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THE ELECTRICITY COMMISSION OF NEW SOUTH WALES

POWER AND TRANSMISSION DEVELOPMENT DIVISION

CIVIL INVESTIGATIONS BRANCH

JERVIS BAY NUCLEAR POWER STATION INVESTIGATIONS FOR CIVIL WORKS

VOLUME 1 – SUMMARY OF GEOLOGY, HYDROGRAPHY AND SITE DEVELOPMENT

DECEMBER, 1970

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REPORT NO. C.I. 49

SUMMARY

This Report presents the results of site investigations carried out by the Electricity Commission of New South Wales in conjunction with the Australian Atomic Energy Commission to determine the suitability of an area near Murrays Beach, Jervis Bay (designated Site J.S2) for siting a nuclear power station.

The investigations fall into four categories:

(a) Surveys (land and hydrographic);

(b) Geology and soils investigations;

(c) Hydrographic investigations of the bay and ocean adjacent to the site;

(d) Project formulation and the preparation of cost estimates for the C.W. system.

Volume 1 contains a summary of all the work carried out as well as details of the formulation studies and cost estimates.

Volume 2 contains details of the geology and soils investigations.

Volume 3 contains details of surveys and hydrographic investigations.

The investigations have shown that the site is suitable for the planned purpose. The power station can be sited in a location such that the station bench can be excavated to rock with a relatively small volume of excavation and effective cooling water systems can be developed for either bay or ocean outfalls with reasonable costs.

The proposed station and C.W. system arrangements for bay and ocean outfalls are shown on Figures 3 and 4 respectively of Volume 1.

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1. INTRODUCTION

In June, 1969, the Australian Atomic Energy Commission sought the assistance of the Electricity Commission of New South Wales to investigate sites suitable for the construction of a 500 MW nuclear power station in Commonwealth Territory on the south-eastern shores of Jervis Bay.

Two areas were selected for detailed examination following a site inspection by officers from both Commissions. The areas selected were:

1. An area about one and a half miles east of the Naval College adjacent to and between two rock promontories named Bristol Point and Scottish Rocks (see Figure 1). This site has been designated J.S1.

2. An area immediately west of Governor Head behind Murrays Beach. This site has been designated J.S2.

Investigations were carried out at both sites until early in 1970 when it was decided to adopt the Murrays Beach site (J.S2). The work carried out on the Scottish Rocks site (J.S1) has been presented in E.C. of N.S.W. Report No C.I. 43, entitled "Jervis Bay Nuclear Power Station Project - Investigations at Site J.S1 - Scottish Rocks", dated June, 1970.

This Report presents, in three volumes, the results of the work carried out on the Murrays Beach site (J.S2) up until November, 1970.

This volume (Volume 1) contains a description of the site, a summary of the geological investigations which are detailed in Volume 2, a summary of the hydrographical investigations which are detailed in Volume 3, a brief summary of the relative costs of alternative circulating water systems and recommendations for further investigations.

It was apparent from the initial inspection that the site was topographically suitable for a large power station (see Figure 1) and that adequate cooling water supply could be obtained in a variety of ways. The civil works investigations were therefore directed to establishing the nature of the foundation conditions, to select a station area and grade level, to establish the foundation conditions along alternative routes for the cooling water conduits and to obtain hydrographic data to assist in the selection of the optimum infall and outfall locations.

The Australian Atomic Energy Commission indicated at an early date that a cooling water system discharging to the ocean would be preferred. To meet this requirement at minimum cost, outfall conduit number 1 (see Figure 2) was chosen along the back of Murrays Beach and discharging at the gap between Bowen Island and the mainland. A breakwater to Bowen Island was considered necessary to prevent the return of the bulk of the cooling water to Jervis Bay. Outfall conduit Number 2 was chosen with a tunnel through the cliff section at Governor Head. This route avoided the difficult cliff section of route No. 1 which would require a large and unsightly cut. Outfall conduit number 3 route was chosen to give approximately 3,000 ft. separation between the outfall point and the gap at Bowen Island. A breakwater to the island would not be required with this outfall.

Two bay outfall routes, numbers 4 and 5, were investigated and these were chosen to give adequate separation of the outfall from the infall so as to prevent uneconomic circulation of heated water.

The cooling water system could be arranged in a number of ways, for example, outfall conduit routes numbers 4 and 5 could be intake conduit routes for outfalls 1 to 3. They could also be infall routes with an outfall at the intake shown on Figure 2.

The work was carried out by a number of authorities as follows.

Maps of Jervis Bay Commonwealth Territory to a scale of 400 ft. to 1 in. with 10 ft. contours were made available by the Commonwealth Department of the Interior.

Seismic surveys, photogeological interpretation of aerial photographs, rock testing and petrographic examination of rock cores were carried out by the Bureau of Mineral Resources.

Surveys for the seismic work were made by a Surveyor of the Commonwealth Department of the Interior.

First order triangulation and precise level surveys to fix positions and levels of permanent works for the N.S.W. standard survey origin and datum were carried out by the N.S.W. Department of Lands.

Geophysical "sparker" surveys of the floor of Jervis Bay North of Bristol Point and Scottish Rocks were carried out by staff from the Geology School, University of N.S.W.

The Water Research Laboratory of the University of N.S.W. prepared:

(a) Estimates of storm wave statistics for the site using wind data collected by the Electricity Commission at Tallawarra and the Navy at the Jervis Bay air field;

(b) Estimates of the maximum water levels at the site;

(c) Rock sizes required for a breakwater between Bowen Island and Governor Head;

(d) The effectiveness of a skimmer at the C.W. intake for a bay outfall.

Staff from H.M.A.S. Creswell operated the tide recorder installed at the Naval College and an ONO current meter.

Electricity Commission of N.S.W. personnel have:

(a) Operated two recording current velocity meters and a wave and tide recorder in the Bay and analysed the records obtained from these instruments.

(b) Carried out geological mapping, supervised drilling and logged cores obtained by contract drillers working under the E.C. of N.S.W. period drilling contract.

(c) Supervised laboratory testing of soil and rock samples. Soils tests were carried out by George Wimpey & Co. Ltd. under a period Works Order and by E.C. personnel at Leichhardt Laboratory. Rock testing was carried out by the School of Civil Engineering, University of Sydney, and by the Metropolitan Water, Sewerage and Drainage Board. Petrographic analyses were carried out by Coffey and Hollingsworth and Aminco Pty. Ltd.

(d) Prepared preliminary station arrangements, preliminary designs to fix cooling water conduit sizes and have prepared cost estimates of alternative cooling water systems civil works

The overall programme was directed by officers from the Electricity Commission of N.S.W. in consultation with the Australian Atomic Energy Commission.

