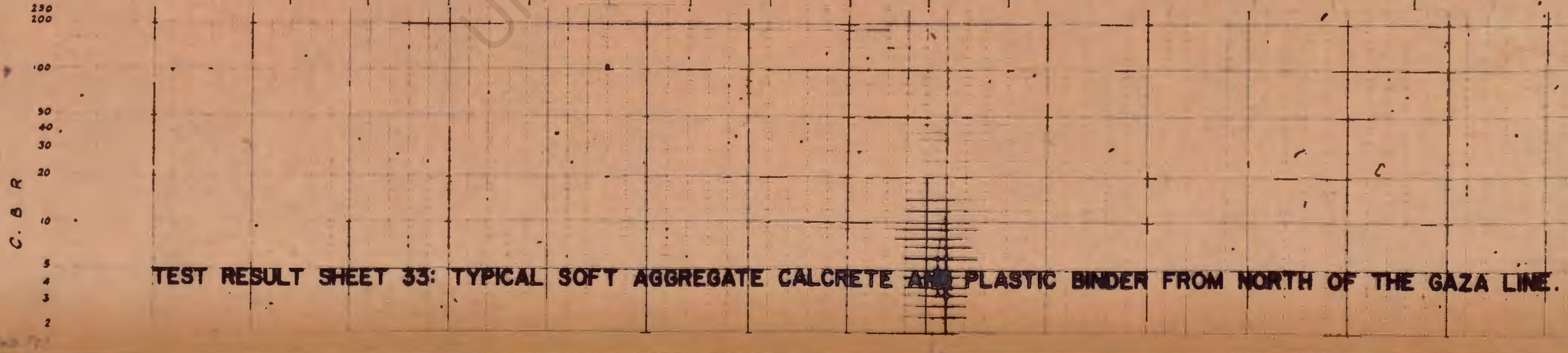
Material	Horizon measured from top of base	Min % of mod. AASHO Density required	Range of Opt. moist. content	Approx. Quantity yds ³

REMARKS

Visual Description	calc[illegible] & sdy. cl	calc[illegible] & sdy. cl	calc[illegible] & sdy. cl	calc[illegible] & sdy. cl	[illegible]	calc[illegible] & sdy. cl	calc[illegible] & sdy. cl	calc[illegible] & sdy. cl	[illegible] & sdy. cl	[illegible] & sdy. cl
Stabilized with 5x mould										
Sample Nº / ND CBR	431	432	426	427	655	4[illegible]	430	4[illegible]	4[illegible]	49
Hole/depth below exist grd level	1 72"-96"	1 96"-120"	2 72"-90"	2 90"-108"	3 72"-120"	4 72"-96"	4 84"-108"	6 78"-102"	7 84"-96"	8 100"-114"
PRA classification (group index)	A1-a	A1-a	A1-a	A1-b	A1-b	A1-a	A1-a	A1-a	A1-a	A1-a
Screen analysis 1½ / 3/4	81 67	89 75	100 83	90 79	77 65	90 70	85 78	[illegible]	53 46	12 4
0 85 / 0 078	31 25	44 35	40 34	49 43	47 42	34 26	49 40	[illegible]	39 35	3 3
0 0 [illegible] / 0 0029 0 002	20 3/2	27 4/3	20 7/6	35 9/8	35 7/6	19 [illegible]	26 6/6	[illegible]	20 4/4	2 [illegible]
Soil mortar grading: coarse sand / C fine sand	10 23	25 24	16 25	16 22	17 21	26 10	30 22	22 23	20 22	20 19
M fine sand / F fine sand	30 19	23 17	29 16	27 25	30 22	24 27	22 16	22 14	23 17	27 20
Silt / Clay	6 4	5 2	11 3	7	0 2	6 2	8 3	6 3	5 [illegible]	6 6
Atterberg limits: LL / PI	S.P	N.P	S.P.	S.P	N.P	S.P	N.P	N.P	N.P	N.P
L SH	0.5	0.0	1.0	2.25	0.0	0.5	[illegible]	0.0	0.0	1.0
Opt. moisture content / Density at mod. AASHO										
Mould moisture content / Density, CBR 95% 90%										
Density										
C B R										
Swell										

Visual Description	br[illegible]	[illegible]	br[illegible]	br[illegible]	br[illegible]
Sample Nº	442	443	444	445	446
Hole/depth	1 [illegible]	1 [illegible]	2 12"-66"	3 12"-60"	4 12"-78"
PRA classification	A2-6	A2-[illegible]	A2-4	A2-4	A2-4
Screen analysis	[illegible]	[illegible]	100	100	100
	[illegible]	[illegible]	90 19/16	91 16/13	90 20/16
Soil mortar grading	14 [illegible]	14 20	10 12	10 20	10 20
	31 [illegible]	30 20	30 23	37 21	30 23
	4 [illegible]	0 [illegible]	6 10	3 [illegible]	6 6
Atterberg limits	27 [illegible]	[illegible]	23 [illegible]	19 5.0	22 6
L SH	4.0	[illegible]	[illegible]	[illegible]	2.5

C B R Density Diagrams



TEST RESULT SHEET 33: TYPICAL SOFT AGGREGATE CALCRETE AND PLASTIC BINDER FROM NORTH OF THE GAZA LINE.

BORROW PIT INFORMATION

BORROW PIT Nº

Farm :

Owner :

Chainage :

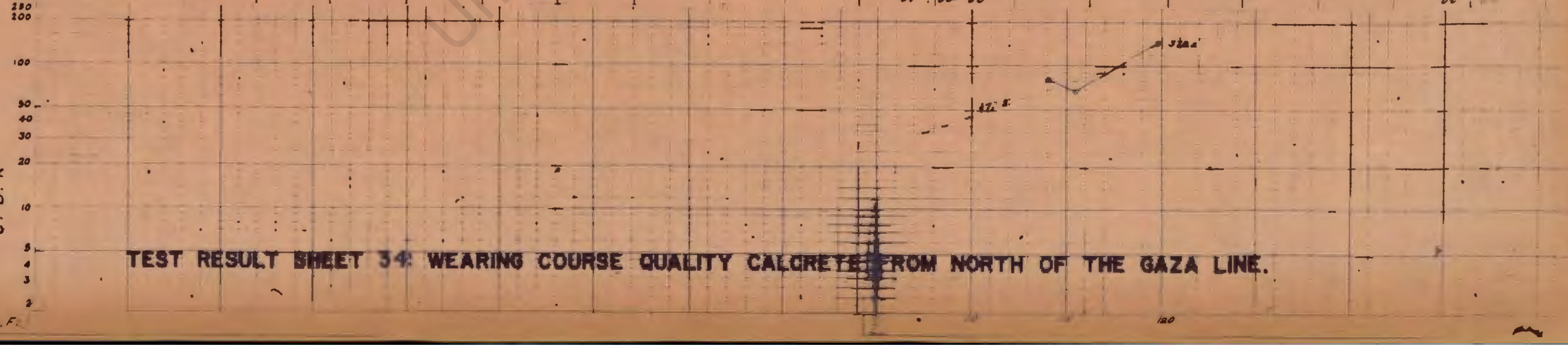
COMPACTION REQUIREMENTS and QUANTI

Material	Horizon measured from top of base	Min. % of mod AASHO Density required	Range of Opt moist content	Approx. Quantity yds. 3

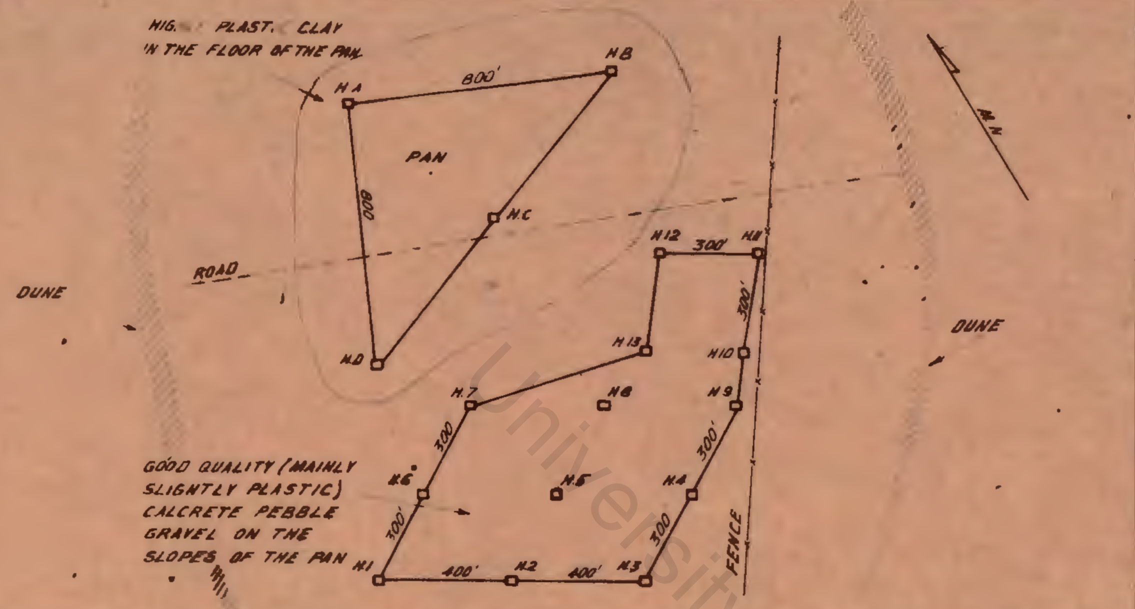
REMARKS

	Deposit 0.8 Pan		Slope	Deposit 8.0			Deposit 18.5			Deposit 29.0			
Visual Description	dk gry sl	gry sl	[illegible]	lat. [illegible] + gry sl.	gry sl	lat pbls + l gry sl	lat. blds + gry sl.	lat. blds + gry sl	lat pb's + lt gry sdy sl	dk gry sdy sl	[illegible] sdy sl	[illegible]	[illegible] sdy sl
Stabilized with; Ex mould								Ex mould					Ex mould
Sample Nº IND/CBR				376	[illegible]	377	372	372	373	24	25	26	26
Hole/depth below exist. grd level	6 0"-14"	7 14"-76"	8 0"-26"	1 6"-18"	2 18"-60"	2 60"-78"	1 12"-38"	1 12"-36"	2 [illegible]	0"-20"	[illegible] 55"	[illegible] 72"	55 72
PRA classification (group index)	A2-6	A7-5	A2-4	A2-4	A2-4	A2-7	A1-b	A1-a	A1-a	A2-4	A2-4	A1-b	A1-b
Screen analysis - 1½ / - 3/4		96 91	85 46	90 66		68 64	58 37	100	[illegible] 57	100	[illegible]	86 75	100
0.85" / - 0.078	100 93	83 67	27 24	27 22	100	36 26	25 21	60 48	34 27	87 97	[illegible]	52 44	56 46
0.0 68" / 0.0029, 0.0021	66 31/25	75 46/42	20 4/2	20 6/4	93 23/18	21 6,4	16 4/3	37 5/8	19 5,3	81 16/8	84 [illegible]	36 7/6	37 6/5
Soil mortar grading: coarse sand / C fine sand	11 17	3 8	6 15	9 16	7 17	25 19	17 18	25 17	32 20	6 23	6 [illegible]	16 23	26 19
M. fine sand / F fine sand	26 20	14 20	[illegible]	31 25	32 25	22 16	26 25	23 20	21 17	44 13	[illegible]	32 16	32 17
Silt / Clay	15 11	14 35	6 3	10 9	13 6	11 5	8 4	12 3	8 4	- 0 -	6 3	[illegible]	10 2
Atterberg limits: L L / P I.	53 13	70 33	45 8	31 10	30 8	43 11	14 3	5 P	5 P	5 P	5 P	5 P	5 P
L SH.	7.0	11.0	6.5	5.5	3.5	6.0	1.0	1.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Opt moisture / Density at mod. AASHO	17.3 107.0							11.2 118.9					13.1 115.3
Mould moisture content / Density, CBR 95% 90%	17.5 101.7 96.3							11.2 113.8/109 107.3/37					13 107.6 102.0
Density	107.6 102.7							113.9 115.3 114.0					113.3 107.6
C B R	86 64							148 50 82					109 56
Swell	0.0 0.0							0.1 0.0 0.0					0.0 [illegible]

C. B. R. Density Diagrams



TEST RESULT SHEET 34: WEARING COURSE QUALITY CALCRETE FROM NORTH OF THE GAZA LINE.



BORROW PIT INFORMATION

BORROW PIT No

Farm

Owner :

Chainage :

COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of base	Min. % of mod AASHO Density required	Range of Opt moist content	Approx. Quantity yds 3

REMARKS

		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Visual Description		pbls + br adj al		[illegible] L bn [illegible] al	calc pbls + L bn adj al	[illegible] 6 [illegible] al	[illegible] L bn adj al	pbls + br [illegible] al		+ L [illegible]	[illegible]	calc pbls + L bn adj al.	[illegible]	calc pbls + L adj al	calc pbls + L al	calc pbls + L al	L cly al	[illegible]	[illegible]	[illegible]	[illegible]
Stabilized with	Ex mould		Ex mould						Ex mould												
Sample No	D C B R	1148	1148 1149	1150	1151	[illegible]	[illegible]	[illegible]	1155	1156	115[illegible]	[illegible]	[illegible]	1171	[illegible]	[illegible]	1159	[illegible]	1161	[illegible]	[illegible]
Hole/depth below exist grd level		[illegible] 66-102"	1 66-102"	2 44"[illegible]	4 72-95"	[illegible]	5 [illegible] 56	6 [illegible]	7 27"-61"	[illegible] 24" 72"	8 [illegible]-56"	9 [illegible]	[illegible] 42"-75"	11 44 72"	12 41"-59"	3 46 75"	A 12"-46"	A 46"-120"	B 0 15	B 15"-60"	B 60"-[illegible]
PRA classification/group index		A [illegible]	A1-a	A1-6	A1-b	A1-[illegible]	A2-4	[illegible]	A1-a	A2-A	[illegible]	A [illegible] 0	A.[illegible]	A1-a	A2-4	A2-4					
Screen analysis	1½ | ¾	98 79	100	76 68	98 72	95 [illegible]	85 [illegible]	93 69	100	92 82	98 76	6[illegible]	98 83	93 67	90 72	85 61					
	0.85 | 0.078	23 2[illegible]	43 46	41 39	47 46	27 26	73 72	29 2[illegible]	50 46	44 41	44 42	[illegible]	42 3[illegible]	29 27	38 36	31 28	100	100	[illegible]	[illegible]	100
	0.064 | 0.028 0.002	25 4/3	33 6/5	33 4/4	38 6/4	24 [illegible]	62 [illegible]	23 43	38 4/5	34 9/7	35 7/5	12 8/1	34 4/6	24 4/3	32 9/8	24 4/3	98 81	94 73	[illegible] 51	[illegible] 66	[illegible] 9
Soil mortar grading	coarse sand | C fine sand	15 27	15 [illegible]	15 13	17 [illegible]	10 [illegible]	14 [illegible]	15 26	15 23	17 [illegible]	17 18	[illegible]	13 22	11 27	10 [illegible]	14 19					
	M fine sand | F fine sand	25 22	24 2.	39 23	27 20	32 31	28 2[illegible]	27 23	26 [illegible]	31 [illegible]	33 23	[illegible]	28 22	28 23	24 19	[illegible]	17	27	49	[illegible]	[illegible]
	Silt | Clay	6 5	5 8	7 [illegible]	6 4	6 [illegible]	[illegible]	5 4	6 8	5 [illegible]	7 4	[illegible] 4	9 6	6 [illegible]	26 [illegible]	20 -	20 63	10 63	19 32	8 59	2 [illegible]
Atterberg limits	L L L | P.	0 [illegible]	[illegible]	0 [illegible]	5 P	[illegible] 1	[illegible]	5 P	8 [illegible]	23 [illegible]	2 P	[illegible]	0 [illegible]	5 P	25 7	[illegible]	76 46	105 68	48 27	69 43	n p
	L.SH	0.0	[illegible]	0.0	[illegible]	[illegible]	[illegible]	40.8	[illegible]	[illegible]	[illegible]	[illegible]	10.5	20.5	3.5	4 [illegible]	17.5	20	8.5	4[illegible]	[illegible]
Opt moisture Density at mod AA[illegible]			7.4 1323						7.5 1287												
Mould moisture content	Density 98% 93%		7.5 [illegible] 1184						7.3 122.8/96 115.6/90												
Density			1302 1272 125						1277 1225 1206												
C B R			330 151 150						240 86 83												
Swell			0.0 0.0 0.0						0.0 0.0 0.0												

C B R Density Diagrams

TEST RESULT SHEET 35: CALCRETE GRAVEL AND CLAY FROM A PAN IN THE KALAHARI.

