Preliminary Report on the Salt Resources of the Pink Lakes in the County of Weeah, Victoria

by

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

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INTRODUCTION.

The Pink Lakes, also known as Linga Lakes, lie in the Parish of Mamengoroock, County of Weeah, in north-western Victoria, about 10 miles north-north-west of the small town of Underbool on the Ouyen to Pinnaroo railway (See Fig. 1). Underbool is 319 miles by rail north-west from Melbourne via Castlemaine, Maryborough and Ouyen, and 322 miles by road (the Calder Highway) through Bendigo Charlton, Sea Lake and Ouyen.

Linga railway station, 7 miles west of Underbool, is used as the trucking point for salt from the lakes, as it is connected with the lakes by a better and more direct road than that to Underbool. The roads to the lakes are very poor and carting is delayed by wet weather in winter and sand drifts in summer.

The three lakes known as the Pink Lakes that are being worked for salt are Sailor Lake, Lake Crosby and Crescent or Home Lake.

The areas of the salt leases are -

Sailor Lake leases	-	206 acres.
Lake Crosby "	-	395 "
Crescent Lake "	-	311 "
		912 Acres.

Portions of the above areas are occupied by the beaches and fore-shores of the lakes, and the total potential salt-bearing surface of the three lakes is actually about 700 acres.

In addition to the Pink Lakes above-mentioned there are in the vicinity two other salt lakes viz:

(a) Lake Poulton, about 70 acres in area, and two miles west of Lake Crosby, and
(b) an un-named lake, here referred to as 'School' Lake, probably rather less than 50 acres in area and situated one mile south of the west end of Crescent Lake.

Salt is formed on both these alkes, but Lake Poulton is somewhat difficult of access on the north-east and north, and School Lake is in a Government Reserve and is not available for leasing.

TOPOGRAPHY.

The country in the vicinity of the lakes is hilly. The elevations consist of sandhills more or less anchored by vegetation although patches of loose drift sand are a conspicuous feature. Mt. Gnarr, a sandhill about 150 feet high, is gradually advancing eastward under the influence of prevailing westerly winds and is about to encroach on a farmyard under its lee.

Although the Mt. Gnarr sandhill lies north and south the less prominent ridges strike east and west, parallel to the prevailing winds. These parallel ridges are irregularly spaced but in some areas are separated by strips of flat ground about half a mile wide. Most of the flats, and many of the ridges are cultivated and at present are under crop. The cultivation of the higher ground has led to the drift sand getting out of hand and drifts have transgressed roads and engulfed small areas of farmland.

In the immediate vicinity of the salt lakes, and particularly on the western side, the land has not been cultivated and is used for grazing sheep and cattle. Here the sandhills are oriented in different directions and are fixed by a cover of scrub and pine. In general the higher ridges carry good stands of Murray pine while the lower ground is principally occupied by mallee, casuarinas and ti-tree. There are patches of low scrub and spinifex.

The general surface of the region falls gently to the north but there are no stream channels. Water which collects in the low lying areas is rapidly absorbed in the sandy soil and sinks into the ground water.

The lakes have neither inlet nor outlet. Each lake is surrounded by low hills. A comparatively high ridge, about 70 feet above the lake level, separates Crescent Lake from Lake Crosby. Elsewhere the hills enclosing the lakes probably do not exceed a height of 50 feet.

The south-western to north-western margins of the lakes have steep slopes rising rather abruptly from the shore-lines, but the oposite shores are gentle slopes with marginal areas of nearly level ground suitable for stacking the salt won during harvesting.

This asymmetry is due to the gradual advance of the sand dunes from the west and suggests that some salt may be buried beneath the western banks of the lakes (see Fig. 2).

GEOLOGY.

The area is occupied by Recent sands. Bores in the vicinity have penetrated unconsolidated sand to an average depth of a little over 200 feet. This sand is underlain by 200 to 250 feet of Kalimnan sediments mainly composed of grey clays containing shells and resting upon polyzoal limestone of Janjukian age. The Kalimnan beds form a fairly impervious barrier between the lower fresh to brackish water and the very saline ground water held in the Recent sands.

The ground water table lies a few feet below the surface. The gradient is low, less than one foot per mine, the fall being to the north-west (See Figs. 1 and 2).

DESCRIPTION OF THE LAKES.

Sailor Lake: This lake which has an area of about 180 acres, was the object of elaborate operations about twenty years ago when a company was formed to produce salt from it. A tramway was constructed from the lake to Linga railway station and electric light was installed on the lake for night operations. The company incurred very heavy losses and went insolvent.

