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REPORT ON THE SALT RESOURCES OF THE PINK LAKES IN THE COUNTRY OF WEEAH, VICTORIA

by

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DEPARTMENT OF SUPPLY AND SHIPPING.

Mineral Resources Survey.

REPORT ON THE SALT RESOURCES OF THE PINK LAKES IN THE COUNTRY OF WEEAH, VICTORIA.

Report No. 1943/12. Plan No. 824.

I. INTRODUCTION

This report follows a preliminary report dated 9th September, 1942, and it is not proposed to recapitulate the matter contained therein, although some references to the preliminary report are necessary.

II. ARE OF SALT LAKES.

The principal purpose of a second visit to the Lakes was to determine accurately the area of useful salt-bearing surface and the nature of the lake beds.

Much evidence confirmatory of the views expressed earlier regarding the structure of the lake beds was noted. However, a plane-table survey revealed that the total extent occupied by recoverable salt is considerably less than a casual inspection would suggest and consists of the following areas, which are shown on the accompanying plan.

Lake.	Water surfaces	Usual harvesting areas.	Extensions of harvesting areas	Total harvestable areas
	acres	acres	acres	acres
Sailor (Becking)	168	120	-	120
Crosby (Gye's)	200	110	40	150
Crescent (Home or Kenyon)	218	(West arm) 50 (East arm) 44	3 7	104
	646	324	50	374

The term, water-surface, is used to represent that area enclosed by the winter high-water mark in calm weather and excludes sandy beaches and some are s where brine is driven by the wind up gently shelving beaches or into flat swampy bays. Usualy harvesting areas means those parts of the lakes that are usually, but not necessarily regularly, harvested. In some years portions of these areas may be passed over for a variety of causes. The extensions are small areas on Crescent Lake over which the bed is strong enough to support rubber tyres vehicles and an area of 40 acres on Lake Crosby which it is believed was harvested in the past, but not in recent years.

III. THE LAKE BEDS.

Sections of the lake beds show the stratification mentioned on p 3 of the earlier report except that, in general, the sand (present near the margins only) and brown and black mud now lie beneath a crust of annual salt about 1-1½ inches thick. At the time of the previous visit this salt had not been deposited. The

lake beds vary in composition and structure from place to place, but the crust of annual salt is very uniform over almost the whole of 646 acres of water surface. The unharvestable portions, i.e. 272 acres, consist of marginal areas in which the annual crust rests on soft mud and, in the case of Lake Crosby, an area of some 30 acres in which soft patches of mud surrounding "blow-holes" are so close together as to render the area quite unsafe for horses or vehicles.

Blow-holes are common to the three lakes, but are more frequently developed on Lake Crosby. They are vents through the thick beds of permanent salt and have more or less vertical walls. They are filled with liquid black mud containing fine gypsum in suspension and possessing a very fould odour. The odour is much more repulsive than that of hydrogen sulphide alone, although that gas is undoubtedly present, and is strongly reminiscent of the smell of indole and skatole, two related products of the putrefaction of nitrogenous organic matter.

The blow-holes provide vents for the ascent of bring when the ground-water level rises, vertical movement of bring through the permanent salt being greatly impeded or absolutely prevented by horizontal sheets of gelatinous mud and the thin surface film of salt with a waxy appearance. The latter is formed probably by diurnal solution of salt by dew and the subsequent redeposition of the salt on evaporation during the succeeding day.

These blow-holes are generally only a few inches across, but they constitute a serious danger to horses and must be avoided when harvesting with horse-drawn scoops. A few larger onces, and groups of them, must be skirted by motor vehicles.

Should conditions permit, the formation of a crust of salt over a blow-hole or group of them, the rise of brine may inject mud beneath the salt crust before it cracks and relieves the pressure. In this way these vents cause a mingling of highly objectionable gypseous mud with surface salt over a radius varying ffom two or three inches to 15 feet.