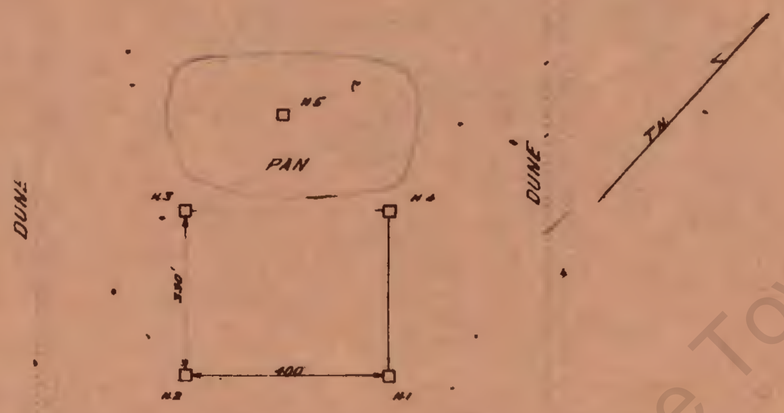
BORROW PIT INFORMATION

BORROW PIT Nº

Farm :

Owner :

Chainage .



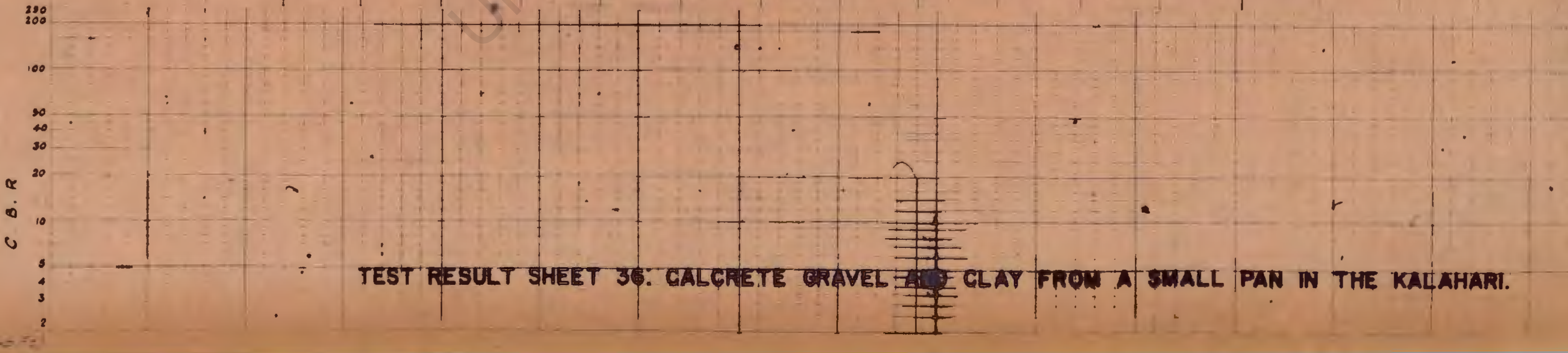
COMPACTION REQUIREMENTS and QUANTITY

Material	Horizon measured from top of base	Min % of mod. AASHO Density required	Range of Opt moist content	Approx. Quantity yds 3

REMARKS

		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
Visual Description		L Br sdy sl	wht sdy sl + calcr pbls	L Br sdy sl	wht sdy sl + calcr pbls	L Br sl	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] clyd	[illegible]	[illegible]
Stabilized with/Ex mould																
Sample Nº	IND C B R	1264	1265	1266	1267	1268	1269	1270	1271	1272	1273	1274	1275	1276	1277	1278
Hole/depth below exist. grd level		1 6"-78"	1 78"-120"	2 0"-42"	2 42"-94"	3 0"-18"	3 18"-34"	3 34"-60"	3 60"-80"	3 80"+	4 0"-54"	4 54"-90"	4 90"+	5 0"-15"	5 15"-39"	5 39"+
P R A classification (group index)		A2-4	A2-4	A2-4	A1-b	A2-6	A2-6	A2-6	A2-4	A2-4	A2-4	A2-6	A2-6	A7-5	A7-6	A7-6
Screen analysis	1½ - 3/4		100 98		97 91	100	100	100	99 90	100	100	100 87	100 91			
	0 83 - 0.078	100	81 79	100	60 57	92 91	87 86	88 88	38 35	93 91	33 33	48 44	69 67	100	100	100
	0 0164" - 0.0029, 0 0021	78 11/7	65 11/7	76 10/6	45 9/8	67 18/15	[illegible] 16/14	78 16/16	29 8/6	78 16/15	34 10/8	33 10/8	54 14/11	92 68/65	98 92/91	96 92/91
Soil mortar grading	coarse sand - C. fine sand	13 17	20 25	24 15	21 24	26 15	26 16	23 14	30 30	20 15	23 17	27 22	19 23	6 6	2	2 1
	M fine sand - F. fine sand	37 25	23 31	31 24	23 22	24 17	26 15	29 20	21 21	31 21	52 10	26 20	23 19	13 7	3 2	4 2
	Silt - Clay	5 3	6 3	4 2	7 3	3 15	3 12	4 6	7 10	[illegible]	- 2 -	5 13	4 12	[illegible]	9 2	9 2
Atterberg Limits	L L - P I.	S P	S P	S P	S P	24 12	25 12	S P	26 10	S P	S P	21 12	25 11	52 35	88 69	70 45
	L SH.	0.5	<0.5	<0.5	<0.5	2.0	2.0	<0.5	2.5	1.0	<0.5	2.0	2.0	14.0	[illegible]	15.0
Opt moisture	Density at mod AASHO															
Mould moisture content	Density/C B R 95% 90%															
Density																
C B R																
Swell																

C.B R Density Diagrams

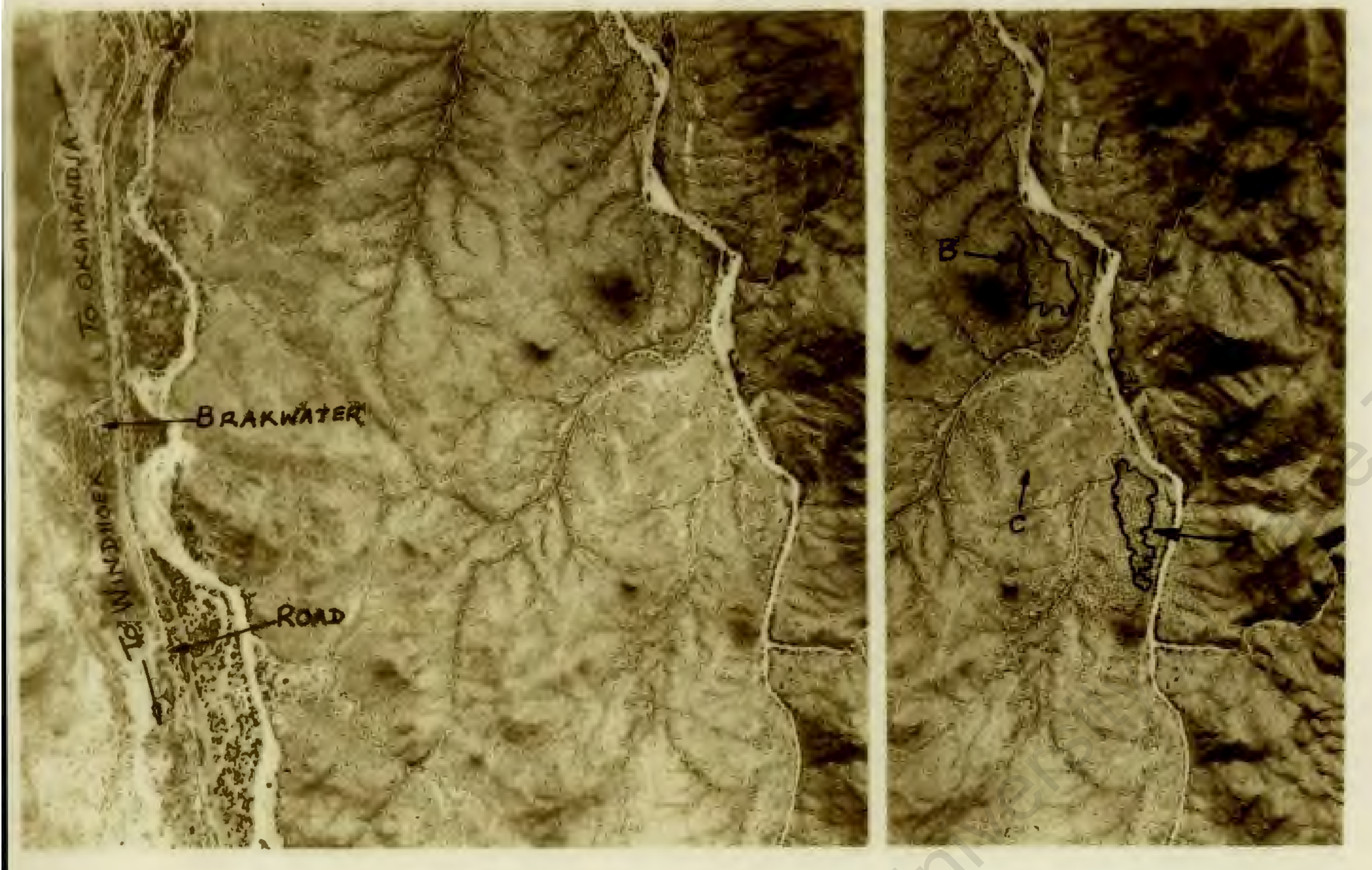


TEST RESULT SHEET 36. CALCRETE GRAVEL AND CLAY FROM A SMALL PAN IN THE KALAHARI.

APPENDIX C : STEREOGRAMS 1 TO 29 AND MOSAICS 1 TO 2

Below is a reference list with details of the contact prints used in the preparation of Stereograms 1 to 29 and Mosaics 1 and 2. Unannotated contact prints of stereopairs and stereotriplets comprising Stereograms 1 to 29 are, however, also included in appendix D which is under separate cover, in order to allow a detailed examination under a large magnification stereoscope to be made of features and areas referred to in the text.

Stereogram /Mosaic	Job No.	Strip No.	Photo Nos.
Stereogram 1	294	15	4860, 4861
" 2	"	17	3338, 3339
" 3	"	17	3337, 3338
" 4	"	19	3232, 3233
" 5	"	18	3249, 3250
" 6	"	46	15,839, 15,840
" 7	"	49	16,985, 16,986
" 8	"	14	3432, 3433, 3434
" 9	"	14	3429, 3430, 3431
" 10	"	12	3546, 3547, 3548
" 11	502	38	8354, 8355
" 12	"	41	8651, 8652
" 13	"	40	8576, 8577
" 14	"	42	8772, 8773
" 15	"	37	8247, 8248
" 16	"	36	8171, 8172
" 17	"	34	7974, 7975
" 18	"	35	8080, 8081
" 19	"	33	7885, 7886
" 20	"	30	7626, 7627
" 21	"	37	8249, 8250
" 22	"	2~~8~~6	7~~428~~203, 7~~429~~204
" 23	"	26	7205, 7206
" 24	"	23	6973, 6974
" 25	"	24	7039, 7040
" 26	"	2~~6~~8	7~~203~~429, 7~~204~~428
" 27	Grootfontein - -Runtu	-	926, 927
" 28		-	940, 941
" 29	S256/62	3	7320, 7321
Mosaic 1	502	34	7976
	"	35	8080
" 2	S256/62	2	7309, 7310
		3	7320, 7321

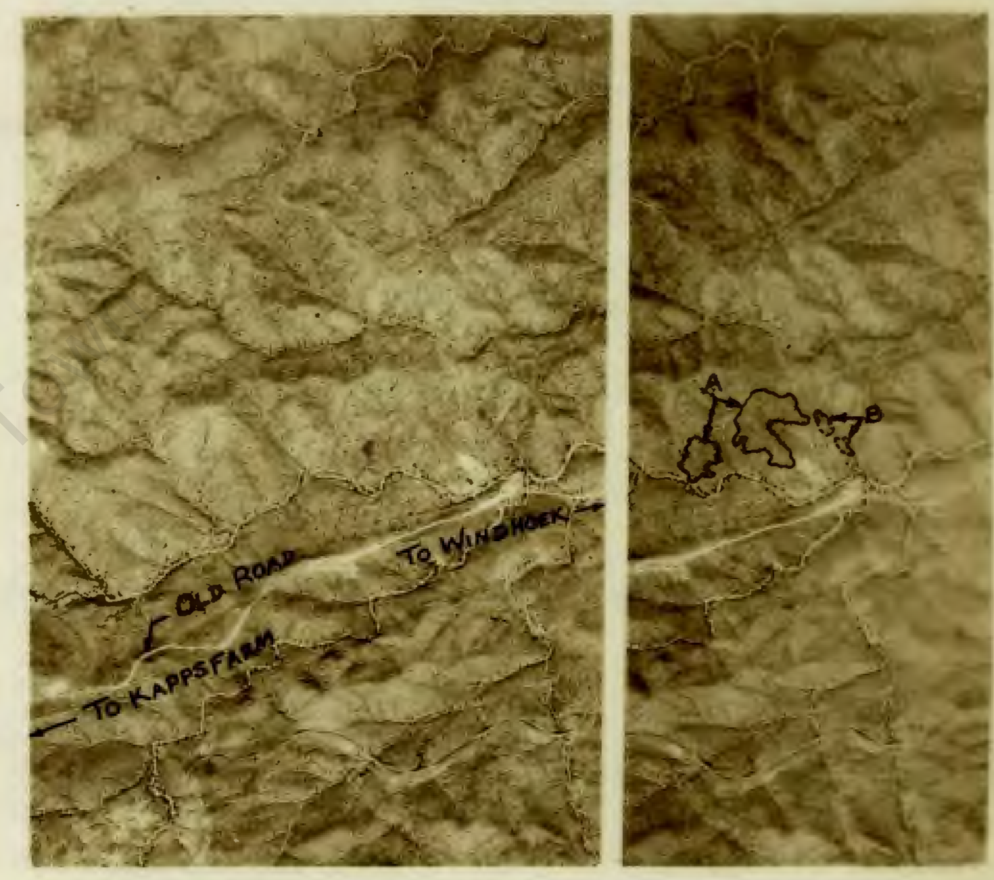


STEREOGRAM 1

(i) Area A contains natural basecourse gravel (see Test Result Sheet 1).