2. SITE LOCATION, ACCESS AND TOPOGRAPHY

Jervis Bay, located on the east coast of Australia at latitude 35°S, is a large, open, deep inlet about 10 miles (16 km.) long in the N to S direction by seven miles (11 km.) wide in the E to W direction (see Figure 1). At present the Bay is undeveloped except for small villages, the principle one being Huskisson, and the Commonwealth Government's Naval College establishment on the southern peninsula. The whole of the area, except for 28 square miles (72 square km.) on the southern peninsula which is Commonwealth Territory is within the state of N.S.W. Murrays Beach, the site of the Jervis Bay Nuclear Power Station, is on the northern tip of the Commonwealth Territory (see Figure 1).

Access to the site is available only by road or sea. A bitumen road extends 125 miles (200 km.) from Sydney to the Naval College and a bitumen access road is currently being constructed over the remaining four miles (6.5 km.) from near the Naval College to the station site at Murrays Beach (see Figure 1). Jervis Bay is navigable, over a wide area, for large vessels but no port facilities are available. Rail access is available from Sydney to Bomaderry which is 29 road miles (47 km.) north of the station and commercial aircraft services are available from Sydney to Nowra.

The southern (Bherwerre) peninsula of Jervis Bay is a comparatively low lying area being mostly less than R.L. 300 (R.L. 91 m.)*

* All levels included in this Report refer to a datum which is - R.L. 100 Standard Datum.

with a maximum elevation of about R.L. 554 (R.L. 169 m.) at Bherwerre trigonometrical station, 2½ miles (4.4 km.) to the south of Murrays Beach and the Naval College. Governor Head forms the northern tip of Bherwerre Peninsula (see Figure 2). Murrays Beach is to the west of the headland. Bowen Island, to the north, is separated from Governor Head by a shallow stretch of water about 800 ft. (240 m.) wide.

South from Governor Head (see Figure 2) the country rises precipitously from the sea with sandstone cliffs about 120 ft. (36 m.) high. From the cliff edge, for two miles (3.2 km.) south of Governor Head, the land rises more gradually to levels of R.L. 300 (R.L. 92m.) within about 400 ft. (122 m.) of the shoreline and then falls very gradually to the westward to the Jervis Bay foreshore.

Around Murrays Beach there is little exposure of rock and except for the rocky promontory at the western end of the beach and the cliffs on the coast, south from Governor Head, the land is covered with sand and supports a dense growth of native shrubs and trees. South from Murrays Beach along the Bay foreshore there is a small cultivated pine tree plantation but apart from this the land is undeveloped with no population within three miles (4.8 km.).

On the ocean side, the sea floor falls steeply from the cliff edges to about R.L. 40 (R.L. 12 m.) within a distance of 100 ft. (30 m.). Between Governor Head and Bowen Island the sea floor rises abruptly from the ocean side to general depths of about R.L. 80 (R.L. 24 m.) and shelves down to the westward in Jervis Bay at a gradual slope. To the north and west of Murrays Beach the bay floor falls gradually from the foreshore to depths of R.L. 80 (R.L. 24 m.) within distances of 800 ft. (240 m.) and 400 ft. (120 m.) respectively. Northwards from the rocky promontory at the western end of Murrays Beach (see Photograph 1) there is a shallow sand bar at R.L. 82 to R.L. 88 (R.L. 25 m. to R.L. 27 m.) stretching to the north and east to Bowen Island.

The station area (see Figures 3 and 4) is relatively low ground, levels ranging from R.L. 120 to R.L. 150 (R.L. 37 m. to R.L. 46 m.), with a gradual slope of 3.5%.

3. SURVEYS

The following maps of Commonwealth Territory, Jervis Bay, were available when site investigations for the nuclear power station at Jervis Bay commenced in 1969:

Commonwealth Territory

(i) 1:12000 with 10 ft. contours.
Published by Survey Branch, Department of Interior, Canberra, 1967.

(ii) 1:4800 with 10 ft. contours.
Published by Survey Branch, Department of Interior, Canberra.

Datum for these plans is mean high water St. Georges Basin. *

* For relationships between Datums refer Volume 3.

Hydrographic Charts

(i) 1:18300 Soundings in fathoms.
Published by the U.K. Admiralty, 1894. Datum is lowest water obtained during one lunation.

(ii) 1:150000 Soundings in fathoms and feet.
Published by the Hydrographic Service, R.A.N., 1957.
Datum in Jervis Bay area is 8 ft. below a B.M. cut in the pile to which the tide pole is attached at the Naval Jetty, Captains Point, Jervis Bay.

(iii) 1:37500 Soundings in fathoms and feet.
Published by Hydrographic Service, R.A.N., 1955.
Datum is 11 ft. below the top of the S.W. concrete pile of the crane support close eastward of the R.A.N. Jetty, Captains Point.

The following maps and surveys were produced as a part of these investigations:

Station Area

(i) 1:1200 with 2 ft. contours.
Survey by Foxall, Lines and Ayres for E.C. of N.S.W.
Datum is - R.L. 100 ft. Standard Datum.

(ii) The E.C. of N.S.W. Survey Branch established twelve 1st order survey stations around the proposed site and Surveyors from the N.S.W. Lands Department:

(a) Determined the co-ordinate positions for each station using a tellurometer.

(b) Determined the level of each station relative to State Standard Datum using precise levelling techniques.

Hydrographic Charts

(i) 1:1200 with 2 ft. contours in gap between Governor Head and Bowen Island.
Survey by Foxall, Lines and Ayres for E.C. of N.S.W.
Datum is - R.L. 100 ft. Standard Datum.

(ii) 1:480 with 2 ft. contours and spot levels between Governor Head and Bowen Island.
Survey by Foxall, Lines and Ayres for E.C. of N.S.W.
Datum is - R.L. 100 ft. Standard Datum.

(iii) 1:4800 with 10 ft. contours and soundings in feet for areas covering bay foreshore from Bowen Island to Bristol Point and offshore in ocean from Bowen Island to 1 mile south.
Survey by Decca Surveys, Australia, for Australian Atomic Energy Commission.
Datum is 11 ft. below the top of the S.W. concrete pile of the crane support, close eastward of the R.A.N. Jetty, Captains Point.

4. GEOLOGY AND FOUNDATION INVESTIGATIONS

In order to determine the station location with the most suitable foundations, field investigations were carried out which included geological mapping, geophysical surveys, diamond and auger drilling and field ripping tests. In situ, penetration and permeability tests were supported by laboratory petrographic examination of core samples and strength testing on rock samples.

Jervis Bay is located on the southern side of the Sydney Basin which is filled with Permian and Triassic Age sedimentary and volcanic rocks. The Murrays Beach area is underlain by a series of sandstone and silty sandstones which belong to the Lower Permian Conjola Formation. These rocks are gently folded and, in the station area, dip to the northwest at angles of between 3^o and 6^o to the horizontal.