Each lake is surrounded by a shelving sandy beach composed largely of gypsum sand and underlain by black mud and gypsum crystals. Immediately off-shore, the annual salt crust is thin and is supported on a layer of soft mud overlying either gypseous sand or seams of hard salt. This thin salt crust cannot support any weight and is not harvested. Continual seepage of saline ground-water into the lakes keeps the mud soft near the margins. As pointed out in the preliminary report, timber corduroys are necessary to provide access across this marginal soft belt to the harvesting areas.

The width of the soft belt surrounding the harvesting areas varies from place to place and appears to be a function of the angle of the slope of the beach. A gently sloping beach causes a more rapid retreat of the bring during the crystallising stage, while steeper slopes permit the formation of thicker crusts of salt with, necessarily, less mud underneath.

The lake beds are discussed in greater detail in later sections of this report which treat of each lake separately.

IV. THE ANNUAL SALT.

The crust of annual salt was not in existence at the time of the previous visit to the Lakes (in August, 1942) but it was stated that the layer formed annually at the Pink Lakes was generally less than half an inch in thickness. An examination of the lakes surfaces at many points however disclosed that the annual crust averages

between 1 and 1½ inches in thickness. There is a gradation in size of the crystals composing this crust. The upper part, with athickness of ¼ to ½ inch, consists of finely granular white salt with considerable free space between the crystals. This upper layer merges into compact pink salt below with crystals up to ¼ inch size. There is no sharp line of demarcation between these layers but the lower salt is of poorer quality and its compactness makes scooping more difficult. For these reasons the lower half of the annual crop has been left each year and the depth scooped has come to be accepted as the thickness of the annual crop.

The top layer of white salt appears to have been formed partly by rapid deposition just before the brine sinks below the surface and after the small quantity of mud present has been entrained in the lower salt, and partly by evaporation of brine brought to the surface by capillarity as suggested by Dr. F.J. Campbell. The removal of the brine to below the white layer prevents the continued growth of the constituent crystals in the upper layer to the sizes commonly present in the lower portion of the annual crust.

The annual salt crop rests on the mud described in the vertical section given in the earlier report and this mud in turn lies on a hard fairly smooth floor of very compact crystalline salt. The thickness of the mud layers varies from place to place and further details will be found in section 6 of this report.

V. METHOD OF HARVESTING.

Until this year harvesting was carried out with horse-drawn scoops, but the horses have now been replaced by trucks and tractors.

The first scooping of the lake surfaces aims to recover the whilte salt without admixture of the pink. This salt, known as No 1, is little different in composition from the pink, but is in a finer state of division and has a much better appearance.

The 'first cut' removes about ¼ inch and gets the bulk of the good quality salt. The surface is then scarified to about the same or rather greater depth and the 'second cut' taken. This recovers the remainder of the white salt and about ¼ inch of the pink and completes the harvesting operations.

The remaining pink salt is never removed and redissolves in winter with the rise of the ground water level leaving the top of the permanent salt exposed to the brine, except for a thin layer of slimy mud.

At a later stage in this report it is recommended that harvesting should be so conducted as to recover the whole of the annual salt. This modified procedure will be referred to as "deep harvesting".

VI. DESCRIPTION OF THE LAKES.

A. Sailor Lake (or Lake Becking).

(1) **Inaccessible area.** The unworkable area of this lake consists of the marginal soft band described above. The belt is up to 5 chains wide on the eastern shore where the beaches are wider and slopes comparatively gentle. There are some blow-holes in Sailor Lake, but the area affected by them is negligible and they are not shown on the plan. As suggested in the report of 9th September last, it has been found that trucks and tractors can operate

over softer ground than horses, but it is not considered that any extension of the usual harvesting area on Sailor Lake will be appreciable and accordingly no allowance has been made.

(2) Harvestable area. This consists of 120 acres of lake surface which bears an annual salt crust of very uniform thickness of 1½ inches resting on the permanent salt.

The top of the permanent salt forms a hard level floor of great strength.