(ii) Area B contains gravel similar to that found in Area A.

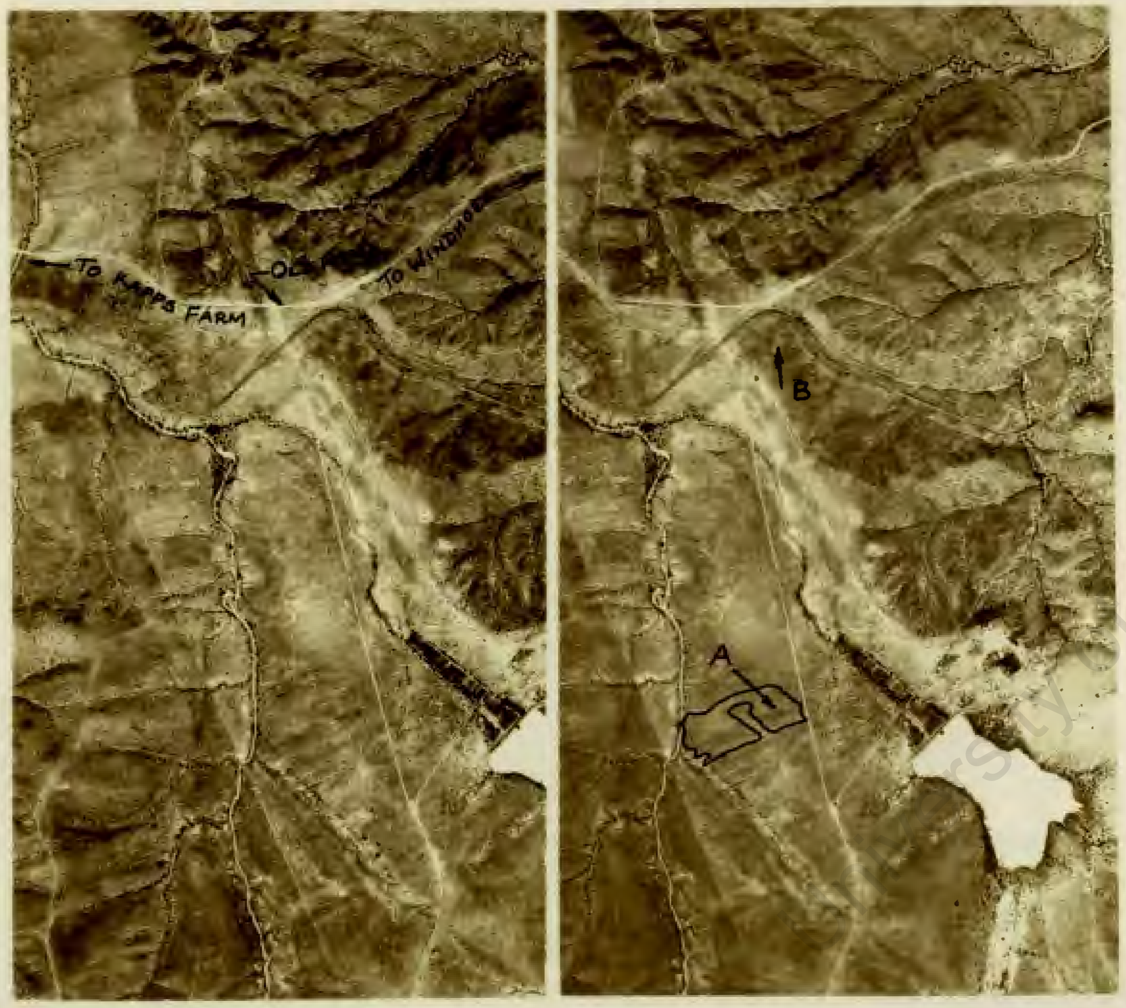
(iii) The arrow C points to the locality illustrated in Photo 5.



STEREOGRAM 2

(i) Areas A contained natural basecourse gravel (see Test Result Sheet 2).

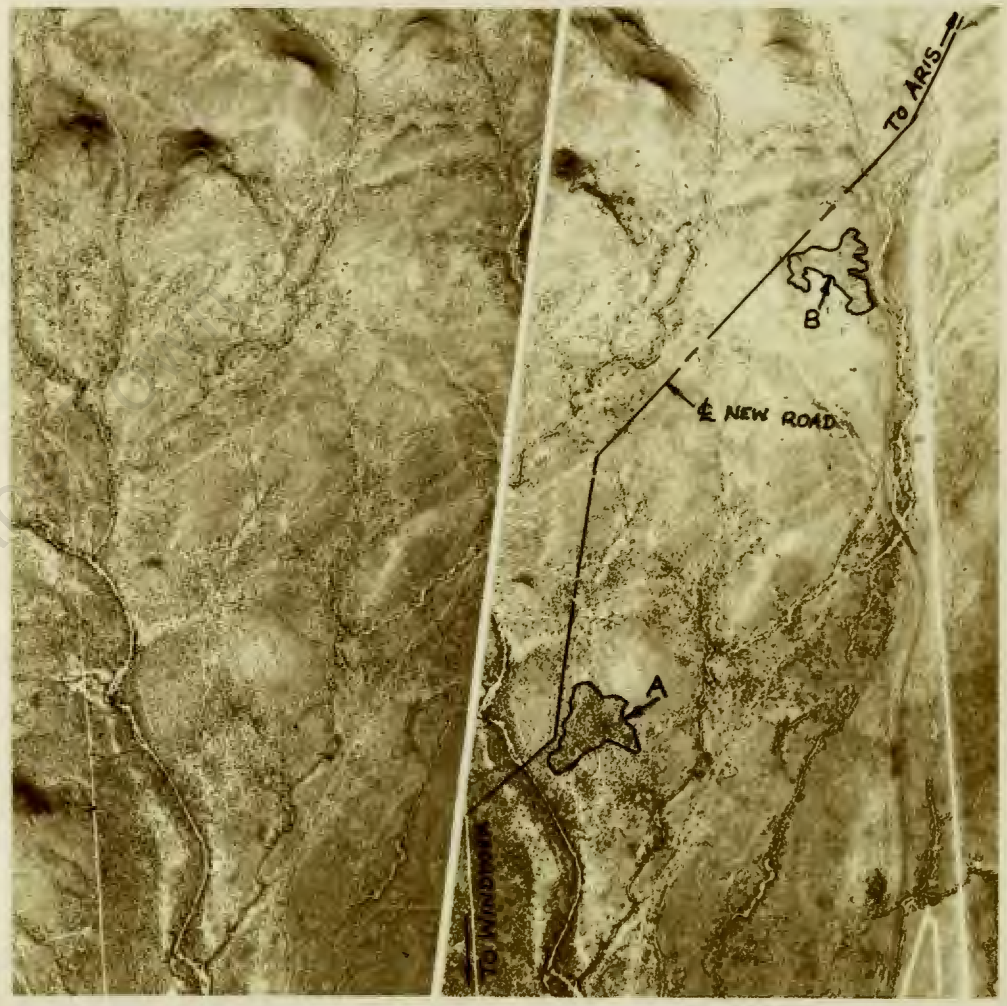
(ii) In Area B on the other hand, a contact between mica schist and quartzite formations is covered by thick scrub bush.



STEREOGRAM 3

(i) Area A contained natural subbase gravel (see Test Result Sheet 3).

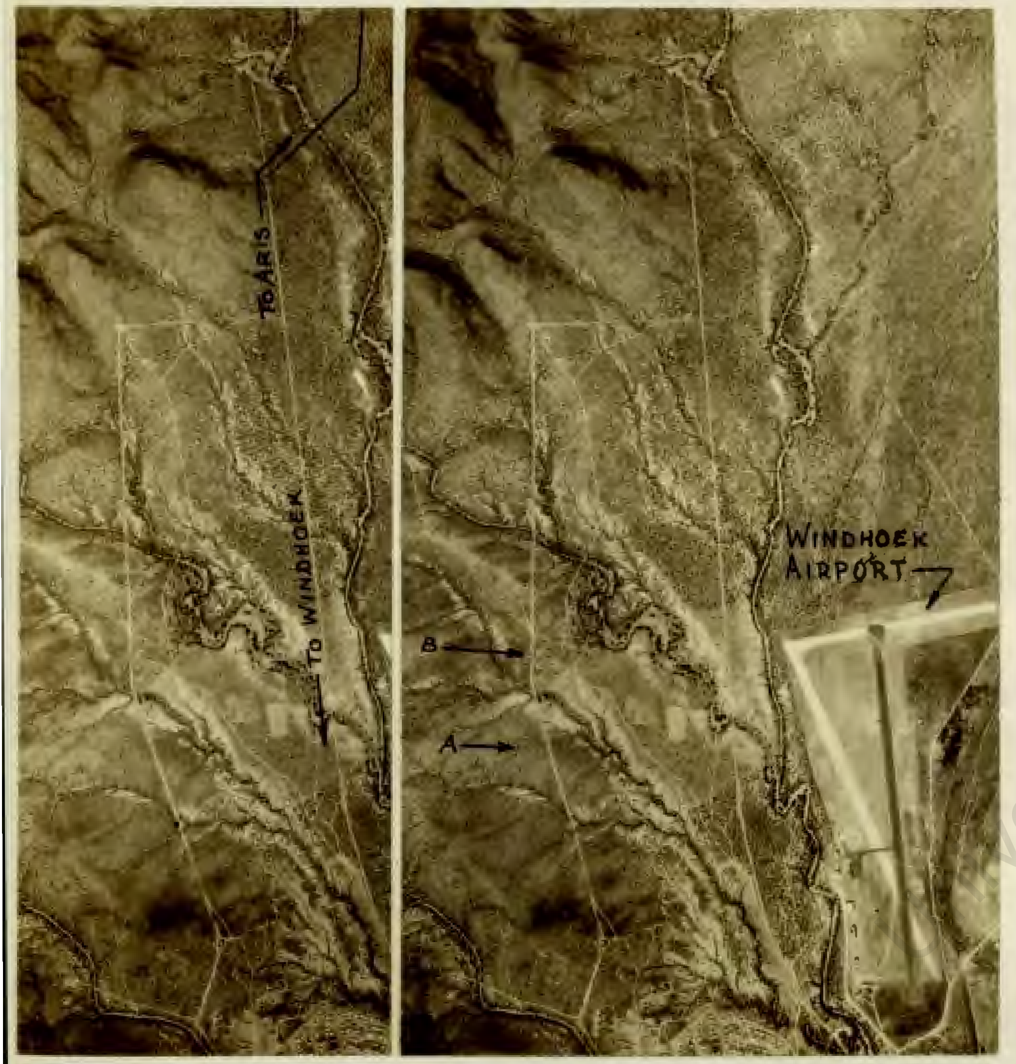
(ii) Arrow B points to the locality of a workable thickness of quartz gravel (see Test Result Sheet 4).



STEREOGRAM 4

(i) Area A contained natural basecourse gravel (see Test Result Sheets 4 & 4A).

(ii) Area B contained similar gravel to that of Area A.

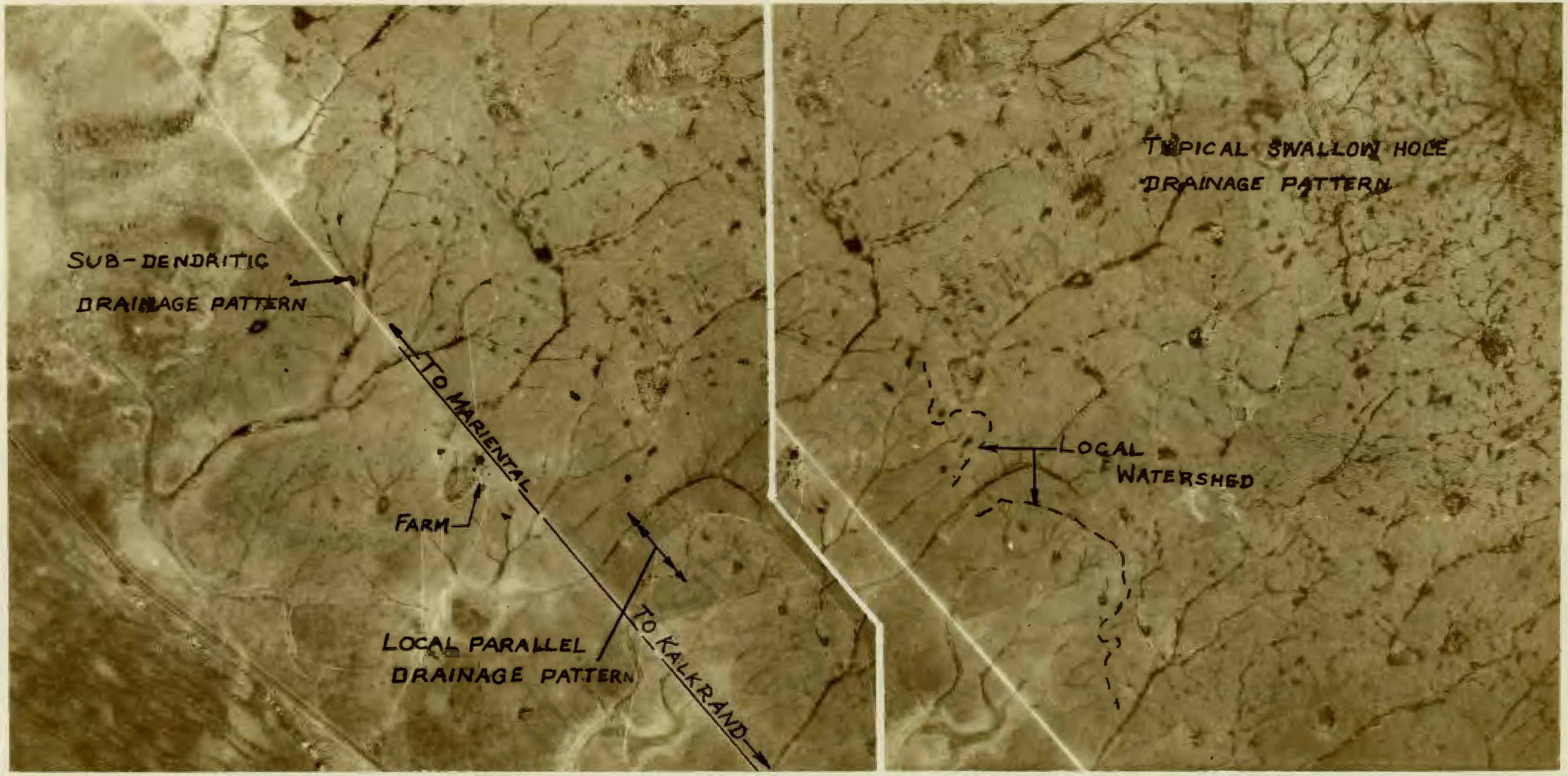


STEREOGRAM 5

A and B indicate the localities from which lime-stabilised subbase gravel was derived.