4.1 ROCK TYPES AND PROPERTIES

Rock exposures near Murrays Beach are almost exclusively restricted to outcrops on the coastline. Geological mapping in the area, supplemented by drilling, has enabled the detailed geological succession near the station site to be evaluated. Beneath a surface covering of sand which averages 10 ft. (3 m.) but which is considerably deeper south of Murrays Beach, the rocks can be divided into three groups. For the purpose of this investigation these groups have been called the Upper White Sandstone, the Intermediate Grey Silty Sandstone and the Lower Light Grey Sandstone.

The Upper White Sandstone is the highest geological formation in the area. It is composed of medium to coarse grained, almost pure white, quartz rich sandstone and reaches a thickness of more than 60 ft. (18 m.) on the bay west of Murrays Beach. It forms the tops of the cliffs at Governor Head. The rock is uniform in composition and is rather friable. Strength testing of samples gave unconfined compression strengths ranging from 2,000 to 9,000 p.s.i. (13.8 to 62 N/mm^2) with an average modulus of elasticity of about 0.2×10^6 p.s.i. (1380 N/mm^2). Close to the base of the white sandstone an increase in silt content has produced a much weaker rock.

The Intermediate Grey Silty Sandstone ranges in thickness from 30-50 ft. (9-15 m.) and is exposed in the cliffs just south of Governor Head. The rocks within this formation vary widely in composition, but, in general, have a much higher silt content than the rocks above and below. Although cliff forming, the silty sandstone is very friable. Compressive strengths ranging from 300 to 8,000 p.s.i. (2.1 to 55 N/mm^2) were obtained from samples taken from within this group. The average modulus of elasticity is about 0.1×10^6 p.s.i. (690 N/mm^2).

The ocean cliffs south of Governor Head are formed by the Lower Light Grey Sandstone. This formation is at least 150 ft. (46 m.) thick in the station area and is made up of grey quartz rich sandstones with a low to moderate silt content. These rocks

are much more resistant than the sediments above. Compressive strengths range from 5,000 to 14,000 p.s.i. (34.5 to 96.5 N/mm^2) and the average modulus of elasticity is about 1.3×10^6 p.s.i. (8,300 N/mm^2).

Although jointing is present in all coastal exposures, it is often widely spaced and tight. Evidence of minor fault movement along the ocean cliffs was observed but the fault planes are narrow and relative displacement has been small.

4.2 STATION SITE

The station area has been chosen in the location where minimum excavation to grade level has been required and where a maximum depth of Upper White Sandstone occurs. Ripping tests have shown that it will be possible to rip the material to grade level, but that suitable bearing capacity rock exists close to that level. The testing of the rock has shown that a typical turbine house column footing located on Upper White Sandstone with a loading of 25 tons per square foot (2.68 N/mm^2) would settle less than 0.5 ins. (13 mm.) and that a 150 ft. (45.7 m.) diameter reactor building with an average loading of 5 tons per square foot (0.54 N/mm^2) located either on the Upper White Sandstone or the Intermediate Grey Silty Sandstone would settle about 0.6 ins. (15 mm.).

4.3 COOLING WATER CONDUITS

The intake canal and circulating water pumping station (see Figures 2, 3 and 4) would be excavated from strong white sandstone. For a station layout with a bay outfall the excavation for a channel into the bay would require the removal of approximately equal quantities of sand and rock.

Based on the foundation investigation, outfall No. 5 is to be preferred to outfall No. 4, as much less excavation is involved and the canal invert would be located on more resistant rock. Both outfalls No. 1 and No. 2 would have to be constructed through deep sand and weathered rock south of Murrays Beach. The rock forming Governor Head is not particularly strong and would not be suitable for use as rip rap. The first thousand feet (305 m.) of outfall No. 3 south-east from the station would cross weathered Intermediate Grey Silty Sandstone and would probably be constructed more economically by cut and fill methods. The remaining 2,000 ft. (610 m.) to the ocean coast would be tunnelled in strong Lower Light Grey Sandstone.

4.4 NATURAL CONSTRUCTION MATERIALS

There are large amounts of sand around the station but due to its poor natural grading some mixing may be necessary to give a material suitable for fine aggregate in concrete.

There are no suitable sources of coarse aggregates close to the station site. However, there is an established aggregate plant at Burrier on the Shoalhaven River, upstream of Nowra, and an established quarry winning monzonite (an igneous rock) at Milton. Both of these sources, which have been inspected, would provide suitable material.

Although considerable quantities of sandstone rock will be excavated in reducing the station site to grade level, this material will be fully used on the access road construction. Some additional material will be available from excavations below grade level but the bulk of the rock required for breakwater construction will most likely have to be won from a separate quarry. There is an old sandstone quarry located about one mile (1.6 km.) south of the Naval College and an initial examination of this material including accelerated weathering tests indicates that it is probably suitable for use in breakwaters within the bay. This material has been used for the breakwater construction at the Naval College and it has stood up satisfactorily for many years. If a breakwater is needed from Governor Head to Bowen Island and rock armouring of the structure were to be used, then sandstone would not be considered satisfactory, but monzonite from Milton may be found suitable provided that satisfactorily large sizes could be economically quarried.

5. HYDROGRAPHIC INVESTIGATIONS

Jervis Bay is a large inlet, permanently open to the sea with a wide, deep channel, but the surrounding catchment area of only 110 square miles (285 square km.) is small. The only watercourse of any significance is Currambene Creek which enters the bay on the western side near Huskisson. Flood levels in the bay are small and the inflows from Currambene Creek cannot affect the currents or water quality near Murrays Beach. The water levels and currents around the station site can be due only to wind waves and seiches within the bay together with tides and the residual effects of tsunamis, ocean currents and ocean waves.

5.1 DATA COLLECTION

Instrumentation for recording of tides, waves, currents and winds was found to be inadequate at the commencement of investigations. Although tide gauges were maintained during earlier occupancy of the Naval College (these records have not been located), there was no automatic recording gauge until July, 1969, when the Electricity Commission placed an instrument at Captains Wharf. This instrument was maintained until June, 1970, when it was replaced by the Commonwealth Scientific Industrial and Research Organisation with a better quality instrument which has recorded tides and seiches since then. An automatic instrument recording wave heights, wave periods and tide levels was installed during 1970 at a point 300 feet (90 m.) offshore at the site of the proposed cooling water intake canal (see Figure 2). Two automatic instruments recording current velocities and water temperature were installed during April, 1970 and June, 1970. The first instrument was placed 700 ft. (213 m.) offshore and inside the gap at Governor Head at a depth of 18 ft. (5.5 m.) below M.S.L. and the second instrument was placed 1,500 ft. (457 m.) offshore from the rocky promontory at the western end of Murrays Beach (see Figure 2) at a depth of 14 ft. (4.3 m.) below M.S.L.