A very thin layer of fluid black mud with a gelatinous brown film on top separates the annual from the permanent salt and permits the whole thickness of 1½ inches to part cleanly from the floor.

A typical section of the bed of Sailor Lake is -

White and pink salt	1½ inches.
Brown and black mud	1/16 inch.
Crystalline salt layer	2 to 3 inches.
Similar layer with coarser crystals	3 to 4 inches.
Clear glassy salt crystals.	more than 2 feet.

The three lower salt layers contain some entrained mud and gypseous sand.

B. Lake Crosby (or Gye's Lake).

(1) Inaccessible areas. The soft marginal belt around the lake is similar to that described above and occupies about 80 acres. A broad tongue of muddy ground extends nearly across the lake from east to west and is occupied by closely spaced groups of blow-holes and soft muddy patches. This tongue has an area of some 30 acres, and is covered with a salt crust totalling probably 3,000 tons, but none of this salt could be recovered as the crust is too weak to support vehicles or even persons walking upon it.

(2)Usual harvesting area. This area of 110 acres occupying the northern half of the lake is similar to the harvesting area of Sailor Lake and the descriptions of the latter apply equally well in this case except that the mud layer between annual and permanent salt tends to be thicker and the section is not so uniform in thickness.

(3) Additional harvesting area. Additional salt to that usually harvested can be won from an area of 40 acres south of the tongue of muddy ground mentioned above. This area has not been harvested for many years principally because of the slight difficulty of access round the muddy ground and a lack of much suitable ground for stacking salt on the banks of the south-west side of the lake.

Typical sections of the lake bed are as follows -

1. Northern harvesting area.

White and pink salt	1 to 1½ inches.
Brown and black mud	variable, probably ⅛ inch average.
Stratified crystalline salt with black bands	4 to 6 inches.
Coarsely crystallin salt	more than 18 inches.

2. Southern harvesting area.

White and pink salt	¾ to 1 inch.
Brown and black mud	about ½ inch.
Stratified crystalline salt	4 to 6 inches.
Gypsum sand	2 to 6 inches.
Coarsely crystalline salt	more than 18 inches.

3. Inaccessible Muddy tongue.

White and pink salt	¼ to 1 inch.
Fluid black mud and fine gypsum	not less than 2 feet.

4. Inaccessible Shore line.

Sand	1 to 3 inches.
Black mud	0 to 1 inch.
Gypsum crystals and sand	1 to 4 inches.
Salt	0 to 1 inch.
Sand	not less than 2 feet.

C. Crescent Lake (or Home Lake or Lake Kenyon).

1. Inaccessible area. The marginal soft strips and the narrow neck joining the two arms of Crescent Lake cannot be harvested.

2. Harvestable areas. The western arm has not been harvested for two years and now bears a crust of 1½ inches of white and pink salt over an area of 53 acres. The eastern arm bears a crust of rather greater thickness but some trouble may be experienced with mud which may become admixed with the salt when the proposed deep harvesting is attempted. Mud beneath the annual salt crop is thicker in this part of the lake than elsewhere and there is some risk that traffic on the lake will break through the crust causing mud to be squeezed up through the resulting cracks. However, this season's No. 1 salt has been gathered from an area of 10 acres without any difficulty so far.

3. Additional harvesting areas shown on the plan represent small extensions of the usual areas where the foundation beneath the annual crust is probably strong enough to bear rubber tyred trucks, but could not be worked with horses.

Sections of the bed of Crescent Lake are given below -

Eastern Arm.	Near north shore. inches	Centre	Near south end of harvesting area inches.
White and pink salt	2	1¾	2
Stratified salt and black mud.	1½	8¼	1
Gypseous sand	not present	2	not present
Coarsely crystalline salt.	1½	not less than 24.	5
Mud	¾	not known	not less than 24.
Coarse glassy salt crystals	not less than 18	not known	not known.