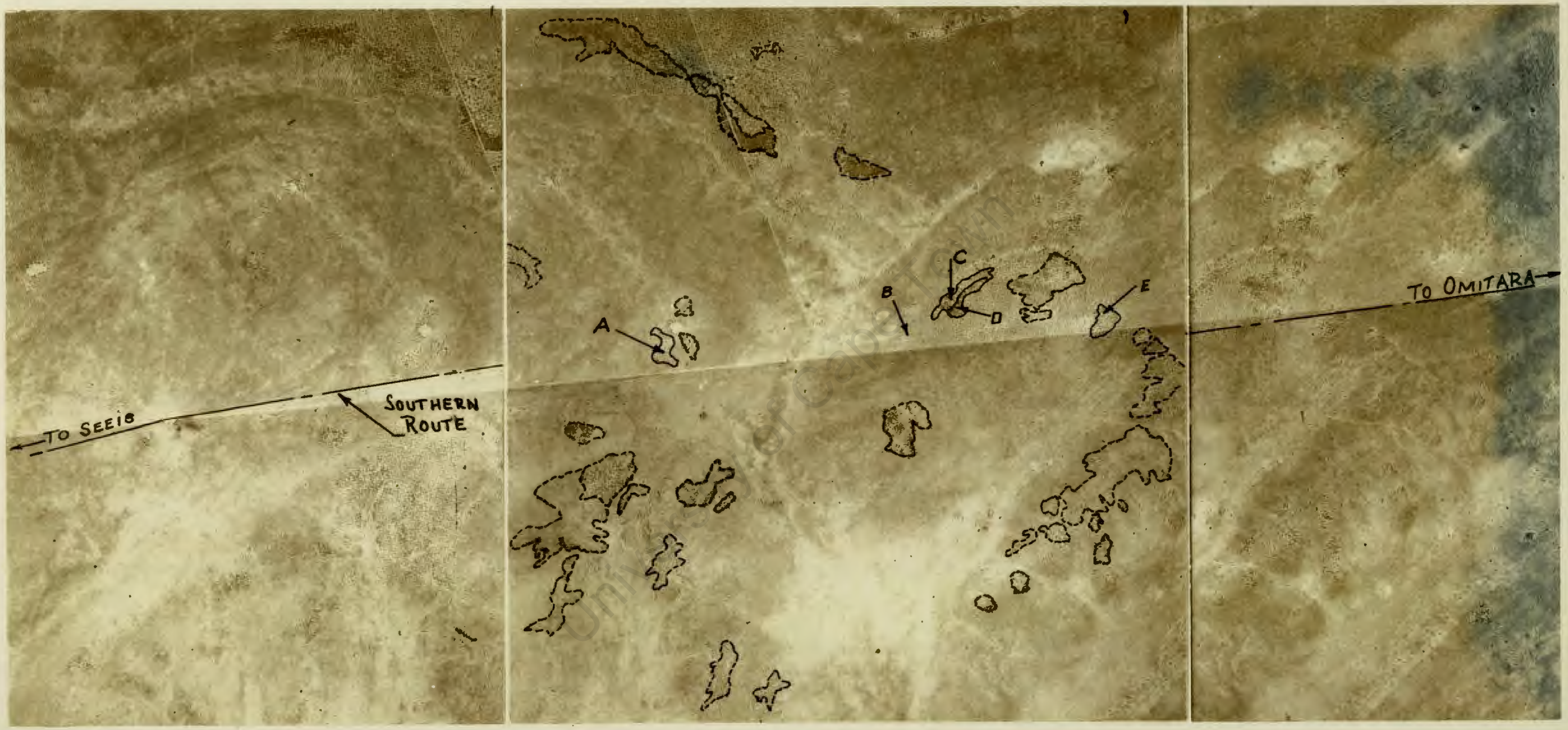
STEREOGRAM 6

A indicates the locality of a quartz gravel deposit used in the basecourse. (See Fig. 4, Borrow pit 10).



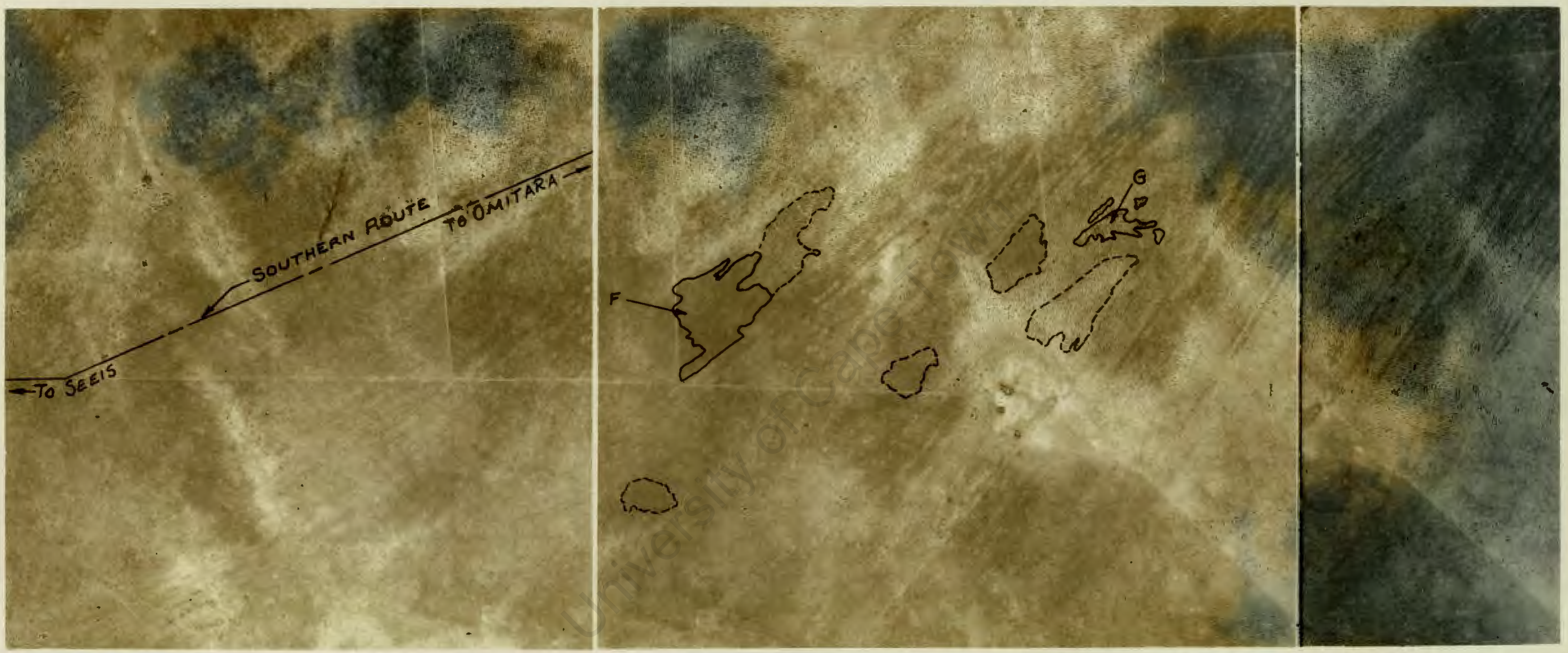
STEREOGRAM 7

The dotted line marks a local watershed formed by a thick layer of quartz pebble gravel which has protected the underlying basalt from erosion. (See Fig. 4, Borrow Pits 1, 2, 3 and 3A).



STEREOGRAM 8

A, B, C, D, E indicate sampling points along the southern route. (See Test Result Sheet 6 and Fig. 5). Dotted areas are similar by analogy, some having also been field checked.

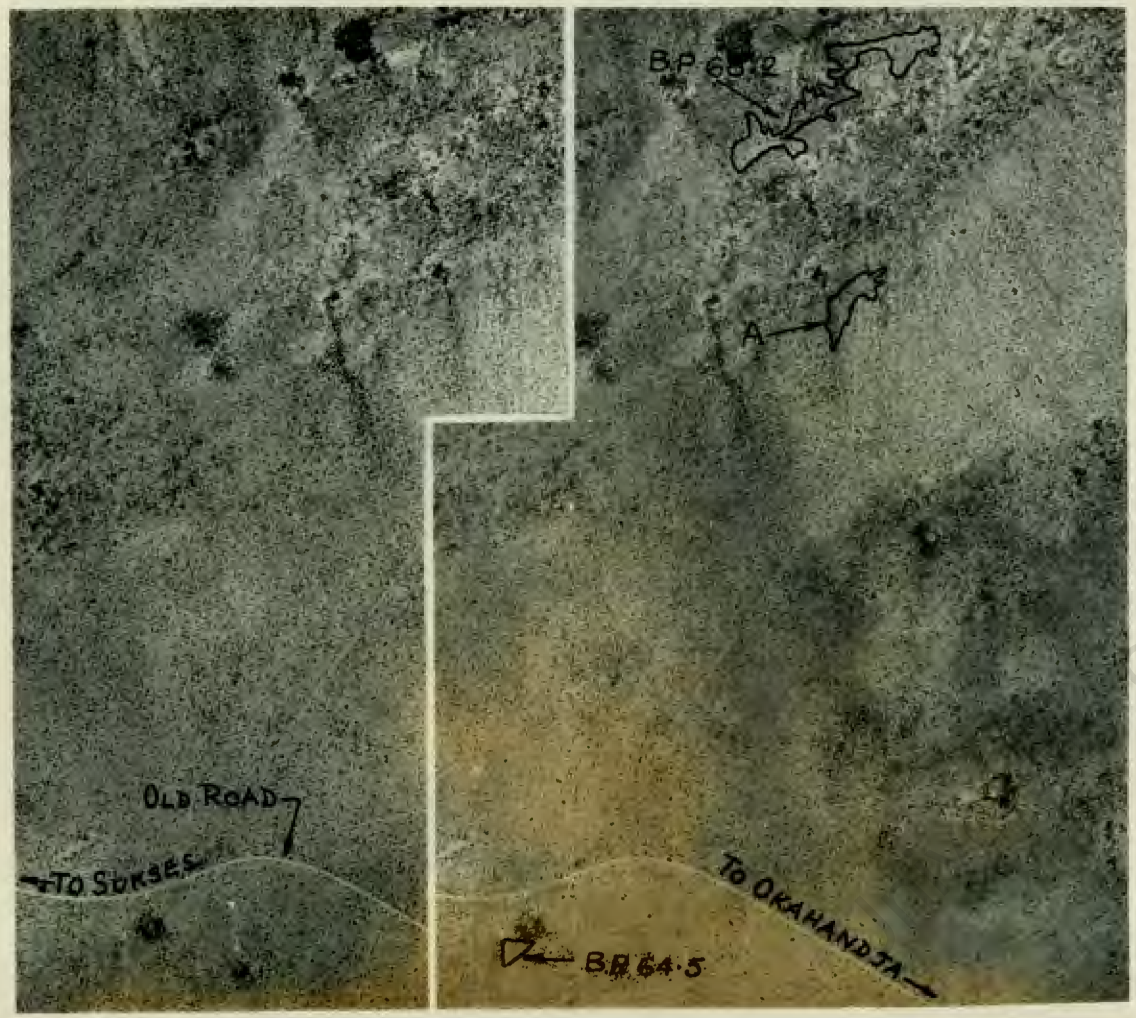


STEREOGRAM 9 (Stereotriplet)

F and G indicate sampling points along the southern route. (See Test Result Sheet 6 and Fig.5). Dotted areas are similar by analogy, some having also been field checked.

STEREOGRAM 10 (Stereotriplet)

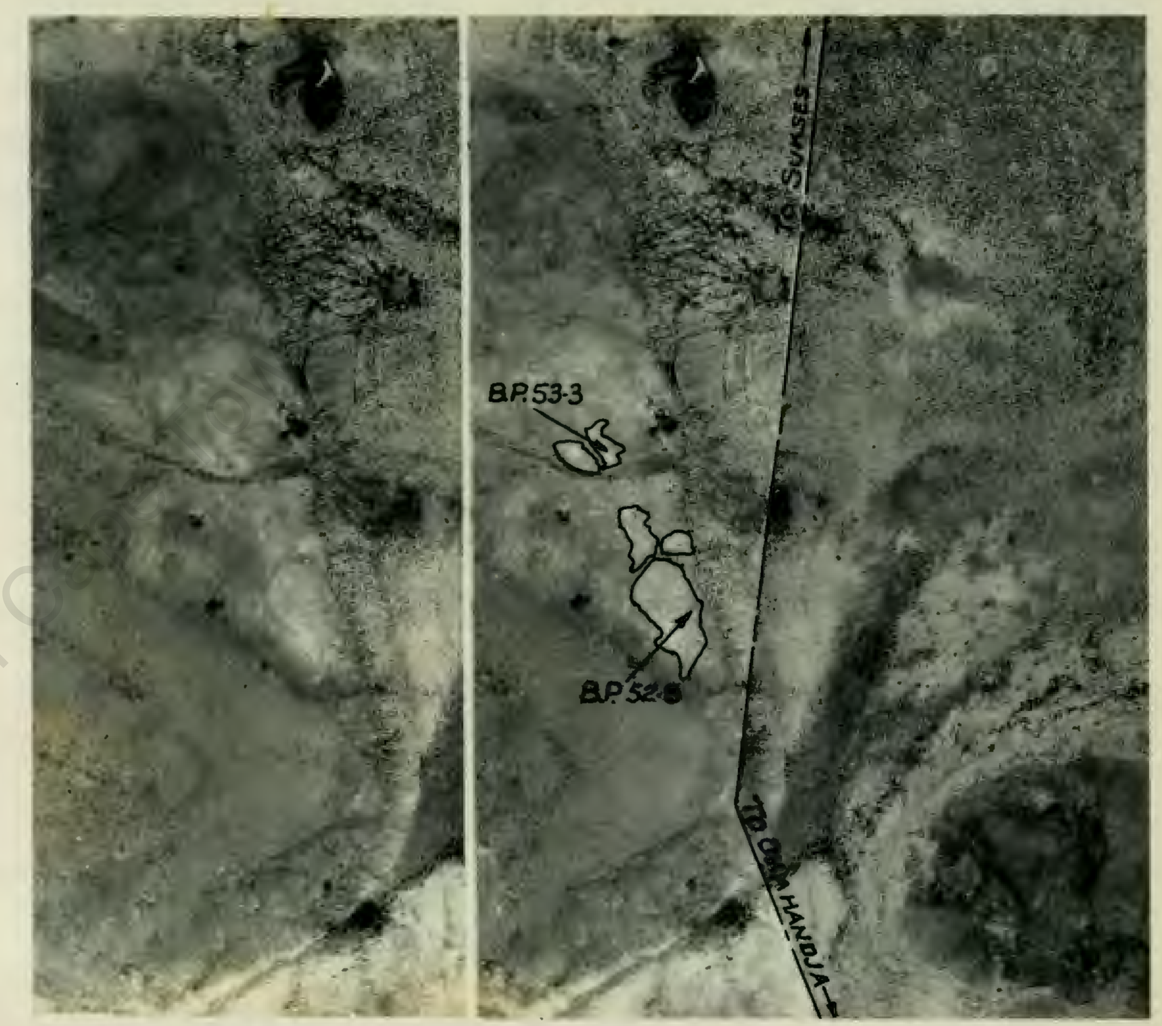
K indicates a sampling point along the northern route. (See Test Result Sheet 6 and Fig. 5). Dotted areas indicate some of the additional gravel deposits.