In addition several surveys of currents were made in the bay and ocean using tethered and free drogues.

A permanent weather station was installed during June, 1970 at the station site (see Figure 2) with instruments recording wind velocities at different levels, rainfall, temperature and humidity. Longer term records of these factors are available from surrounding district stations at the Naval College, Naval Airstrip at Jervis Bay, Naval Base at Nowra and Point Perpendicular Lighthouse.

5.2 WATER TEMPERATURES

Water temperatures have been recorded once daily at the Naval College since April, 1969, but at the station site the only records are those from the two current meters installed during 1970. A few temperature profile measurements have been made during the autumn and winter of 1970, but the more critical summer period temperatures will not be covered until the coming season. The Naval College records from 1968 to 1970 indicate a maximum bay water temperature of 77°F (25°C), average 65°F (18°C) and minimum of 57°F (14°C). These records indicate that the average water temperature in Jervis Bay is similar to that in the shallow lakes used by the Commission for cooling water but that the range in temperatures of only 20°F (11°C) is 19°F (10.5°C) less than the range in the coastal lakes.

5.3 MAXIMUM WATER LEVELS

The general station area or grade level was adopted as R.L. 115 (R.L. 35 m.) on the basis of investigations made by the Water Research Laboratory (see Appendix E, Volume 3) on water levels in Jervis Bay. This report recommended that an amount of 14 ft. (4 m.) above I.S.L.W. (Indian Spring Low Water), being the sum of high tide, seich and run-up from a tsunami and wind waves, would be a reasonable assessment of the maximum water level on the bay shore. The adopted grade level of R.L. 115 (R.L. 35 m.) is approximately 18 ft. (5.5 m.) above I.S.L.W. This grade level was chosen to provide for drainage from the site during high water level conditions and also to provide a nominal freeboard above the assessed level.

5.4 CURRENTS IN JERVIS BAY

The results of bay current velocity measurements and drogue tracking have indicated that there are no predominant or predictable patterns of water movement except for the gap region between Bowen Island and Governor Head. In the gap there is a westward movement of water from the ocean to the bay during times of high ocean swells. Otherwise, the current velocities appear to be complex changing patterns resulting from both tides and winds with wind effects more dominant. It should be noted that the current meters have, of necessity, been installed at depth so that the currents in the top few feet have not been measured except by drogues. Although it is not expected that there is a significant velocity variation with depth, additional investigations will be made into this matter.

5.5 COOLING SYSTEM PERFORMANCE

The ocean outfalls are so remote from the infall that the temperature of the cooling water drawn into the station will be unaffected by the warm water discharge.

For the two bay outfalls, there will be some recirculation of heated water under certain weather and current situations. On the basis of the current measurements, drogue trackings and wind records it appears that there is no preferred arrangement for the bay cooling water conduits. An intake conduit located on the western side of the station (see Figure 2) with an outfall on the northern side is probably no more likely to have movement of warm water from the outfall to the intake due to natural currents than with the reverse orientation of conduits. However, it is clear that a deep cooling water intake channel can be built more cheaply on the western side of the station (see Figure 2) than elsewhere, because deep water is available closer in shore at this point. From preliminary environmental investigations conducted by the Australian Atomic Energy Commission, it is probable also that an intake on the western side would have less trouble with weed fouling of screens than with a northern location.

Estimates have been made of the extent to which the bay will be heated by the discharge of cooling water. These estimates have been based on a heat rejection rate of 5152 x 10^6 Btu per hour which is the highest heat rejection rate of the nuclear system tenders received and the results of surveys of the temperature distributions in the lakes used for cooling at power stations operated by the Electricity Commission of N.S.W. as well as theoretical calculations of heat exchange rates for varying increases in water surface temperature.

For still conditions, when there are no natural tidal, wave or wind induced currents in the bay, it has been estimated that with either the No. 4 or No. 5 bay outfall. the water temperature at the infall would be increased by about 2-3°C at the surface and the hot water layer would be about 10 ft. thick. Under conditions of strong south-westerly currents which have been recorded in the bay, it is estimated that the surface temperature at the intake would be increased by about 4-5°C and the hot water layer would be about 7 ft. thick. With strong north-easterly currents, there would be no increase in inlet water temperatures above natural temperature.

The Water Research Laboratory has examined the use of skimmers on cooling water intakes to reduce intake of warm surface water. A report on this (see Appendix F, Volume 3) theoretical and experimental work indicates that for conditions with a 20 ft. (6.1 m.) deep intake channel, flow of 10 cusecs per foot width (0.93 m^3/sec/m.), upper water surface layer 5 ft. (1.5 m.) thick with temperature 5°F (2.8°C) higher than the lower layer, the flow of water from the upper layer would be 25% of the total flow. In order to have the total flow from the bottom cooler layer only, it would be necessary to reduce the intake flow to 3 cusecs per foot width (0.28 m^3/sec/m.).

5.6 BOWEN ISLAND BREAKWATER ROCK SIZES

Investigations were made by the Water Research Laboratory of design wave heights and armour requirements for a proposed breakwater in the gap from Governor Head to Bowen Island. This investigation (see Appendix G, Volume 3) using a two dimensional model indicates that ocean waves greater than 35 ft. (10.7 m.) would break before reaching the step in the ocean floor (see Section 2) but that these waves would cause the maximum run-up of 27 ft. (8.2 m.) on the breakwater. The model indicated that three layers of armouring with 7 ton angular rock on a 1:2 slope would be necessary. It was noted in the report that artificial armouring with concrete sections would give lower damage results on a breakwater and that a three-dimensional model would be required to fully establish the requirements for a structure in this situation.

6. PROJECT FORMULATION AND PRELIMINARY ESTIMATES OF CIVIL WORKS COSTS FOR ALTERNATIVE COOLING WATER SYSTEMS

6.1 PROJECT FORMULATION

The station site was selected from geological considerations (see Section 4.2 above) so as to have the maximum thickness of the upper white sandstone immediately below the station bench level and yet have a minimum of excavation to level the site to grade.

The station bench level was selected at R.L. 115 (R.L. 35 m.) from considerations of maximum water levels in the bay (see Section 5.3 above)

With the station arrangement and location shown on Figure 2, the circulating water infall conduit would be most economically located on the western side of the station where the length of high cost conduit is least and where the distance to deep water also is least. There is no clear environmental or additional hydrographic reason for examining an alternative location for the infall (see Section 5.4 above) and the single location shown on Figure 2 was therefore adopted.

The cooling water outfall conduit could discharge either to the ocean or to Jervis Bay.