The lake is roughly pear-shaped in plan tapering to the north. The eastern shore is gently sloping and carries mallee and casuarinas. The western shore is flanked by sandhills and steep banks thickly vegetated with mallee and spinifex.

There are narrow sandy beaches around most of the perimeter of the lake, but on part of the western and southern margins the beach is formed of ropy masses and nodules of granular gypsum. The masses are soft and spongy to the touch and apparently have been formed by the crystallisation of gypsum on strips of bark or other organic matter.

At the time this inspection was made Sailor Lake contained about two inches of brine at a point 200 yards from the shore and it is doubtful whether the water was appreciably deeper at the centre of the lake.

It was not possible to examine the whole of the lake bed but an area of approximately 50 acres was examined in some detail. Advantage was taken of a strong northerly wind which had driven the brine about 50 yards from the normal margin, and a hole was dug in the lake bed, which showed the following section:

A. (Sand
(Brown gelatinous mud
(Black mud containing hydrogen sulphide.) about 1 inch.

B.	(Coarsely crystalline salt with some free space (Hard coherent mass. Stratified.	3 inches
C.	(Very coarsely crystalline salt (up to ¾" cubes) (with much free space filled with freely circulat- (ing brine. Mass not coherent, not stratified.	3 inches to 4 inches
D.	Coarsely crystalline compact salt similar to B. -	4 inches.
E.	Coarsely crystalline loose salt similar to C. -	(more than 3 in.)

The hard coarsely crystalline salt lying beneath a film of mud is referred to in this report as the 'permanent' salt to distinguish it from the 'annual' salt formed as a loose crust every year.

The brine freely circulating in the comparatively loose salt beneath the hard crust prevented further digging in this hole.

Small excavations made at various points within the lake area beneath the brine tend to confirm the section given above, but mud stirred up by digging remained suspended in the brine and prevented visual observation of the underlying salt. Fragments brought to the surface revealed the presence of coarsely crystalline salt to a depth of 10 to 12 inches at least.

Hard salt was also found under the beach sand on the north-western side of this lake.

It was stated that during a previous summer the lessees had sunk a hole three feet deep which passed through salt similar to that described above and was still in salt when abandoned. There seems no reason to doubt this statement.

On the western bank of the lake a hole about one foot deep revealed clear gypsum (selenite) crystals embedded in the mud and no salt was encountered.

Under the influence of prevailing south and westerly winds the brine in the lake is driven towards the northern end and consequently a thicker crust of annual salt results near the north and north-east banks.

Lake Crosby: This lake is rather similar in shape to Sailor Lake and lies about half a mile south-east from it. Its area is about 280 acres. Lake Crosby is stated to have been the best producer of annual salt in the past but this appears to be directly related to its size and to no other factor.

It has gently sloping banks on the northern and eastern sides, and steep banks and small cliffs on the other sides. The western banks consist of sandhills with a band of travertine which outcrops about eight or ten feet above the lake level.

In other respects Lake Crosby appears to be very similar to Sailor Lake. No search for buried salt in the banks or beneath the brine was carried out.

The southern portion of this lake, about one-third its total area, is a very poor producer of annual salt. The crust formed is stated to be thin and dirty.

Crescent or Home Lake: This lake has a total area of about 240 acres. It consists of two limbs a mile apart and connected at their southern extremities by a relatively narrow neck. Each limb has an area of about 100 acres and the whole lake presents in plan the form of a wide letter U open to the north.

In the past, banks have been built across the neck at two points to effect some control of the brine but these banks are now breached and have no effect; for reasons given later it is unlikely that banks built on the lake beds were of use at any time.

The western portion of the lake is rather inaccessible on the northern, eastern and southern sides. The western banks have been used for stacking salt but there is very little level ground available and salt stacks are liable to inundation with a change of wind.

The eastern lobe of the lake has been an important producer of annual salt for many years.

Selenite crystals were found in the mud at the northern and western edges of this part of the lake and it is not known whether any salt underlies the sand and mud, but it seems probable that conditions here are essentially the same as at Sailor Lake but with a thicker layer of mud covering the salt.

Lake Poulton: This small lake with an area of approximately 70 acres, lies 1½ to 2 miles west of the Pink Lakes and has not been worked for salt. It was stated that salt forms on it in the summer but that owing to the smallness of the lake and to the swampy ground on the north-east shores, which makes approach a little difficult, it was not considered worth harvesting.