STEREOGRAM 11

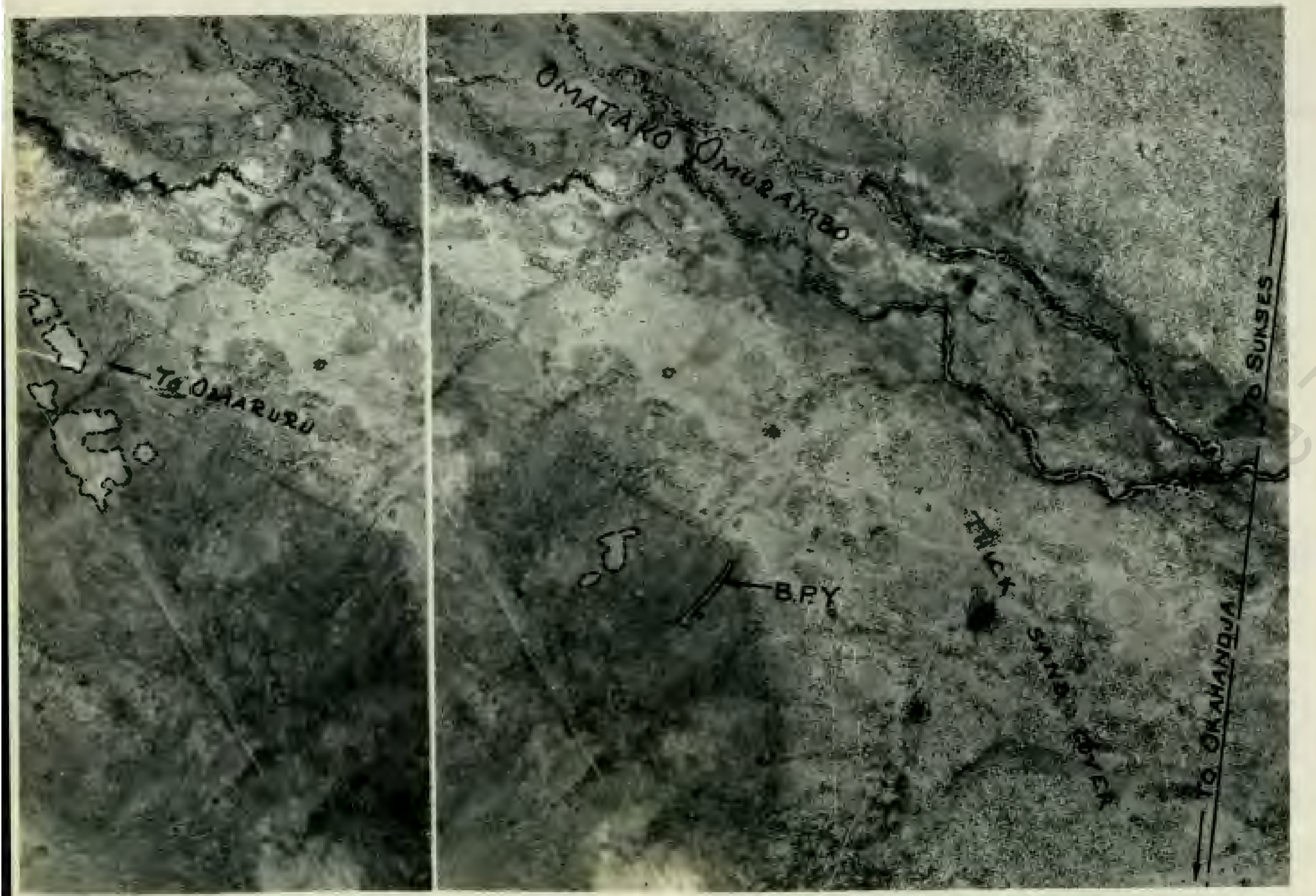
(i) Borrow Pit 68.2 consisted of a quartzose lateritic gravel deposit, which was fully used in the basecourse. (See Test Result Sheet 9).
Area A contained gravel similar to that of Borrow Pit 68.2

(ii) Borrow Pit 64.5 contained calcrete of shoulder quality. (See Test Result Sheet 7).



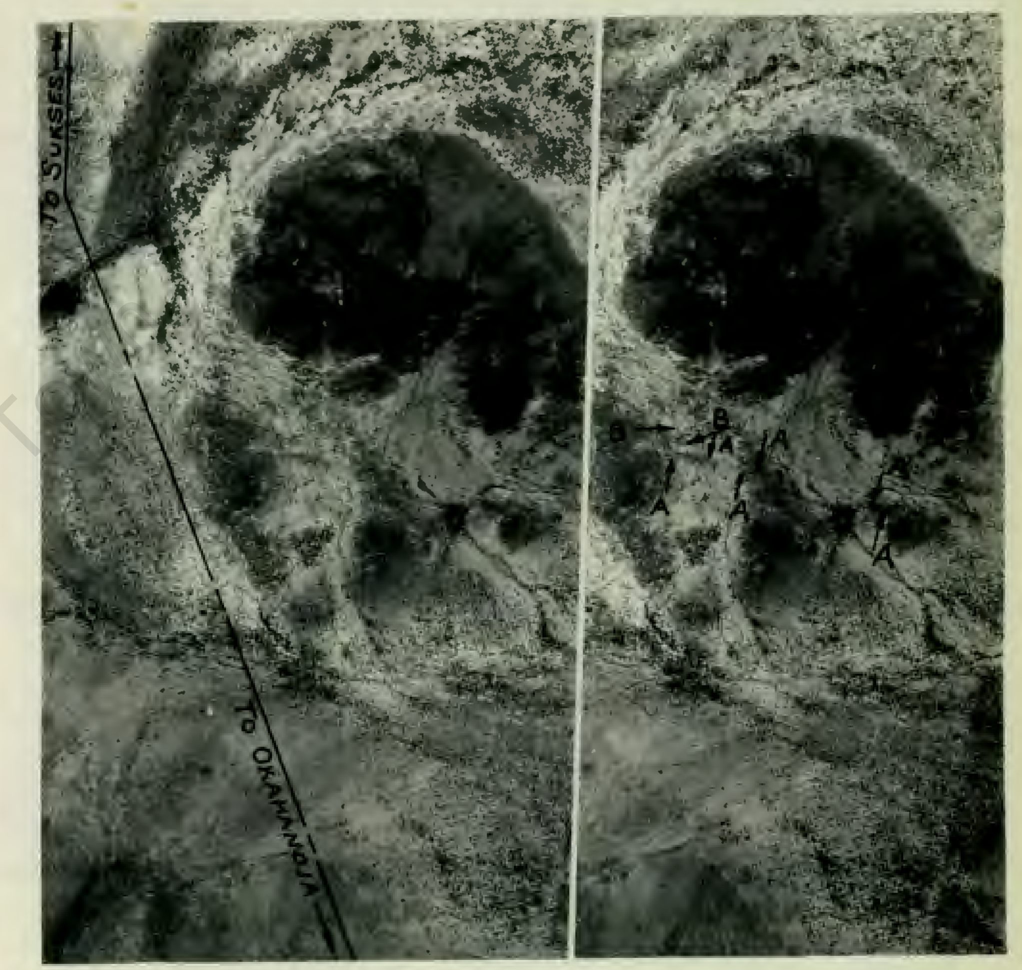
STEREOGRAM 12

The demarcated areas are relatively better developed calcrete occurences. The exact positions of shoulder Borrow Pits 52.8 and 53.3, located by the Consultants, are indicated by the respective arrow tips.



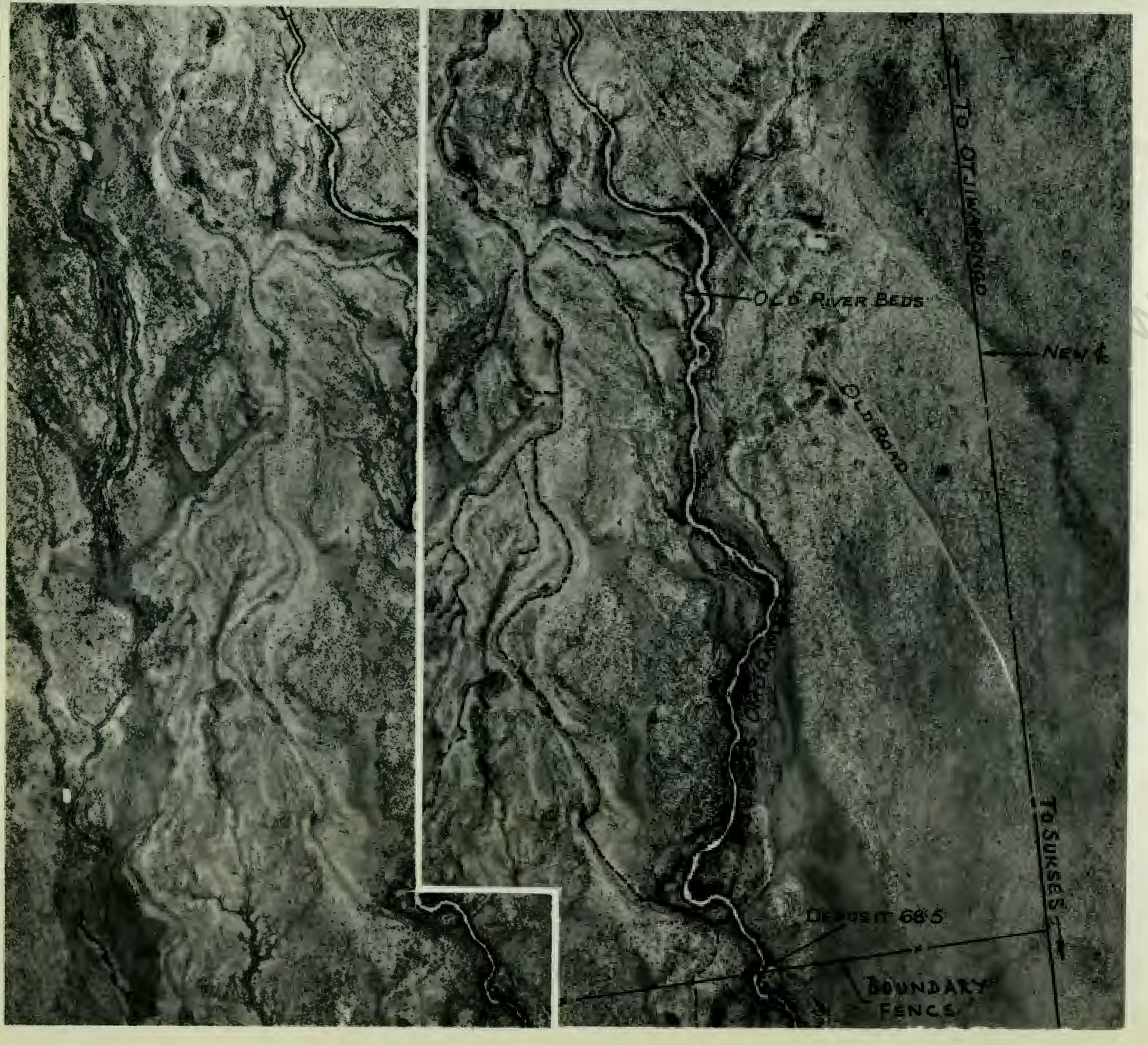
STEREOGRAM 13

The feature in which shoulder borrow pit Y is situated is demarcated with a full line and the exact borrow pit locality by the tip of the arrow. (See Test Result Sheet 8).
The dotted areas are further calcrete sources of potential shoulder material.



STEREOGRAM 14

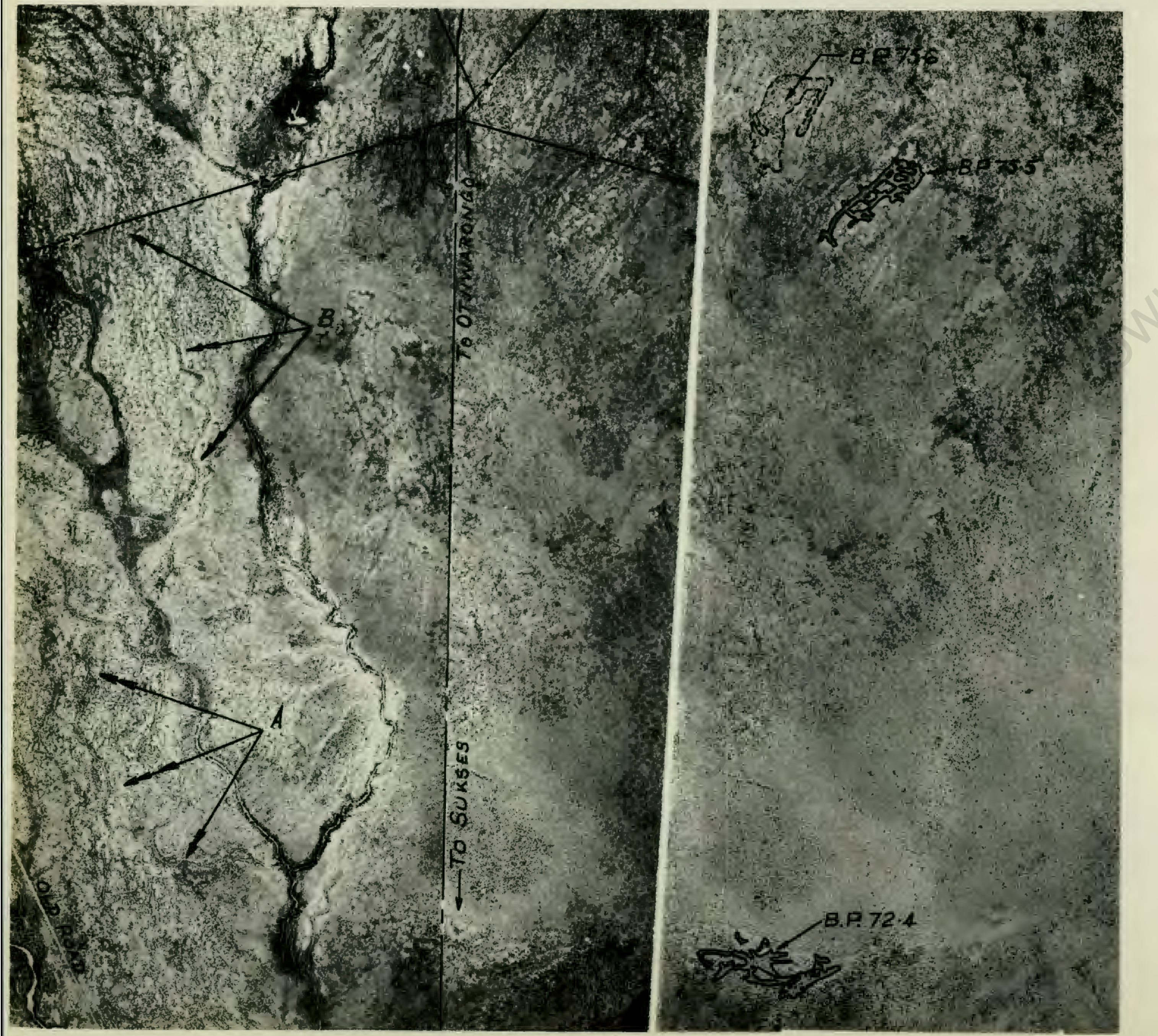
The tips of arrows A point to a dolerite outcrop. A subsidiary dolerite exposure is indicated by the tips of arrows B.



STEREOGRAM 15

(i) The old river system is indicated by a dotted line along one side of the raised river beds. The main bed is intact and easy to follow but some of the tributaries have been eroded away in places and are discontinuous.

(ii) Sand for slurry sealing was taken from the raised beds adjacent to the sand surface dressing deposit 68.5, the position of which is shown by the point of an arrow. (See Test Result Sheet 22 and Fig. 8).