An ocean outfall was favoured by the Australian Atomic Energy Commission as being desirable from ecological considerations particularly in relation to releases of radioactive material to the environment. Three alternative ocean outfall conduit locations were chosen, Nos. 1, 2 and 3, to determine the optimum. It was assumed that outfalls Nos. 1 and 2 would require a breakwater from the mainland to Bowen Island to prevent the return of the bulk of the outfall water to Jervis Bay, but location No. 3 was sufficiently distant from the gap that a breakwater to Bowen Island was unnecessary.

Initially, it was suggested that thermal effects resulting from a bay outfall might interfere with the Royal Australian Navy's sonar installation in Jervis Bay but subsequently the Navy advised that this would not be a problem.

With a bay outfall, the discharge would need to be sufficiently separated from the infall so that uneconomic circulation of heated water was prevented and the locations Nos. 4 and 5 (see Figure 2) were assessed as being adequate for this purpose provided that a submerged intake was constructed.

The model and analytical work carried out by the Water Research Laboratory has shown that for the temperature stratification predicted at the infall under still conditions, a skimmer can be made to be fully effective in preventing the drawing in of warm surface water provided the flow rate is kept at or below 3 cusecs per foot width. If the flow rate is increased to 10 cusecs per foot width, the skimmer is of no benefit, but the increased depth of the intake channel associated with the skimmer results in lower average temperatures (see section 5.5 above).

The extent of the penalty incurred by having higher inlet water temperatures cannot be assessed with accuracy until the nuclear system and fuel costs are known. However, a preliminary estimate based on costs for conventional base load coal-fired plant in N.S.W. indicates a penalty of the order of $120,000 if a bay outfall is adopted rather than an ocean outfall; this penalty is very small in comparison with the extra capital cost involved in the construction of an ocean outfall.

There will be occasions, however (such as under strong north-easterly winds and south-westerly currents in the bay), when the warm water discharge will travel to the intake close to the shore and there would be significant recirculation of warm water. Under these conditions of strong temperature stratification, a deep submerged intake would be of value and it is recommended that a skimmer be constructed in front of the C.W. pumping station should the bay outfall be adopted.

6.2 COST ESTIMATES

Cost estimates for the cooling water system civil works have been prepared as part of the overall cost study for the station. The flow rates considered range from 800 to 1200 cusecs corresponding to the range of cooling water flows contained in the Nuclear Steam Supply Tenders. Unit prices are based on current (mid-1970) contract costs, Snowy Mountains Hydro-Electric Authority data and, in the case of large diameter reinforced concrete pipes, prices quoted by manufacturers. Unit rates are summarised in Table 1 below.

TABLE 1

Typical Unit Rates used in Cost Estimates

Bay Infall and Outfall Conduits	
General Excavation	$1.5 per cu.yd.
Rock	$15 per cu.yd.
Breakwaters	$3 per cu.yd.
Concrete	$80 per cu.yd.
Steel	$1,350 per ton
Backfill	$2 per cu.yd.
Rip-Rap	$4 per cu.yd.
Ocean Outfall Conduit	
10 ft. Diameter Tunnel	$400 per lin.ft.
10 ft. Diameter Pipe	$90 per lin.ft.
Bowen Island Breakwater average	$3.6 per cu.yd.

6.3 OPTIMISATION STUDIES

The economic sizes of closed conduits and channels have been determined from economic studies which take account of construction costs, energy charges to overcome friction capitalised over the life of the station and power demand charges appropriate to the friction head loss. The value of $252 per kW has been used for capitalised power and demand charges.

6.4 INITIAL COST ESTIMATES

Initially cost estimates were prepared for the outfalls for a single capacity of 1,000 cusecs (28.3 m^3/sec.) to determine the relative costs of the ocean discharge alternatives 1, 2 and 3 and of alternatives 4 and 5 discharging to the bay. Each outfall was considered to start at a common point 400 ft. (122 m.) on the eastern side of the turbine building (see Figure 2).

No. 1 Outfall

This conduit cost was estimated on the basis of a 10 ft. (3.05 m.) diameter reinforced precast concrete pipe laid in a trench and backfilled so as to restore a grass cover along the section of conduit to the east of the station and along the southern edge of Murrays Beach. From the offtake point of conduit 2 (see Figure 2), the alignment of No. 1 conduit is along a rocky cliff close to the water's edge and it would be necessary to backfill the pipe in several places with mass concrete. Because of the rock cliff, it would not be possible to restore this section to a natural unspoilt state.

The breakwater was assumed to be a pervious dumped rock structure with crest level at R.L. 115 ft. (R.L. 35 m.). This level would be adequate to prevent overtopping by the majority of ocean waves but some overtopping and some flow of water would occur through the structure during storm conditions. The breakwater was assumed to be constructed with sandstone rock below water level with an armour covering of igneous rock quarried at Milton. The Water Research Laboratory has made a preliminary study and a small scale model (see Volume 3) to determine the magnitude of ocean waves reaching a breakwater at this site and this work has indicated that a dumped rock breakwater is probably adequate. However, further study may establish that precast concrete armour plate units are necessary and the cost estimate would be increased thereby.

No. 2 Outfall

The first section of No. 2 outfall and the breakwater is the same as described previously for No. 1 outfall. From the offtake point from the No. 1 conduit (see Figure 2), this conduit would be a short length of 10 ft. (3.05 m.) diameter concrete lined tunnel discharging to the rock platform on the ocean side.

No. 3 Outfall

This conduit was estimated on the basis of a 10 ft. (3.05 m.) diameter concrete lined tunnel discharging to the ocean through a concrete box type structure constructed in the cliff face. This tunnel would be constructed from one face only at the station end. The ocean end would be constructed by excavating a rectangular shaft close to the cliff face behind a short section of rock that would be necessary to protect the works from ocean waves during construction. The shaft would be lined with a structural concrete box connecting with the tunnel that would house stop logs and lifting gear that would be required initially to close the tunnel and for subsequent maintenance closures. On completion of the tunnel and outfall structure, the protective rock section would be excavated with the bottom section blasted into the ocean. Geological investigations have shown that the tunnel route adopted for these estimates (see Figures 2 and 4) will have poor rock conditions for the first 1,000 ft. (305 m.) and that a cut and cover construction may be required.

No. 4 Outfall

This conduit follows a similar alignment as No. 1 conduit as far as Murrays Beach where it would discharge. This conduit would be a 9 ft. (2.74 m.) diameter reinforced precast concrete pipe laid in a trench, backfilled and restored with a grass cover. The discharge would be across Murrays Beach which would be excavated to form a dissipator and outlet channel to deep water. The outfall would be protected from sand encroachment from the beach with short sections of sandstone rock breakwaters.

No. 5 Outfall

This conduit is similar to the No. 4 outfall but the discharge would be across a natural rock platform that would need to be excavated for a shallow depth only. A sandstone rock breakwater would be necessary on the north-western side of the outfall to channel the discharge away from the infall to an equivalent separation as outfall No. 4.