Its possible yield by ordinary harvesting methods would probably lie between 1500 and 2000 tons of recoverable salt.

The difficulties of access could be overcome comparatively easily.

'School' Lake: This lake is approximately 50 acres in area and is situated about one mile south of the Pink Lakes and in a Government Reserve. It is also stated that a salt crust forms on this lake in the dry season. The banks are rather steep but there are places where salt could be stacked on the banks for trucking. The possible yield by harvesting would be about 1000 tons, assuming that conditions are similar to those in the Pink Lakes.

UNDERGROUND WATER.

Very saline water occurs in the Recent sand, and bores for stock purposes are drilled to a depth of about 450 feet to tap the brackish, but useable, water beneath the Kalimnan shelly clays.

Beyond general statements that shallow water has been struck in each bore put down in the locality and that it has been cased off on account of its high salinity, there is no information regarding the quality or composition of this water.

Two samples were collected in order to obtain an idea of the composition of the shallow water, but they cannot be regarded as very satisfactory for this purpose. Sample S4 was taken from a small spring which emerges about 8 feet about the level of Sailor Lake on the north-east bank; and S6 was derived from a well sunk near a salt stack on the bank of Crescent Lake and at one time used to supply water for washing salt. The well is a few yards from the margin of the lake, and the water in it stands at the same level as the lake.

ANALYSES IN PARTS PER 100,000 ø

	Sample S4	Sample S6.
Chlorine	87	6,920
equivalent to Sodium chloride	144	11,418
Total salts	163 ≠	14,030

≠ Contains organic matter.
ø W.R. Jewell, Melbourne, analyst.

Prolonged rain during the past winter was responsible for numerous seepages into the lakes at various points about their circumferences. Samples of these seepages could not be collected owing to the very small quantity of water available but the salinity of all of them, as indicated by the taste was very much higher than that of sample S4.

It is probable that the water represented by this sample is derived from a small perched aquifer in the sandhills which has been replenished by the recent high rainfall.

Sample S6 is certain to be contaminated with concentrated brine from the nearby lake. It is approximately 3½ times as saline as normal sea-water.

All the bores seen were cased with 4" casing and equipped with windmills. The demand on these bores is small and there is no record of any of them having been pumped to their maximum capacity.

Samples from three bores shown on the accompanying section were analysed with the following results -

ANALYSES IN PARTS PER 100,000 ø

	Underbool Bore. 10 Miles S.S.E. of Crescent Lake.	Bore, Sec. 12. Par. Mamengor-oock. 5 Miles S.E. of Crescent Lake	No. 1. Bore, Mamengoroock. 2½ miles S.E. of Crescent Lake.
	(1)	(2)	(3)
Chlorine	398	454	490
Calculated to Sodium chloride after satisfying magnesium and calcium in samples (2) and (3)	657	681	750
Magnesium	not det.	16	18
Calcium	not det.	9	9
Total salts	755	824	948

ø W.R. Jewell, Melbourne, Analyst.

The time of the visit to the lakes coincided with the end of an exceptionally wet winter. It was generally agreed among residents of the district that the 1942 winter had been wetter than for many years.

Men who had had experience of the salt lakes were of the opinion that the depth of water at the time of this visit was between 4 and 9 inches but Sailor Lake contained only about 1½ to 2 inches of water at a point 200 yards distant from the shore. Mr. A. Hall, who has been associated with salt production from the lakes for several years was inclined to think that the level of the lake bed has risen noticeably during the past two or three years. He based his suggestion on observation of an iron spike driven into the lake bed. Four years ago the head of this spike was protruding just above the solid lake bed, later it was noticed to be flush with the bed, and has now disappeared.

The evidential value of these observations may not be great, but there is a strong suggestion that the lake bed level is rising. If this is so, the principal cause must be additions to the permanent salt bed. The amount of salt carried into the lakes in a normal year is negligible since there are no open channels feeding the lakes, and the wind-borne dust is merely sufficient to discolour the salt slightly.

The levels of the lake beds approximate closely to the wet season ground water table, with the result that the rains of an exceptionally wet winter, such as that just experienced, do not cause any appreciable rise of the water level in the lakes above that of normal seasons, as it would do if they had impervious bottoms.

Ground water movement is sufficiently sluggish to permit concentration of the brine in the lakes to pass beyond saturation with resulting precipitation of salt. Apparently conditions are so nicely balanced at the Pink Lakes that the fall of the water table in early summer occurs before magnesium salts are precipitated and the magnesia-rick bittern drains away leaving a crust of very pure salt to be harvested. The presence of sufficient magnesium to seriously contaminate the salt if precipitated is shown in the analysis of lake brine quoted below.