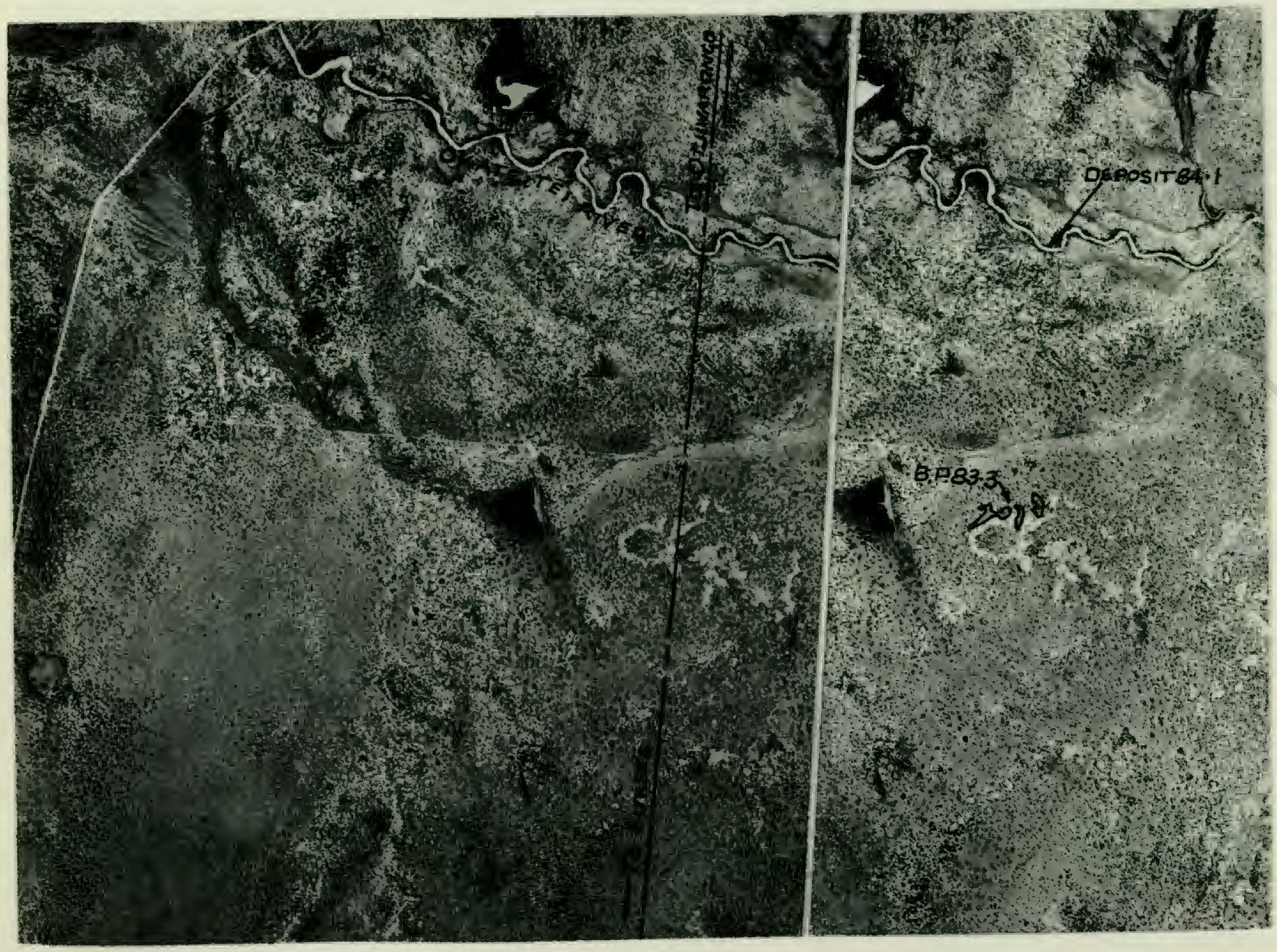


STEREOGRAM 16

(i) A full line delineates the features in which Borrow Pits 72.4 and 75.5 are located. (See Test Result Sheets 10, 10A and 14). A few areas not containing suitable gravel but too small to be delineated, can still be noticed within these demarcated features.

(ii) Within the boundaries of the dotted line are a series of small features. Borrow Pit 75.6 is located in a few of these. (See Test Result Sheets 11 and 11A).

(iii) Arrows A and B indicate large areas containing features similar to those in which Borrow Pits 72.4, 75.5 and 75.6 were established. However, sand to depths exceeding 10 feet was encountered in these features.



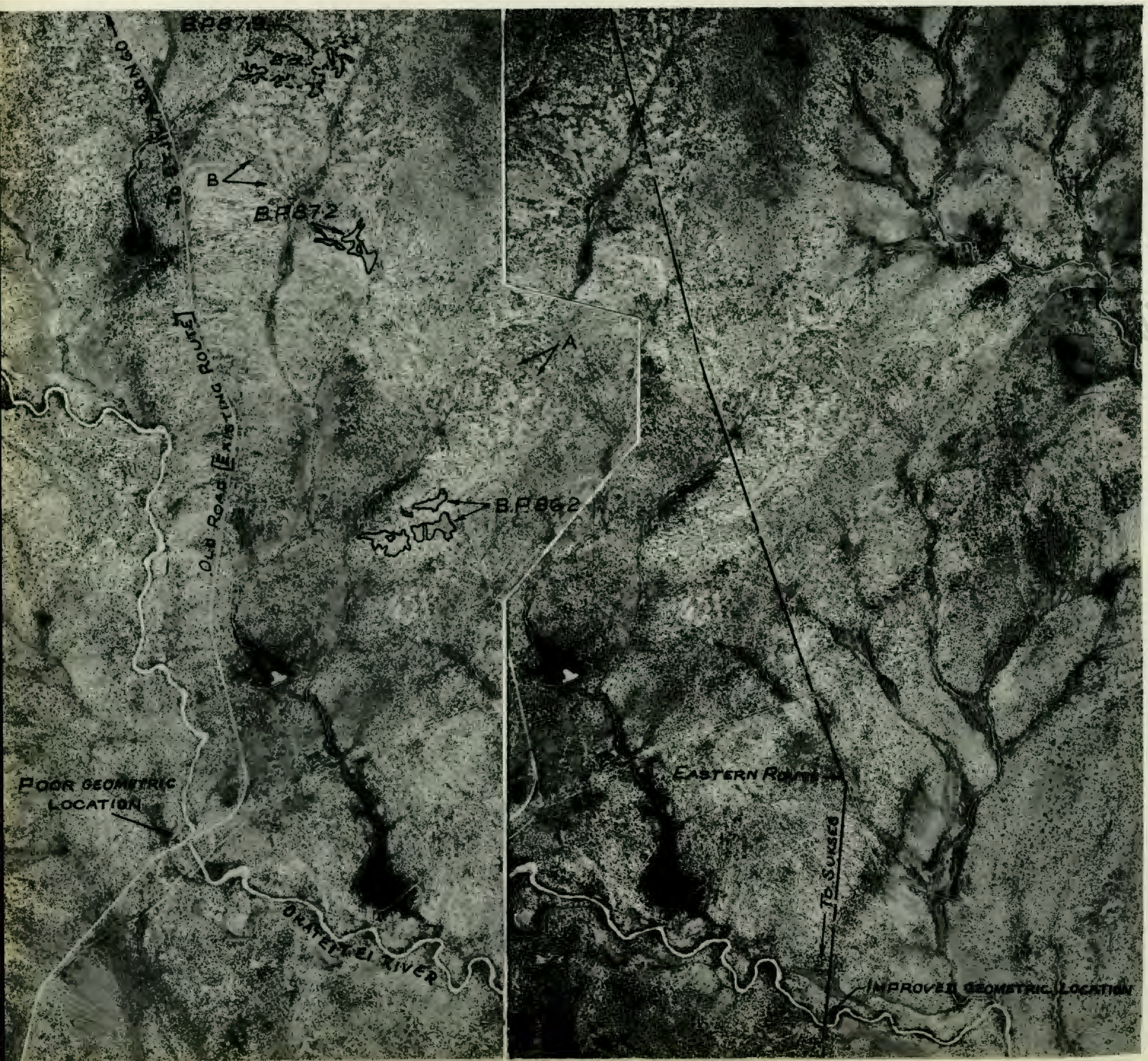
STEREOGRAM 17

(i) Borrow Pit 83.3 is located in the features indicated. (See Test Result Sheet 12).

(ii) The sand surface dressing deposit 84.1 in the Okateitei River straddles the centre line. (See Test Result Sheet 23).

STEREOGRAM 18

The positions of Borrow Pit 79.0 are shown. The area is very broken and exact demarcation on this scale of photography is not possible. (See Test Result Sheet 13).



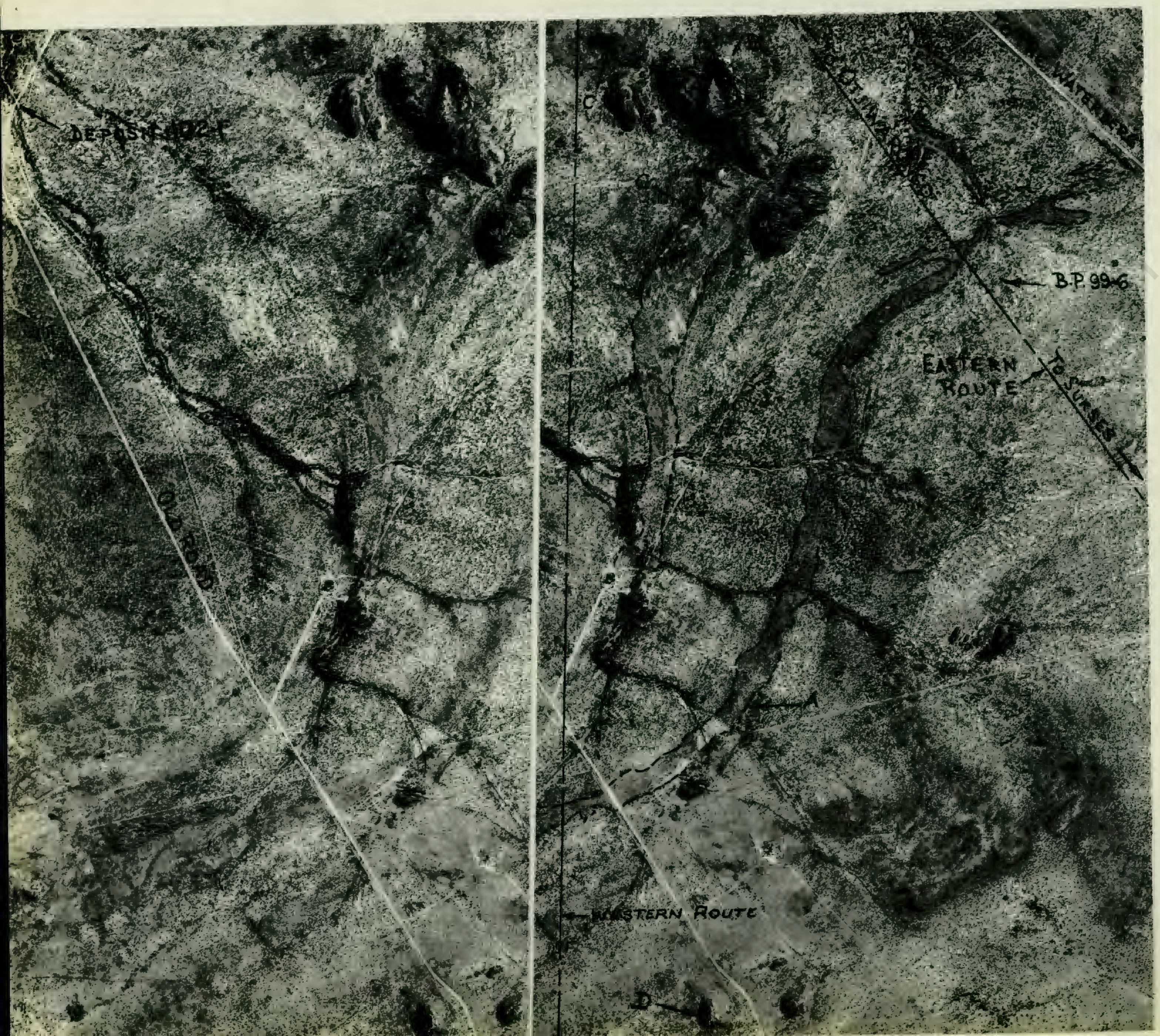
STEREOGRAM 19

(i) A full line demarcates low plasticity granite Borrow Pits 86.2 and 87.2 together with possible extensions in the same or adjacent similar features. (See Test Result Sheets 15, 15A, 15B and 16).

(ii) A dotted line marks the general limits of the low plasticity granite area in which Borrow Pit 87.9 is located. Within this area a number of small "islands" of higher plasticity granite can be observed, but on this scale of photography, exact delineation of these is not possible. (See Test Result Sheet 17).

(iii) The tips of arrows A and B are also in the type of feature in which low plasticity granite can be expected. These features have been left undelineated to allow a clear stereoscopic image for observation of the airphoto indicators.

(iv) Note the superior geometric location of the eastern route across the Okateitei River.



STEREOGRAM 20

(i) The dotted lines delineate two bands of crystalline limestone.

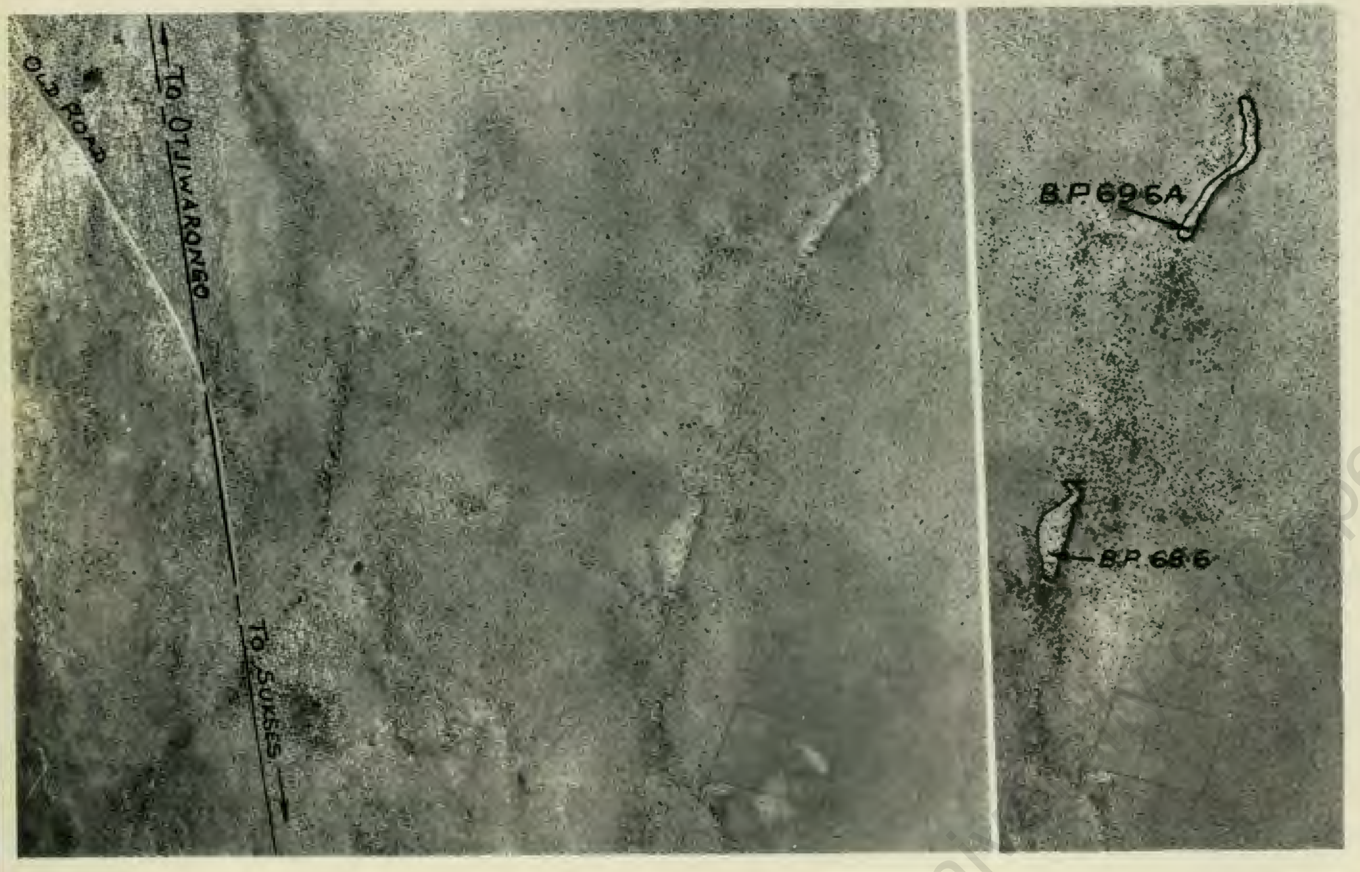
(ii) Arrow A points to the contact area next to one of the bands which was sampled during the materials appraisal of the Western Route (See Test Result Sheet 18). Borrow Pit 99.6 is established close to the same band of crystalline limestone and next to the centre line and was sampled after re-location to the Eastern Route. (See Test Result Sheets 19 & 19A).