Comparative Costs of Outfalls Nos. 1, 2, 3, 4 and 5

The following estimated contract construction costs (including 10% contingency) were determined for the five outfall conduit proposals with a capacity of 1,000 cusecs (28.3 m^3/sec.). These costs, and all other costs, included herein, do not include engineering on costs such as investigation, design, supervision, or owner's general overheads.

Outfall No.	Contract Cost (including 10% Contingency) $
1	1,350,000
2	1,500,000
3	1,450,000
4	350,000
5	290,000

As discussed in Section 6.1, outfalls Nos. 4 and 5 would require the construction of a deep intake channel and skimmer (estimated to cost $150,000) which should be allowed for in this comparison of bay and ocean outfalls.

No. 5 outfall is less costly than No. 4 and has the added advantages of causing less disturbance to flora and would leave Murrays Beach undisturbed. Two disadvantages of No. 5 location (see Figures 2 and 3) are the need for a long breakwater to achieve separation from the infall and the route of No. 5 outfall may cause more interference with other construction works than No. 4. Overall, it would seem that No. 5 outfall is the best location for a bay discharge.

The cost differences in the three ocean outfall proposals are not particularly significant having regard to the accuracy of the estimates. No reason can be advanced to favour No. 2 over No. 1 outfall and therefore the choice in location is between No. 1 and No. 3 ocean outfalls. No. 1 location has the following disadvantages:

(i) The possible cost increases for the breakwater because of additional armour requirements, and additional quantities if the crest level is raised above R.L. 115 (R.L. 35 m.) to prevent or reduce overtopping;

(ii) The disturbance to Murrays Beach is extensive;

(iii) Possible erosion or shoaling changes to the bay that may be brought about by the construction of the breakwater.

No. 3 location has the following disadvantages:

(i) The possible cost increases in the tunnel resulting from adverse geological conditions;

(ii) The difficult construction conditions for the outfall at the ocean cliff face, but this alternative would cause the least disturbance to the environment.

6.5 COST ESTIMATES FOR BAY AND OCEAN OUTFALL CONDUITS

Further estimates of cost were made for No. 3 and No. 5 outfalls, to the ocean and bay respectively, for discharge capacities of 800 cusecs (22.7 m^3/sec.), 1,000 cusecs (28.3 m^3/sec.) and 1,200 cusecs (34.1 m^3/sec.). These outfalls were considered to start at a common point on the eastern side of the turbine house (see Figures 3 and 4).

No. 3 Outfall

For No. 3 outfall, the proposed conduit system consists of a reinforced concrete square box structure leading from the turbine house to a semi-circular spillway. The spillway controls the water level for syphon recovery from the condenser and discharges to a fully concrete lined tunnel that discharges to the ocean through a concrete box structure on the ocean cliff face as previously described. The economic conduit sizes determined are given in Table 2 below:

TABLE 2

Economic Conduit Sizes for Outfall No. 3

Discharge Capacity	800 cusecs (22.7 m^3/sec.)	1,000 cusecs (28.3 m^3/sec.)	1,200 cusecs (34.1 m^3/sec.)
Box Section	9'0" x 9'0" (2.74 m. x 2.74 m.)	10'0" x 10'0" (3.05 m. x 3.05 m.)	11'0" x 11'0" (3.35 m. x 3.35 m.)
Tunnel	9'3" diameter (2.82 m.)	10'0" diameter (3.05 m.)	10'9" diameter (3.28 m.)

No. 5 Outfall

For No. 5 outfall, the proposed conduit system consists of a reinforced concrete square box structure leading from the turbine house to a reinforced precast concrete pipe, thence through a concrete lined transition to an unlined rock channel to a concrete spillway, for controlling the water level for condenser syphon recovery. The spillway discharges to the bay through a shallow excavated rock channel. The direction of the discharge would be controlled by a rock (assumed to be sandstone) breakwater. The conduit sizes determined are given in Table 3.

TABLE 3

Economic Conduit Sizes for Outfall No. 5

Discharge Capacity	800 cusecs (22.7 m^3/sec.)	1,000 cusecs (28.3 m^3/sec.)	1,200 cusecs (34.1 m^3/sec.)
Box	9'0" x 9'0" (2.74 m. x 2.74 m.)	10'0" x 10'0" (3.05m. x 3.05m.)	11'0" x 11'0" (3.35m. x 3.35m.)
Culvert	10'0" diameter (3.05 m.)	11'0" diameter (3.35 m.)	12'0" diameter (3.66 m.)
Channel Width	--------- 12'0" (3.66 m.) with variable depth ------		
Spillway Width	32'0" (9.76 m.)	40'0" (12.40 m.)	48'0" (14.64 m.)

Comparative Costs of Outfalls Nos. 3 and 5

The following comparative estimated contract construction costs (including 10% contingency) were determined:

Discharge Capacity	800 cusecs (22.7 m^3/sec.)	1,000 cusecs (28.3 m^3/sec.)	1,200 cusecs (34.1 m^3/sec.)
No. 3 Outfall	$1,650,000	$1,750,000	$1,900,000
No. 5 Outfall	$280,000	$300,000	$330,000

6.6 COST ESTIMATES FOR INFALL CONDUIT

The costs of the infall conduit were estimated for the arrangements shown on Figure 3 for the bay outfall arrangement and Figure 4 for the ocean outfall. With the bay outfall, a skimmer and deep inlet channel has been allowed for. With the ocean discharge, this provision would not be necessary but otherwise the intake arrangement is the same.

The intake would consist of twin rock (assumed to be sandstone) breakwaters surrounding an excavated channel leading to the reinforced concrete intake pumping structure. This structure would include a trash rack section, a fine screen section housing vertical band screens, a pump section housing three 50% capacity mixed flow pumps which discharge to steel penstocks which join into a single reinforced concrete square box conduit leading to the western wall of the turbine house. The costs of the 350 ft. (107 m.) section of conduit within the turbine house (see Figure 2) between the end of the infall conduit and the beginning of the outfall conduit are not included.

The dimensions of the structures are given in Table 4 below.