THE ANNUAL SALT.

It is stated that the layer of salt formed at the Pink Lakes is generally less than half an inch thick on average, and increases in thickness and quality towards the northern ends of the lakes.

The annual salt is harvested by scraping it into heaps with horsedrawn scoops. It is then shovelled manually from the heaps into a motor truck which is driven up a low ramp of timber to the shore. Here the salt is shovelled into a stack which may be built up until it contains several hundred tons. It is worth noting that whilst the lake surface can support horses and motor-trucks it is found necessary to provide a timber mat in the form of a low ramp to bridge the sand and mud around the edges of the lakes.

The use of horses and trucks on the lake surfaces throws some light on the strength of the upper crust of permanent salt. A light draught horse weighs about 1,300-lb. and, walking, distributes this weight over three points of small area. From this it would appear that rubber tyred tractors could be supported on the lake with a margin of safety.

Of the total area of the lakes (700 acres) probably only 400 acres carry sufficient annual salt to make harvesting profitable.

In calculating the available quantity of annual salt the factor used by Dr. R.L. Jack in Bulletin No.8 of the Geological Survey of South Australia has been used. Dr. Jack found that the average quantity of salt recovered per inch of crust amounted to 100 tons per acre.

With an average thickness of one-third of an inch of harvestable salt the yield would be about 35 tons per acre, or a total of 14,000 tons. It was claimed by the lessee that the greatest recovery of salt in one season was 15,000 tons and that it would be possible to harvest a maximum of 20,000 tons. So far observations tend to confirm these figures but an examination of the lake in the dry season will be necessary to permit a definite opinion to be formed.

THE PERMANENT SALT.

Mineralogically the permanent salt consists of an agglomeration of halite crystals. These crystals are nearly all cubes but a few imperfect octahedra were noticed. The characteristic 'hopper' structure was observed rarely.

The cubes are highly perfect but are nearly always somewhat intergrown. In the specimens seen the crystals varied in size from nearly microscopic to cubes with edges exceeding ½" in length.

The crystals consist of a series of concentric shells representing different periods of growth, and many contain within them one or more films of black mud. These films have formed as thin coatings on partly grown crystals which, again becoming immersed in brine, have continued their growth entraining the film of mud within the enlarged crystal. Some of this mud fills minute vughs in the angles between intergrown crystals and in the interfacial solid angles.

The salt is not hygroscopic, but on breaking open the crystals containing mud it is found that the mud is wet.

The crystals tend to cleave fairly readily along the muddy partings.

In the mass the salt is grey in colour and banded. Lighter bands alternate with dark bands and probably represent seasonal changes.

Slightly brownish bands may be due to wind-borne dust during the summer, grey bands to included black mud and light bands periods of rapid crystal growth in early summer.

In the specimens recovered these alternating bands are about ¾" thick.

The bed of salt in situ presents a solid face of cubic crystals but there is much free space, probably amounting to about 25% of the total volume occupied in the thickness of salt bed examined. These free spaces form connected channels for the free passage of brine from place to place within the salt beneath the lake bed.

The permanent salt when crushed presents a dirty greyish appearance but simple experimental washing with warm saturated salt solution effected a great improvement. It was demonstrated that crushing to about minus 20 mesh will be necessary to free included mud and permit effective washing.

It is known that a sheet of salt over one foot thick exists over an area of 50 acres in one lake alone. Allowing 25% of free space in this salt the tonnage amounts to 90,000 long tons.

This figure is derived by direct calculation from the specific gravity of salt which gives the weight of one cubic foot as 123 lb. or 1.1 cwt. and has been experimentally confirmed with specimens of the permanent salt from the Pink Lakes.

It is probable that the whole area of the lake beds, excluding some small patches of soft mud known to the harvesters, is underlain by salt to a greater or lesser depth.

There is little local knowledge relating to the thickness of the salt bed, but the evidence of the lessee and contractor indicates a depth in excess of 3 feet, and it is asserted that previous operators have sunk through 27 feet of salt on the north-east edge of Crescent Lake.

Discounting this latter figure and tentatively accepting the figure of three feet it will be seen that within the 700 acres of lake surface there may be over 3,000,000 tons of salt.

Possibly Lake Poulton and School Lake could also contribute to the quantities of salt if needed.