Neck	Eastern end inches	Centre inches	Western end * inches
White and pin salt	1½	2	1½
Stratified salt with black mud	not present	4	not present
Black mud	1	6	3
Crystalline salt	3½	4	not present
Gypseous sand and mud	more than 24	more than 24	4
Pure glassy salt	not known	not known	more than 24

* On edge of harvesting area.

Western Arm.	South-western side. inches.	North-eastern side. inches.	Centre inches	North-western corner inches
White and pink salt	1	1½	1½	1½
Black mud and salt	½	about 1½		
Crystalline salt	1¾			
Black band	¼			
Crystalline salt	2¾	4	8½	about 8½
Black band	¼			
Coarse glassy salt crystals.	more than 21	more than 24	more than 15	more than 15

VII. QUANTITY OF ANNUAL SALT AVAILABLE.

Some difficulty has been experienced in selecting a factor for calculating the tonnages of salt given in the table below. One acre-inch of massive salt without intersticial spaces contains 220 tons. Recent harvesting on the Pink Lakes yielded 33 tons of salt per acre from the first cut, equivalent to 130 tons per acre-inch if the cut is taken to be of average depth of ¼ inch. However, the depth of a shallow cut over a large surface cannot be measured with exactness and the tonnage of salt recovered has been estimated by measurement of the stack resulting from harvesting a large area.

The factor finally used is that quoted by Dr. R.L. Jack (Bull. No. 8 S.A. Geol. Surv.) viz. 120 tons per acre-inch and this figure is considered to be somewhat conservative in view of the very compact nature of the lower portion of the annual salt crust.

The following table shows the estimated quantities of salt which may be recovered by deep harvesting on each lake.

Lake	Area acres	Thickness of crust inches	No. 1 Salt Tons	Other salt Tons	Total. Tons.

Crosby	110	1	3,000	8,500	16,500
	40	1	—	5,000	
Crescent	50	1		9,000	
(west)	3	1½		500	9,500
(east)	44	1½ to 1½	2,600	5,000	
	7	1½		1,300	8,900
			9,200	45,300	54,500

VIII. QUANTITY OF PERMANENT SALT AVAILABLE.

The estimated total quantity of permanent salt beneath the lake beds to a depth of 2 feet is as follows -

Lake	Area Acres	Average thickness of salt inches	Tons of salt.
Sailor	125	18	270,000
Crosby	110	18	237,000
Crescent West arm	60	20	144,000
East arm	40	15	72,000
		Total -	723,000

It is known that salt extends below the northern and northwestern beaches of Sailor Lake, but this quantity has not been taken into account in the table above. It is probable that salt occurs similarly underneath the beach sand at the other lakes.

At various points in the three lakes, salt has been proved to exist at depths up to and exceeding 3 feet, and although the total thickness of permanent salt in the lake beds is probably considerably more than the figures mentioned here, it has not been determined.

The factor used for calculating tonnages of annual salt, viz. 120 tons per acre-inch has been used for estimating the permanent salt.

IX. PROPOSAL TO INCREASE PRODUCTION AT PINK LAKES.

The amount of salt produced by the present methods of harvesting varies from year to year according to the condition of the lake surface at the beginning of the harvesting season and the ensuing weather. Light rain after harvesting brings about a fresh crop of salt by dissolving a portion of the hard residue and reprecipitating it as a soft crust of fine salt. It is also possible that downward percolation of rainwater to the brine level permits the process of capillarity to start again and brings a small quantity of fresh salt to the surface.

The maximum tonnage of salt produced in any one season by harvesting the two layers described above and any fresh crops

now desired to produce 50,000 tons annually.

It is recommended that this production should be achieved by harvesting the total annual salt crop amounting to 54,500 tons either by modifying the usual harvesting methods to enable deeper cuts to be taken after the No. 1 salt has been removed, or by repeating the scarifying and scooping process until the top of the permanent salt is disclosed.

On all but a portion of Crescent Lake this procedure will involve scooping the lower salt in a shallow depth of brine amounting to half an inch or so.