TABLE 4

Salient Dimensions of the Inlet Conduits

Discharge Capacity	800 cusecs (22.7 m^3/sec.)	1,000 cusecs (28.3 m^3/sec.)	1,200 cusecs (34.1 m^3/sec.)
Inlet Channel Bottom Width	76' (23.2 m.)	90' (27.4 m.)	104' (31.7 m.)
No. of Screens	5	6	7
Steel Penstock Diameter	7'9" (2.36 m.)	8'8" (2.64 m.)	9'6" (2.89 m.)
Box Conduit	9'0" x 9'0" (2.74m.x2.74m.)	10'0" x 10'0" (3.05m.x3.05m.)	11'0" x 11'0" (3.35m.x3.35m.)
Infall Canal Invert	R.L. 80 (R.L. 24.4 m.) for the bay outfall case R.L. 88 (R.L. 26.8 m.) for the ocean outfall case		

Comparative Cost for Infall Conduit for Bay and Ocean Outfall Cases

The following comparative estimated contract construction costs (including 10% contingency) were determined:

Discharge Capacity	800 cusecs (22.7 m^3/sec.)	1,000 cusecs (28.3 m^3/sec.)	1,200 cusecs (34.1 m^3/sec.)
Infall for Bay Outfall	$1,450,000	$1,600,000	$1,750,000
Infall for Ocean Outfall	$1,300,000	$1,450,000	$1,600,000

The differences in costs for the bay and ocean outfalls are the estimated costs of skimmers and the deeper intake channel. The costs are for civil works only and exclude all electrical and mechanical items such as trash racks, screens, pumps, valves, gantry, etc.

6.7 TOTAL COSTS

The total estimated contract construction costs for the infall and outfall conduit alternatives are as follows:

Infall plus No. 3 Ocean Outfall

Discharge Capacity	800 cusecs (22.7 m^3/sec.)	1,000 cusecs (28.3 m^3/sec.)	1,200 cusecs (34.1 m^3/sec.)
Construction Costs	$2,950,000	$3,200,000	$3,500,000

Infall plus No. 5 Bay Outfall

Discharge Capacity	800 cusecs (22.7 m^3/sec.)	1,000 cusecs (28.3 m^3/sec.)	1,200 cusecs (34.1 m^3/sec.)
Construction Costs	$1,750,000	$1,900,000	$2,100,000

As has been noted the route of the outfall tunnel (No. 3) is located through approximately 1,000 ft. (305 m.) of poor quality rock. An alternative route, shown dotted on Figure 2, is being investigated to use a cut and cover construction for the section to the east of the station with a tunnel section discharging to the ocean at the same point used for No. 3 conduit. Additional survey and soils data is required for this route but it is not expected that the preliminary estimates of costs for No. 3 outfall will be altered significantly.

7. CONCLUSIONS

The investigations so far undertaken for the civil works at the Jervis Bay Nuclear Power Station site have shown that:

(i) The geological conditions of the selected site are suitable for the construction of the required structures.

(ii) The hydrographic conditions are suitable for the supply and circulation of the required volumes of cooling water with outfalls located either in the bay or on the ocean. There would be some recirculation of heated water with the bay outfall but this would be reduced to an acceptable level during periods when the natural water currents in the bay would cause rapid recirculation by the construction of a skimmer in front of the C.W. pumping station.

The penalty resulting from slightly higher cooling water temperatures with a bay outfall is small compared with the cost of constructing an ocean outfall. There is therefore no justification for adopting an ocean outfall to meet cooling requirements.

An ocean outfall may, however, be required because of ecological considerations having regard for releases of radioactive material from the station.

(iii) The estimated costs of alternative cooling water outfall conduits for 1,000 cusecs C.W. flow with either bay or ocean outfalls are as follows:

	Outfall	Estimated Contract Cost (Including 10% Contingency) $
Ocean Outfalls	1	1,350,000
	2	1,500,000
	3	1,450,000
Bay Outfalls	4	350,000
	5	290,000

Based on these costs and considerations of the technical and amenity advantages and disadvantages of each alternative, it is recommended that outfalls No. 3 or No. 5 be adopted depending upon whether an ocean or a bay outfall is selected.

(iv) The estimated costs for cooling water systems with bay and ocean outfalls are as follows:

Infall plus No. 3 Ocean Outfall

Discharge Capacity	800 cusecs ($22.7 m^3$/sec.)	1,000 cusecs ($28.3 m^3$/sec.)	1,200 cusecs ($34.1 m^3$/sec.)
Construction Costs	$2,950,000	$3,200,000	$3,500,000

Infall plus No. 5 Bay Outfall

Discharge Capacity	800 cusecs ($22.7 m^3$/sec.)	1,000 cusecs ($28.3 m^3$/sec.)	1,200 cusecs ($34.1 m^3$/sec.)
Construction Costs	$1,750,000	$1,900,000	$2,100,000

The estimates are construction costs and include an allowance of 10% for contingencies. They include the costs of the infall channel, infall breakwaters, cooling water pumping station, civil costs, infall conduits up to the turbine hall, outfall conduits from the turbine hall, water level control structures and, from the bay outfall, the outfall channel and breakwater. The costs do not include electrical and mechanical items (trash racks, screens, pumps, valves, gantry, etc.) or owner's overheads or interest during construction.

(v) The following additional investigations for civil works are required:

(a) Drilling and testing of rock in the station area is required for the design of major structures. For this purpose, it will be necessary to have details of the station layout, minimum depths of foundations for structures and foundation loading intensities.

(b) Additional drilling and testing of materials is required for detailed design along the routes of the cooling water infall conduit and the selected outfall conduit.