THE MUD OVERLYING THE SALT BED.

The mud overlying the salt bed is in two layers, an upper one about one-quarter of an inch thick when wet, and a lower and thicker one of black mud saturated with hydrogen sulphide. Both layers thin out towards the centre of Sailor Lake; the combined thickness of both layers was found to be about one-quarter to half an inch at a point 200 yards from the shore compared with 1 inch to 1½ inches at the water's edge.

The upper brown layer is slimy and gelatinous in consistency and hangs together in sheets and strips when disturbed. It appears to consist almost wholly of organic matter and is much swollen with contained water. It would probably dry to a film of little more than pater thickness

The black mud under the lake surface has the consistency of a thin gruel. It appears to be composed of minute particles of black organic matter. When disturbed it remains suspended in the water turning it black.

In some places this black mud underlies the beach sand to a known depth of a foot or more. In some places it has the consistency of tar, has lost its hydrogen sulphide, and is very difficult to wash off the skin. These deeper patches of mud are comparatively rare and have their counterpart in the lakes where they are known as 'blowholes'. These blowholes, about a dozen all told, are marked with stakes so that the harvesters will avoid them during the harvesting season.

When the lessee was questioned as to the effect of the mud when harvesting the loose salt, he stated that the mud caused no trouble simply because it had disappeared. He expressed the opinion that it floated to the surface and was blown ashore before the annual salt crystallized, but it is not thought that this explanation is correct. It seems more probable that the mud dries to a thin film adhering to the surface of the permanent salt and would not be apparent to casual observation. When the lakes are flooded in the ensuing wet season the film of mud takes up water and again expands to its former volume.

It is believed that the hydrogen sulphide is generated by bacterial action on sypsum, but is may be due to the decomposition of organic matter.

DISCUSSION OF THE PROPOSALS PUT FORWARD WITH A VIEW TO INCREASING THE YIELD OF SALT FROM PINK LAKES.

1. Flooding the lakes with water from underground sources to produce additional crusts of salt by natural evaporation.

This proposal assumes that the lakes possess an impermeable floor of clay beneath a layer of salt and that they could be used to hold water during the dry season. Observations indicate that this is not so. The lake beds consist over a considerable area, if not wholly, of layers of coarsely crystalline salt to a depth of at least one foot, and probably several feet. This salt contains sufficient free space to permit almost unimpeded circulation of fluids and any water or brine pumped on to the dry lake surface would immediately descent through the salt to the water table, carrying dissolved salt with it.

The depth to which the water level sinks below the lake beds in summer is not known.

It is possible that specially favourable areas of the lakes might be used as natural evaporating pans if enclosed with low clay banks, but this is doubtful owing to the porosity of the underlying salt. The successful utilization of the lake beds for this purpose would depend upon intercalated seams of clay yet to be discovered.

2. Removal of the permanent salt. Until the lakes can be examined in the summer there is no information available to indicate the dry season level of the water table, It seems however that if the permanent salt is to be removed some of it, at least, may have to be recovered from below the brine.

The resulting exposure of fresh surfaces of brine to the atmosphere suggests that additional salt will be formed by precipitation.

The permanent salt lying below a thin layer of mud, presents a tough fairly smooth surface, but once this surface is broken to form a working face the salt could be easily won by manual labour or some form of plough.

In the description of harvesting methods it has been suggested that the lake surface would bear the weight of tractors but breaking the surface of the permanent salt may so weaken the lake bed as to render the use of heavy machinery impossible. Owing to the successive layers of salt beneath the hard surface crust it is not possible to liken the surface to that of a frozen lake however. The effect of breaking the surface can be determined only by opening a small area and testing it.

The quality of the salt to be won has been discussed and it is apparent that crushing and washing will be necessary to produce a marketable product other than agricultural salt for killing weeds.

If brine from beneath the salt crust is used for washing it may be necessary to clarify it either by settling or filtering to free it from any objectionable black mud suspended in it.

It is probable, however, that brine removed from beneath the salt crust will not be unduly contaminated with the mud which appears to be confined to thin layer above the dry salt. How much mud is filtered out by the salt crust when the brine sinks below the lake bed, and how much remains suspended is not known.

3. Use of artificial evaporators and driers. There are several methods of evaporating liquids used in the chemical industry and those commonly applied to the production of salt in countries where natural climatic conditions are not favourable utilize vacuum pans, either single or multiple, or open grainers.