The margin between the required quantity of salt and the estimated tonnage of annual salt existing is very narrow, namely 4,500 tons and it is possible that, although the estimate is believed to be conservative, the desired goal may not be achieved. Recovery from the easter arm of Crescent Lake may be disappointing owing to the presence of much mud at the surface of the permanent salt as it seems possible that traffic on this part of the lake may break the annual salt, mixing sufficient mud with the salt to render it useless.

Should the above deep harvesting fail to produce 50,000 tons of salt alternative schemes for recovery of the balance will need to be considered and further suggestions are offered below (section XII)

Deep harvesting should be put in hand without delay to enable as much as possible of the salt to be stacked before the lake levels rise and the salt is lost by solution in the incoming ground water. To minimise losses from this cause it would appear desirable to leave the harvesting of the eastern arm of Crescent Lake, in which the brine stands at from 2 to 6 inches below the surface, till last. It is also suggested that harvesting of the deeper salt should be started near the lake margins first where solution of salt might be expected to proceed most rapidly.

X. PROBABLE QUALITY OF THE SALT TO BE RECOVERED BY DEEP HARVESTING.

That there is very little difference in composition between the white and pink salts is evident from numerous analyses that have been made from time to time and five analyses given in a report by Dr. Campbell dated 21/11/24 are quoted. The samples are from stacked salt at Sailor Lake and the figures have been reduced to a dry basis -

Grade No. 1	98.8%	Sodium chloride	0.04%	insoluble matter
1	98.4%	" "	0.07%	" "
1	96.4%	" "	2.6 %	Calcium sulphate
2	99.3%	" "	0.11%	insoluble matter
2	99.2%	" "	0.11%	" "

While these few analyses actually show that the pink salt is of greater purity than the white, it cannot be taken that this is always so, but the figures demonstrate the similarity in composition between first and second qualities. It is apparent that the higher market value of the No. 1 salt is dependant upon its physical rather than its chemical state.

The lowest layer of salt removed by deep harvesting from immediately above the permanent salt is likely to contain much of the brown and black mud layers which are interposed. On Sailer Lake the quantity of mud is so small and it is so highly aqueous as to be virtually negligible, but care may be required to avoid undue contamination on the other lakes.

The colour is not of any importance when the salt is required for chemical purposes and badly discoloured salt from the

Pink Lakes can be absorbed by the increasing demands of chemical industry. However, this point should be discussed with an authority familiar with the requirements of the chemical trade.

XI. EFFECT OF DEEP HARVESTING ON SUCCEEDING CROPS.

The thickness of the annual salt crust depends on the length of time elapsing between the beginning of salt precipitation and the lowering of the brine level to a point at which no further evaporation can take place. In other words the controlling factor is the volume of water which is available for solution and redeposition of salt, and this factor is entirely dependent upon the regional ground water level.

It does not seem reasonable to suppose, in view of the great masses of salt lying beneath the lakes, that the portion of the annual crop left behind by shallow harvesting plays anything but a minor part in contributing to the next successive salt crop. It appears that the residue of annual salt which dissolves with the influx of ground-water in winter recrystallizes to the exclusion of an equivalent quantity of salt partly already existing in the ground-water and partly capable of being taken up from the permanent salt beds with which the ground-water comes into intimate contact.

It is not considered that the new factor introduced by deep harvesting as proposed in this report will have any appreciable effect on the thickness of annual crust when it is compared with the vast influence of the volume of the salt water available for concentration and crystallization.

One effect of deep harvesting may be to cause succeeding crops to become cleaner as mud is removed from the upper surface of the permanent salt.

XII. ALTERNATIVE SUGGESTIONS FOR PRODUCING ADDITIONAL SALT.

Should deep harvesting of the Pink Lakes fail to provide the required 50,000 tons of salt, attention should be directed to the question of harvesting Lake Poulton about 2 miles west from Sailor Lake, and of increasing supplies from Lake Tyreell. The latter Lake is 98 miles nearer to Melbourne than the pink Lakes and is convenient to a railway at Sea Lake.