(iii) The two arrows C indicate crystalline limestone hills. The rest of the hills in this group consist of either granite or a combination of granite and crystalline limestone. Note the difference in the texture between the two materials.

(iv) The tip of arrow B rests on the contact between the granite (top) and the crystalline limestone (bottom) formations which jointly comprise the chief constituents of this particular hill. Note the change of slope and texture which occur along the line of contact.

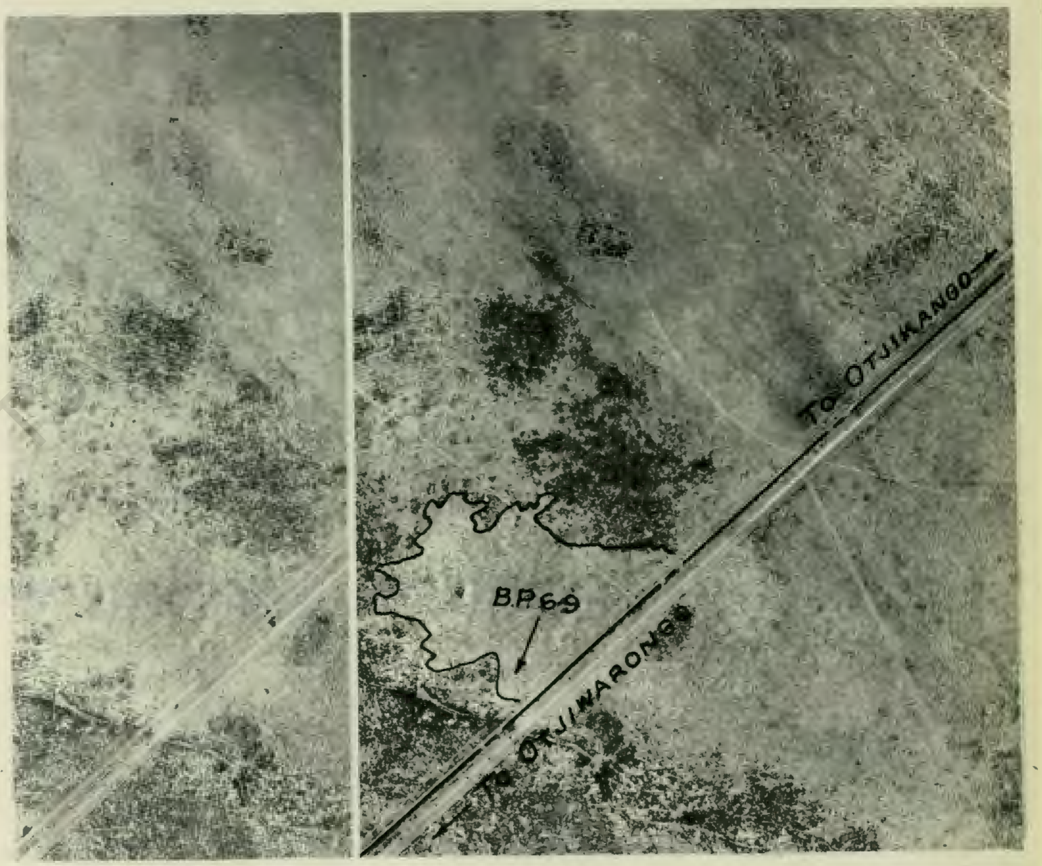
(v) Arrow D indicates the granite hill pictured in Photo 13.

(vi) An arrow shows the location of the sand surface dressing deposit 102.1. (See Test Result Sheet 24).



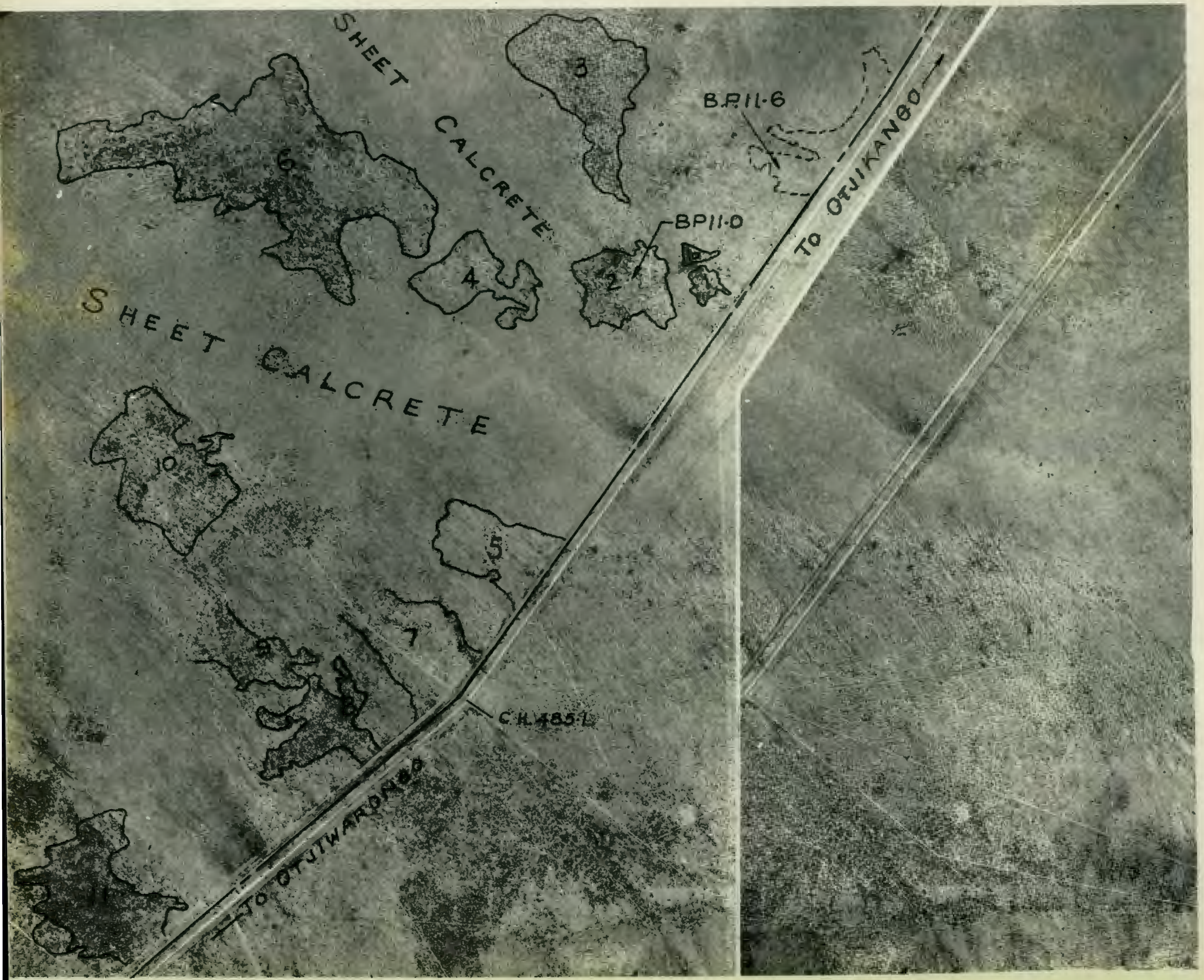
STEREOGRAM 21

The demarcated features consist of calcrete of shoulder material quality. Borrow pits 68.6 and 69.6A are located as indicated in these deposits. (See Test Result Sheets 20 and 21).



STEREOGRAM 22

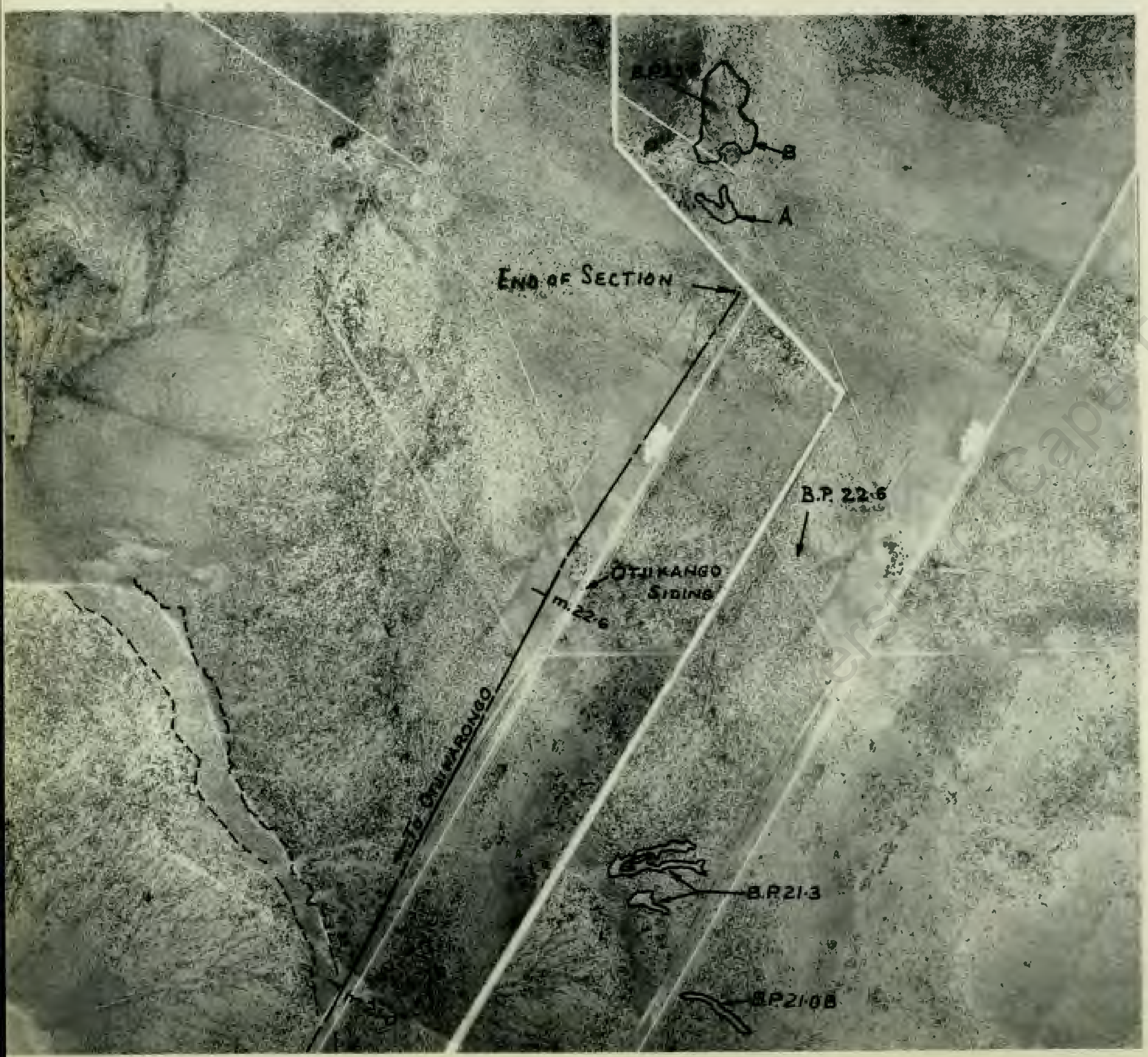
The position of subbase Borrow pit 6.9 within the demarcated limits of a granite occurence is indicated by the point of the arrow. (See Test Result Sheets 29 and 29A).



STEREOGRAM 23

(i) Areas 1 to 11 were originally delineated as possible sources of nodular calcrete suitable for use as screened natural base-course. The numbers 1 to 11 denote the priority order in which the respective areas were to be investigated. Areas 1 and 1a were found to contain powdery calcrete but a suitable deposit of nodular calcrete was located in area 2. (See Test Result Sheets 26 and 26A). There was therefore no further necessity to prospect the other areas. Demarcation lines are approximate only, as the original lines intended for prospecting purposes have been retained in their entirety, so as to better illustrate the method used. Note the comparatively prolific growth and lighter grey tone of the delineated areas in contrast to those of the surrounding terrain where only sheet calcrete occurs.

(ii) The granite area in which Borrow Pit 11.6 is located, is demarcated by a dotted line (see Test Result Sheets 30 and 30A).



STEREOGRAM 24

(i) The dotted lines delineate a band of crystalline limestone.

(ii) The demarcated areas next to this band are small granite occurences in which subbase Borrow Pits 21.3 and 21.0B were established. (See Test Result Sheets 31 and 31A).

(iii) Apart from other similar granite occurences, the remaining terrain flanking the band of crystalline limestone consists of surface limestone, which in places is covered by a thick layer of sand. The nodular calcrete basecourse Borrow Pit 22.6, is located in this surface limestone deposit in the area indicated by the arrow. (See Test Result Sheets 27 and 27A). However, much of the surrounding similar looking area contains unsuitable calcrete in either boulder or powdery forms.

(iv) Demarcated areas A and B are quartzite outcrops. Within area B a workable subbase Borrow Pit (23.9) was tested and proved but the exposure indicated as A is harder and workable gravel has not yet formed. (See Test Result Sheet 32).

TEREOGRAM 25

(i) The dotted lines delineate approximately the limits of granite rock formation. Definition of these boundaries varies from good to poor and exact demarcation would require a series of auger or boreholes, in selected areas. Sand cover is generally between 10 and 20 feet.

(ii) The area in which the quartzose lateritic gravel deposit is located (Borrow Pit 21.1) is demarcated with a full line. (See Test Result Sheets 28 and 28A and Photo 15).

(iii) Arrows A and B point respectively to stands of acacia and apple trees. (See Photo 16).