The former type of plant is elaborate and costly, requires much auxiliary equipment, proper housing, and skilled supervision. Briefly the essential apparatus consists of one or more steam-jacketed pans which operate under reduced pressure. Where more than one pan is used the units are connected in series. The first pan in a series is heated by live steam, the jackets of the second pan receive the vapour from the first and so on. The vapour finally passes to the condenser and a high degree of vacuum, with corresponding low temperature, may be maintained in the last pan of the series. Such evaporators are commonly used in sugar refineries where high temperatures are deleterious to concentrated sugar solutions. The chief advantage of the system as applied to evaporation of salt solutions, where the final product is not affected by temperatures a little above 100°C, is the rapid evaporation (and consequent precipitation of very fine salt) under low pressure. Elaborate plant of this nature would not be justified at the Pink Lakes.

Open grainers are shallow pans of masonry, brick or concrete, two or three feet deep and may be of the order of 10 feet wide by 100 feet long. They are fitted with steam pipes a few inches from the bottom and a mechanical device, preferably a type of pusher conveyor to remove loose solids from the bottom. The pans are filled with brine, and steam at about 20 lb. per square inch is passed through the pipes to heat the brine and hasten evaporation. Precipitated salt is scraped on to a sloping apron at the end of the grainer and drained to a moisture content of about 3%.

Either of the above methods would permit of draining the mother liquor to waste before magnesium salts started to separate.

As far as can be ascertained spray drying has not been used in the salt industry. This method consists of spraying the liquid to be evaporated into a current of warm or hot air either at normal or reduced pressures. Spray driers are commonly used for the preparation of powdered milk. There seems to be no reason why spray drying should not be applied to evaporating brine unless the brine contained a high proportion of salts other than sodium chloride, as all solid matter will be thrown down.

The analysis of brine from Sailor Lake (W.R. Jewell, Melbourne, analyst) indicates that the ratio of magnesium and calcium to sodium is very low. The analysis in parts per 100,000 is given:-

Chlorine	14,940	
Sodium chloride calculated after satisfying magnesium and calcium	24,020	
Magnesium	50	= 192 Magnesium Chloride
Calcium	85	= 316 calcium Chloride.

In the absence of a figure for the sulphuric acid radicle, which is known to be present, it is not possible to calculate the composition of the residue which would be left by the total evaporation of brine of this composition but it appears that the dry salt would contain between 97 and 98 per cent. NaCl the remainder being chlorides and sulphates of calcium and magnesium. Both chlorides are objectionable as they are deliquenscent substances and would render the salt markedly hygroscopic. Their removal would be necessary and could be effected by washing the salt in brine or by adding soda ash to the solution before evaporating. Addition of soda ash would convert the calcium and magnesium salts to carbonates which, in small amounts are not objectionable in salt, and the sodium ion from the soda ash would, united with both acid radicles, form sodium chloride and sodium sulphate.

In this section the question of natural evaporation of lake brine is shallow artificial pans can be discussed.

Climatological conditions in the locality are favourable, Rainfall amounts to 12 inches per annum and nett evaporation is about 40 inches. The rainfall is normally confined to the winter months and the summer is hot and dry with strong winds.

One cubic foot of saturated brine contains 19 lb. of salt. Crystallizing pans one foot in depth would require 120 sq. feet of area for each ton of salt to be produced.

Allowing for evaporation of two feet of brine per annum the annual production of 100,000 tons would require the provision of evaporating pans with a total area of 6,000,000 feet, or 138 acres. The construction of such pans is obviously out of the question.

Any suggestion of applying artificial methods of evaporation to salt production raises the question of cost. Salt is a low priced commodity and the following figures are submitted to show that the cost of production must be kept down.

Salt from the Pink Lakes is sold on rail at Linga at 20/- and 21/- per ton, and as stacked on the lake edge after harvesting is valued at 5/- only.

The selling price is made up as follows -

Cost of harvesting and stacking	5/-
Cost of bagging and handling	1/6
Royalty to Victorian Government	2/-
Rent (on average yield	2/3
Cartage to rail	5/6
✗Bags, supervision and lessee's profit	3/9 - 4/9
	20/- - 21/-

✗Value of second-hand bags per dozen (12 bags to the ton) is 8/9d.
As many as possible are sent back from Melbourne for refilling.

The royalty seems unusually high and if it were substantially reduced the difference could be used to offset the higher costs involved in recovering, crushing and washing the permanent salt.

SUMMARY AND RECOMMENDATIONS.