It has been proposed that production of salt at the Pink Lakes should be increased by quarrying permanent salt from the bed of one of them. Such operations would remove considerable quantities of mud mixed with coarsely crystalline salt and would necessitate crushing and washing the salt before it could be used. The technical difficulties associated with this procedure may not be great, but it is desirable in the interests of simplicity and low costs that they should be avoided if possible. For this reason it is recommended that every attempt should be made to produce the required salt from the annual crop even to the extent of transferring to another locality and so obviate the necessity for crushing and washing plant.

There is also the possibility, which has been raised by the lessees, that the excavation of part of the lake beds might cause the failure of succeeding crops of annual salt by disturbing the natural conditions and causing the drainage of brine to the excavated part of the lake floor. However, as it is held that the level of brine in the lakes is regional ground water level, it is highly improbable that any part of the lake surfaces, except that actually excavated, would be affected.

It is worth noting in passing that excavations in the lake floors which expose brine to the atmosphere during summer act as crystallising pans. One hole excavated in Lake Crosby about 4 or 5 months ago had some 8 inches of very pure flaky salt lying on the

bottom of it. During the very hot weather in the early part of February, it was observed that when brine became exposed, a film of salt formed on the surface within a few minutes. Flakes of salt up to 1/16th inch in thickness could be recovered within 24 hours of exposing the surface of the brine.

This observation opens up the possibility of augmenting supplies by excavating shallow pits to act as evaporating pans during the summer months. Such pits would not need to be deeper than 6 to 12 inches on Sailor Lake and Lake Crosby, but might need to be 12 to 24 inches deep on Crescent Lake owing to the lower level of the brine relative to the top of the salt crust.

XIII. CONCLUSIONS AND RECOMMENDATIONS.

Survey of the Pink Lakes indicates that the total area of annual salt crust accessible to harvesting operations amounts to 374 acres. The crust varies in thickness between ¼ inch and 2 inches and is estimated to contain 54,500 tons of salt.

Over areas more or less coincident with the areas of harvestable crust, thick layers of coarsely crystalline permanent salt occupy the lake beds beneath the annual crust. To a total depth of 2 feet below the surface of the beds of coarse salt contain at least 723,000 tons of salt, but the horizontal limits and thickness of the salt are not known.

The usual practice at the Pink Lakes consists of harvesting about half an inch of the annual salt crust with scarifiers and scoops. By this means15,000 tons of salt can be recovered.

In order to increase this production figure to 50,000 tons, it is recommended in this report that the whole of the accessible salt crust should be recovered by deep harvesting. Should this method fail to saitsfy the increased demand, it is suggested that a nearby lake, Lake Poulton, should be harvested, or that production from Lake Tyrrell, 98 miles nearer to Melbourne, should be increased if possible.

The above deep harvesting is suggested in preference to quarrying of the coarsely crystalline salt layers to avoid the necessity of providing crushing and washing plant to treat the quarried salt.

Deeper working of the lakes, either by deep harvesting over large areas, or by quarrying limited areas, is not considered likely to have any deleterious effect on future salt crops. The former may tend to provide cleaner salt in succeeding years by the removal of mud from the top of the permanent salt layers during the first year's operations and the latter method would provide evaporating pans in which very clean salt would be precipitated during the summer.