STEREOGRAM 2

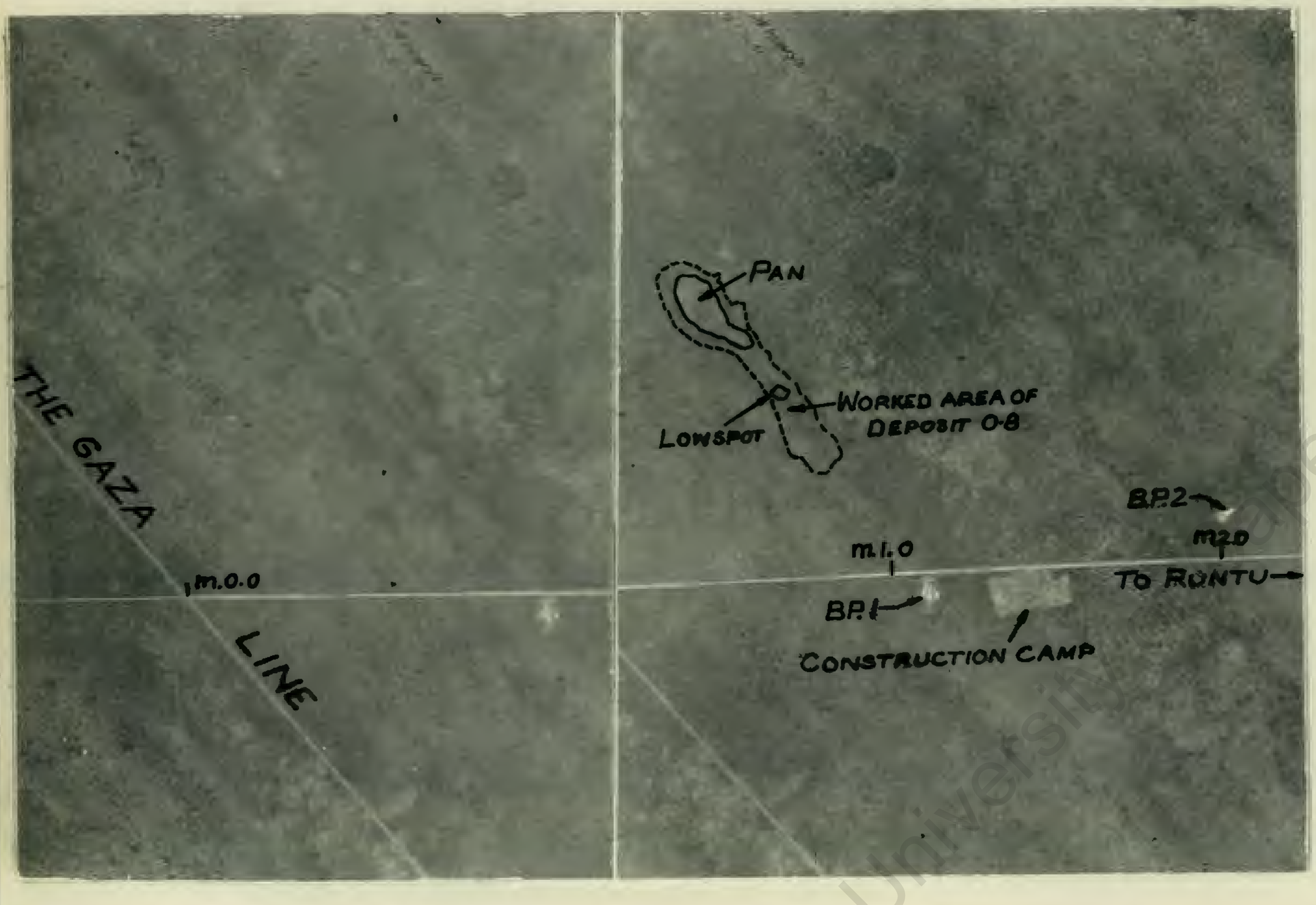
(i) The subbase and basecourse portions of Borrow Pit 1.3 are situated within the demarcated area. (See Test Result Sheets 25 and 25A to 25D). Note the relatively luxuriant growth and the lighter grey tone of this area.

(ii) Arrow A is entirely encompassed by an area with similar airphoto indicators to that of Borrow Pit 1.3. This entire area would be worth prospecting for similar quality calcrete if the necessity arose.

(iii) Arrow B points to a permanent railway crossing suitably positione for use from Borrow Pit 1.3.

(iv) Arrows C indicate stream beds with possible sources of sand for surfac dressing.

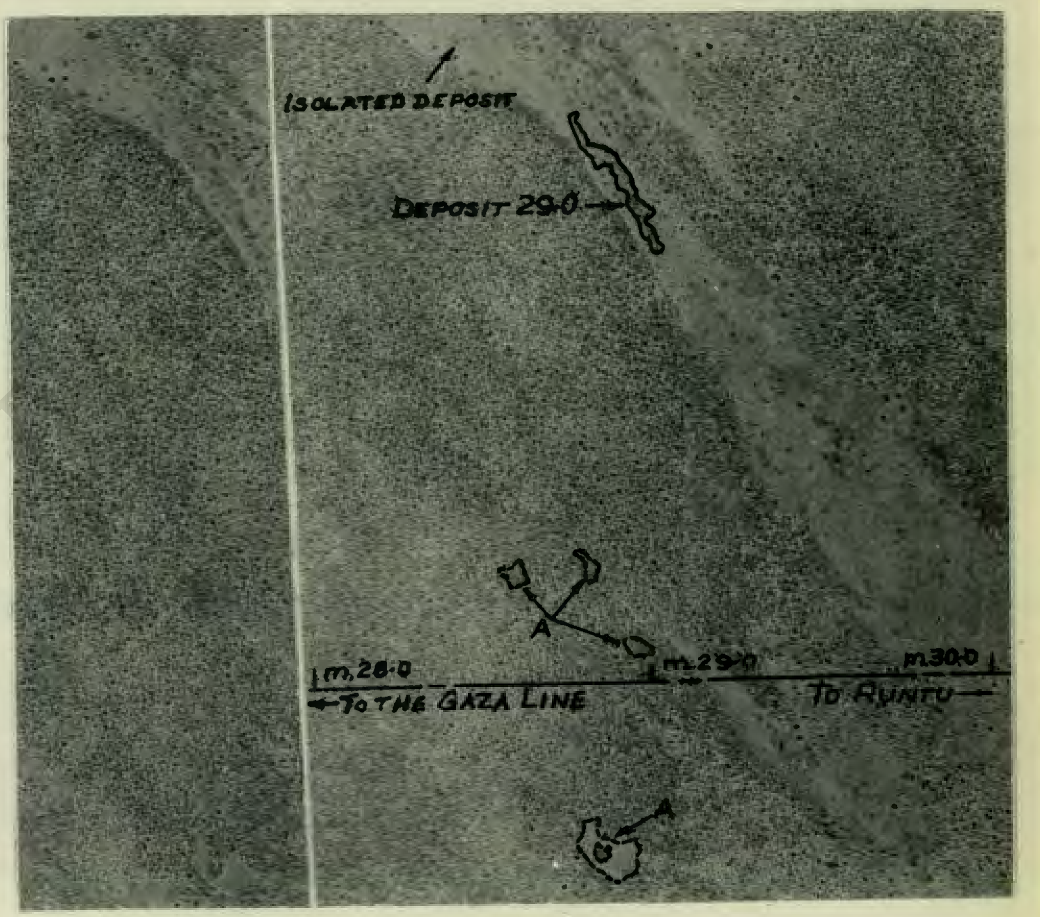
(v) Arrow D points to a tested deposit of sand on the Kalkveld road, which is a suitable surface dressing material.



STEREOGRAM 27

(i) The dotted line delineates approximately the boundaries of the calcrete deposit 0.8. The large pan and a low spot are also demarcated but with a full line.

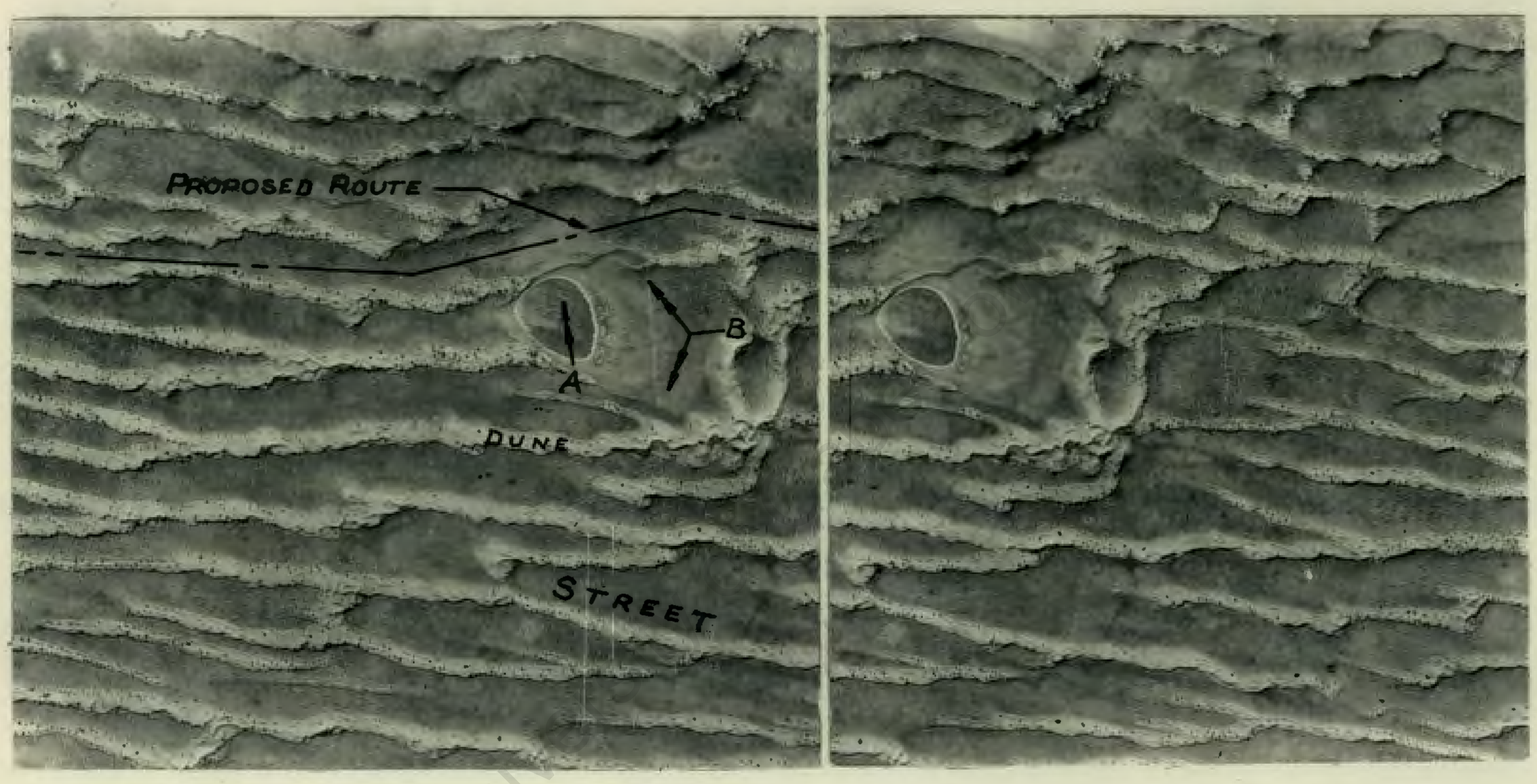
(ii) Borrow Pits 1 and 2 were worked prior to the photography and stand out well; Borrow Pit 1 being within half a mile of the 0.8 deposit.



STEREOGRAM 28

(i) Deposit 29.0 is demarcated with a full line and the position of a small isolated deposit further West is indicated by the point of an arrow.

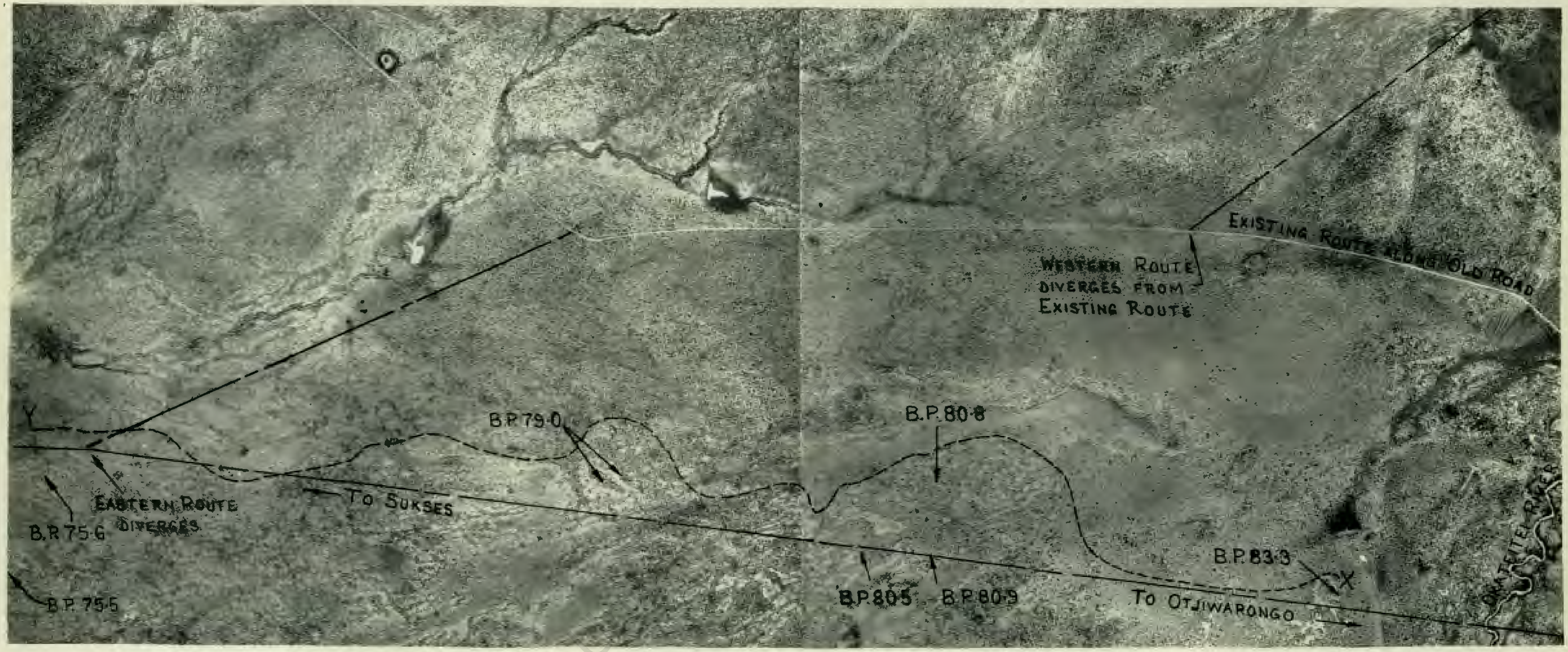
(ii) Arrows A point to pans, delineated by dotted lines, which are typical of this area.



STEREOGRAM 29

(i) The arrow A points to the pan floor from which a range of plastic clays was tested, while arrow B shows the approximate positioning of the calcrete gravel which occurs along the side slopes of the pan. (See Test Result Sheet 35).

(ii) Note the roughly parallel pattern formed by the streets and dunes.



MOSAIC 1 : (i) The dotted line X - Y represents the approximate western boundary of good quality road-building quartz and quartzose lateric gravel deposits. The positions of six specific base and sub-base borrow pits established east of this line are shown, but similar quality gravel exists over the whole of this area.

(ii) The points of divergence of the three possible routes referred to in the text are also indicated.

MOSAIC 2 : (i) Note the change in the pattern of the dunes coinciding more or less with the proposed route. The dunes tend to diminish in size towards the East and their pattern becomes less regular. (See Fig.11).

(ii) Arrow A indicates a low spot typical of those occurring in the streets. Note its darker grey tone compared with that of the street in which it occurs. The adjoining dunes, on the other hand, exhibit a much lighter grey tone (Arrows B), making them readily distinguishable on mosaics.