The salt precipitated at the Pink Lakes is exceptionally pure due to two factors, viz. (a) the very low ratio of magnesium and calcium to sodium in the local ground water and consequently in the lake brines, and (b) the lowering of the ground water in summer which permits the bitterns containing a concentration of magnesium and calcium salts to drain away.

The crust of annual salt formed by the concentration of ground water exposed to the atmosphere in the lakes contains about 15,000 but not more than 20,000 tons of recoverable salt, containing from 98 to 99% NaCl.

The annual salt crust is underlain by a bed of salt containing a small proportion of mechanically held mud. The thickness of this bed is known to be not less than one foot over an area of 50 acres on one lake. Evidence suggests that the thickness of salt greatly exceeds one foot, and that the area so occupied lies between the 50 acres proved and the total area of lake surface, viz. 700 acres.

The total amount of recoverable permanent salt per acre-foot is about 1,800 tons.

It is considered that quarrying the permanent salt will be the most hopeful method of rapidly increasing the output without unduly raising costs.

Salt recovered from the salt bed will require crushing and washing. Brine pumped from beneath the lake surface, being saturated with sodium chloride and containing very little magnesium and calcium salts would be suitable for washing purposes. The brine might require clarification to remove suspended mud.

An alternative method of increasing salt recovery is suggested by the practice of spray drying as applied to milk. Brine, already saturated could be sprayed into a current of hot air. The brine would need treating with soda ash to precipitate magnesium and calcium salts, filtering to remove the precipitate and suspended mud before evaporation. It seems probable that this method would not be able to compete with that suggested above, viz. quarrying the salt bed. The question of comparative costs would have to be investigated.

Other methods of artificial evaporation are apparently excluded by the cost of plant and operating expenses, and solar evaporation in artificial dams or pans is out of the question owing to the large surface area needed to yield worthwhile quantities of salt.

The formation of additional salt crusts by flooding the lakes with water or brine during the summer is not possible owing to the recession of the ground water table and the porosity of the lake beds.

Harvesting of the annual salt might be accelerated by the provision of extra labour, and the quantity of salt gathered might be increased by harvesting Lake Poulton and School Lake in addition to the three lakes included in the present leases. It is possible that insufficient salt will be formed on these two small lakes however, to warrant harvesting.

It is suggested that a more accurate estimate of the amount of permanent salt in the lake beds should be made when the lakes are dry enough to permit test pitting systematically. A plane-table survey of an area embracing at least the three major lakes, and possibly all five, should also be carried out. Apart from the necessity for an accurate plan of the lakes such a map would form a basis for selecting sites for future operations, placing of buildings, pipe lines etc.

No steps should be taken to disturb the permanent salt until the clean annual salt lying above it has been collected and removed.

The lessee has taken up a considerable area of land on the south-western side of the salt lakes to prevent farming on the immediate windward side and consequent trouble with dust. It was noted that cattle were being grazed on this land. This practice which will defeat the object of leasing the land in question, should be discontinued.

(H.B. Owen)
Geologist.

Mineral Resources Survey,
CANBERRA.
9th September, 1942.