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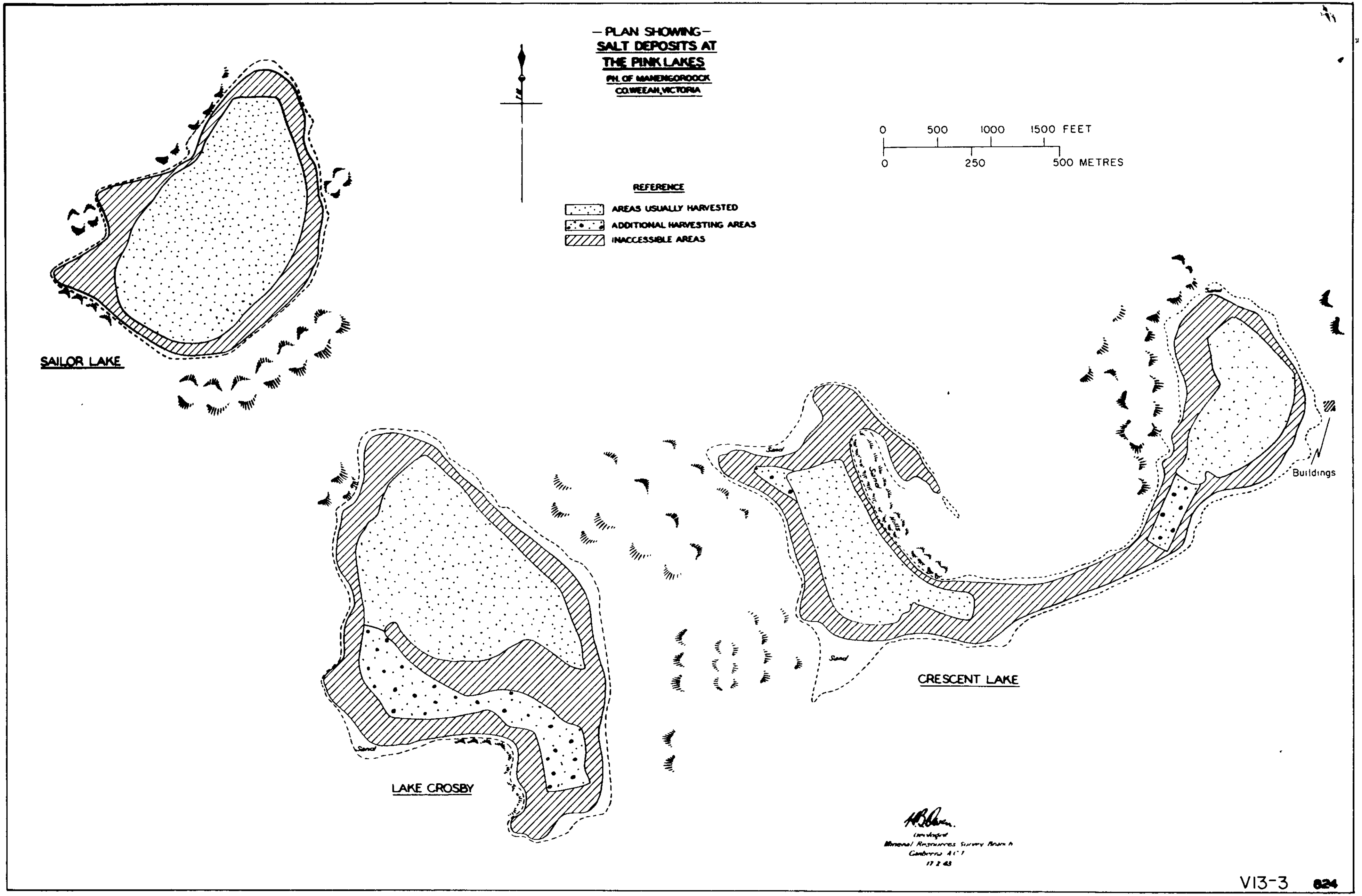

— PLAN SHOWING —
SALT DEPOSITS AT
THE PINK LAKES
PH. OF MAMENGOROOCK
CO. WEEAH, VICTORIA
0 500 1000 1500 FEET
0 250 500 METRES
REFERENCE
AREAS USUALLY HARVESTED
ADDITIONAL HARVESTING AREAS
INACCESSIBLE AREAS
SAILOR LAKE
LAKE CROSBY
CRESCENT LAKE
Sand
Buildings
Mineral Resources Survey Branch
Canberra A.C.T.
17 2 43
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