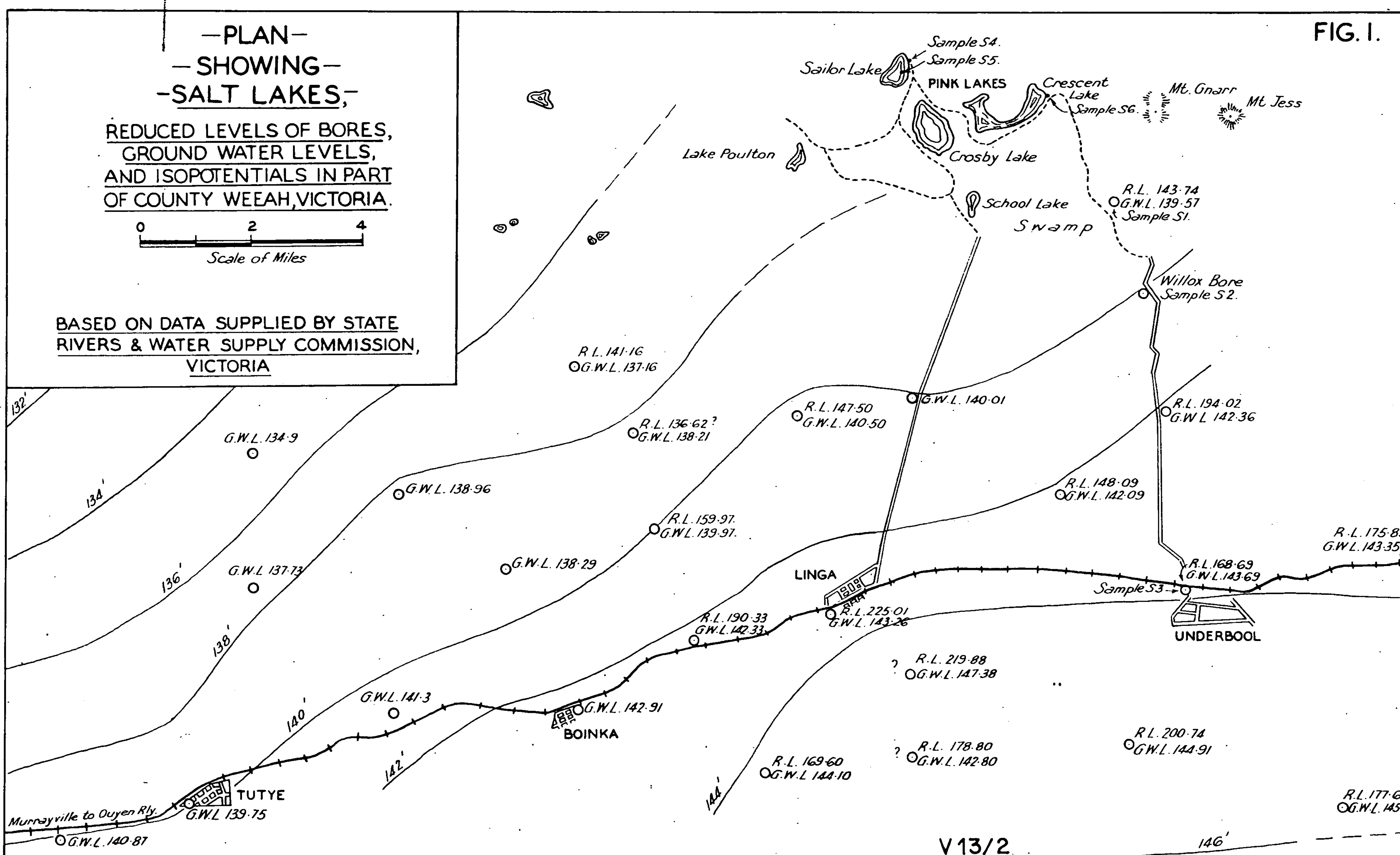
FIG. I.
-PLAN-
-SHOWING-
-SALT LAKES,-
REDUCED LEVELS OF BORES,
GROUND WATER LEVELS,
AND ISOPOTENTIALS IN PART
OF COUNTY WEEAH, VICTORIA.
0 2 4
Scale of Miles
BASED ON DATA SUPPLIED BY STATE
RIVERS & WATER SUPPLY COMMISSION,
VICTORIA
Sample S4.
Sample S5.
Sailor Lake
PINK LAKES
Crescent Lake
Sample S6.
Mt. Gnarr
Mt Jess
Lake Poulton
Crosby Lake
School Lake
Swamp
R.L. 143·74
G.W.L. 139·57
Sample S1.
Willox Bore
Sample S2.
R.L. 141·16
G.W.L. 137·16
G.W.L. 140·01
R.L. 147·50
G.W.L. 140·50
R.L. 136·62 ?
G.W.L. 138·21
R.L. 194·02
G.W.L 142·36
G.W.L. 134·9
G.W.L. 138·96
R.L. 148·09
G.W.L. 142·09
R.L. 159·97.
G.W.L. 139·97.
R.L. 175·85
G.W.L. 143·35
G.W.L 137·73
G.W.L. 138·29
LINGA
R.L. 168·69
G.W.L. 143·69
Sample S3
R.L. 225·01
G.W.L. 143·26
R.L. 190·33
G.W.L. 142·33
UNDERBOOL
R.L. 219·88
G.W.L. 147·38
G.W.L. 141·3
G.W.L. 142·91
BOINKA
R.L. 200·74
G.W.L. 144·91
R.L. 178·80
G.W.L. 142·80
R.L. 169·60
G.W.L 144·10
TUTYE
G.W.L 139·75
Murrayville to Ouyen Rly.
G.W.L. 140·87
R.L. 177·65
G.W.L. 145·15
132'
134'
136'
138'
140'
142'
144'
146'
V 13/2

FIG. 2

SECTION FROM UNDERBOOL TO CRESCENT LAKE