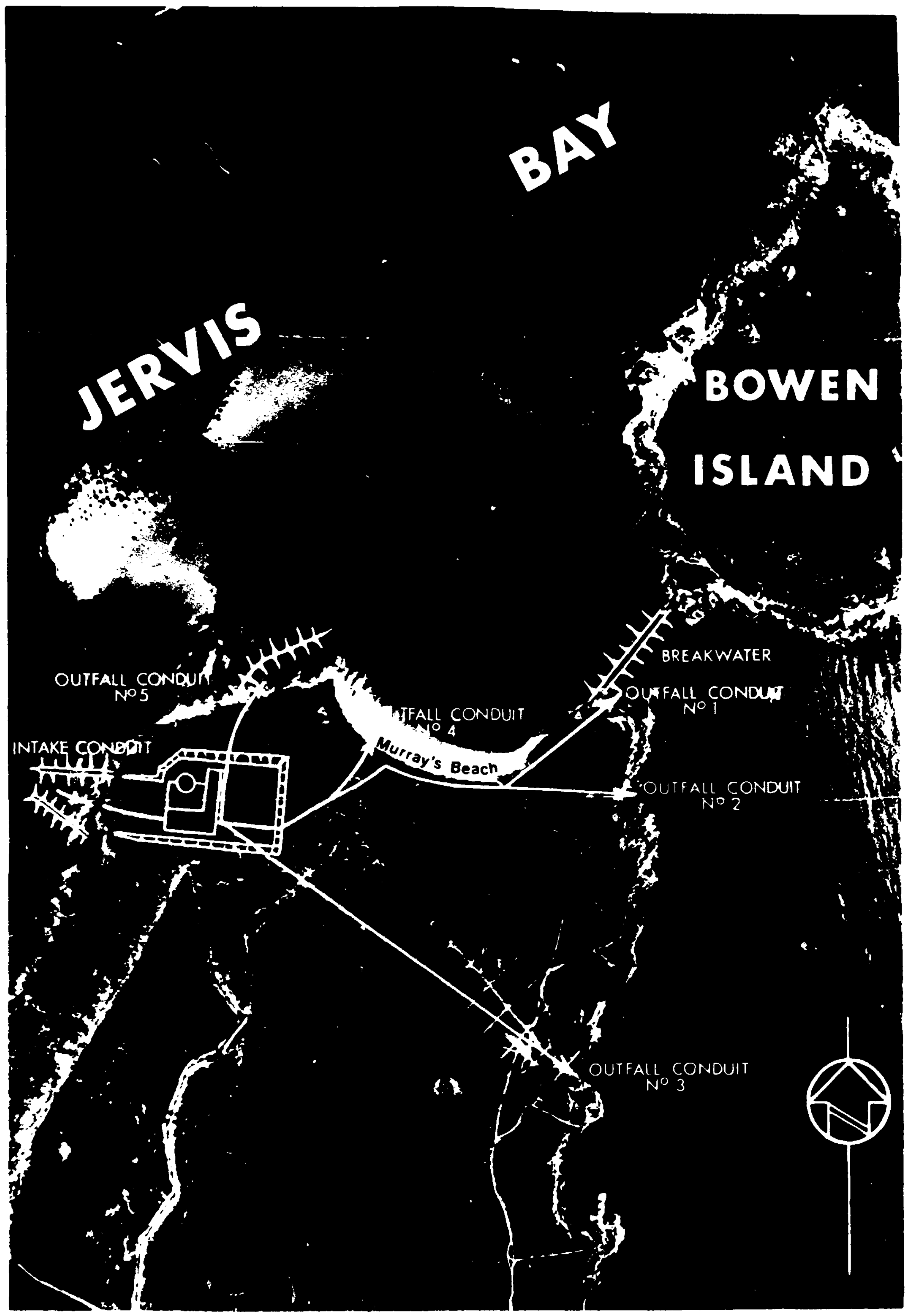
(c) Additional detailed hydrographic survey of the bay floor in the area of the cooling water infall and in the area of the selected outfall.

(d) Additional detailed land survey is required along the route of outfall conduit No. 3 if this outfall is selected.

(e) The present hydrographic surveys of waves, currents, tides and water temperatures should be continued.

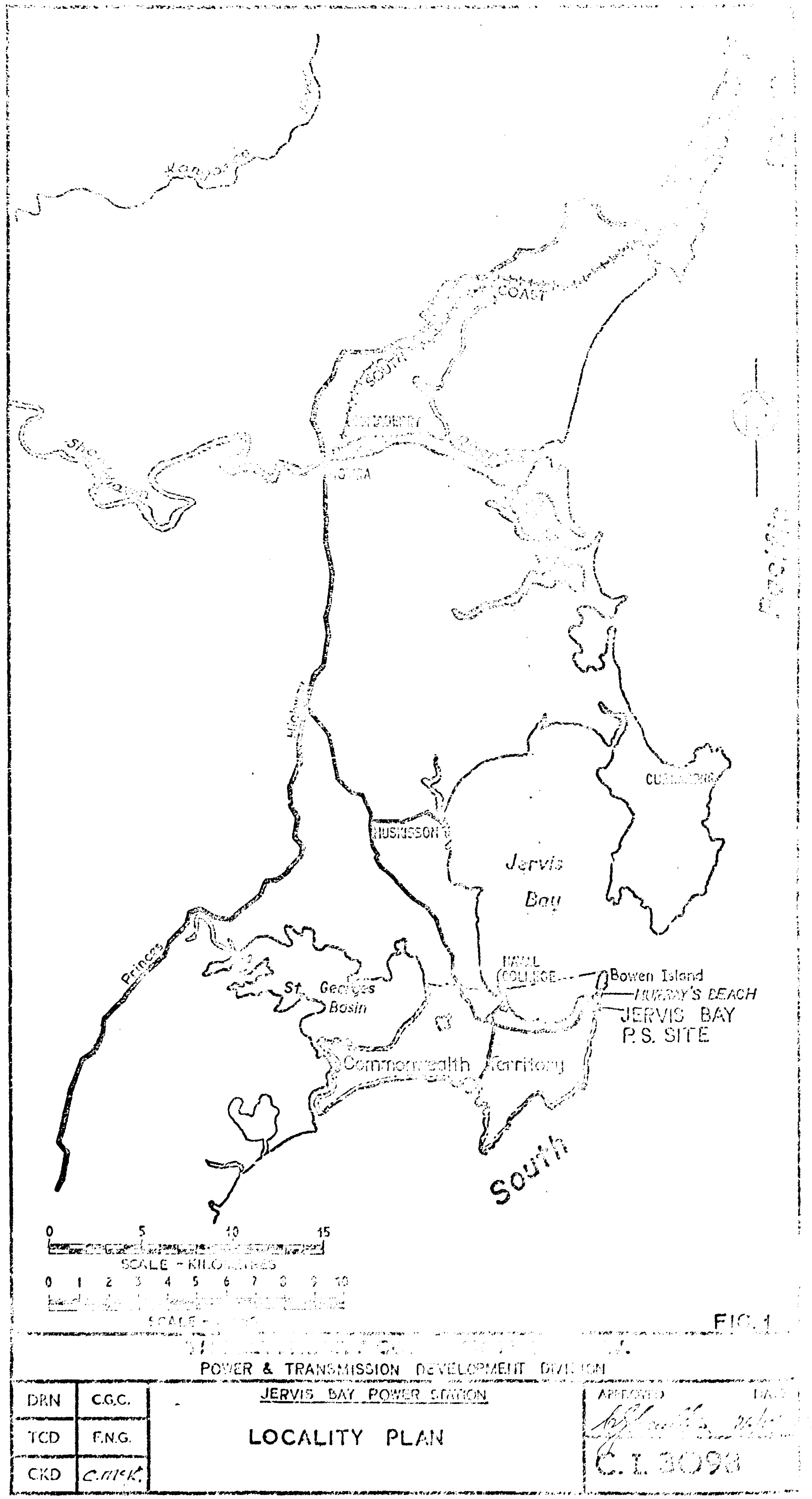
(f) Additional investigations should be made for the supply of concrete aggregates and of rock for breakwater construction. The latter should include examination of the igneous rocks found near Milton and the old sandstone quarry near the Naval College.

(g) Additional theoretical and model hydraulic studies should be made of the cooling water structures after decisions have been made as to the final cooling water flow requirements and whether an ocean outfall is required.



SITE LAYOUT
SHOWING 5 ALTERNATIVE CIRCULATING WATER CONDUIT LOCATIONS

PHOTO 1



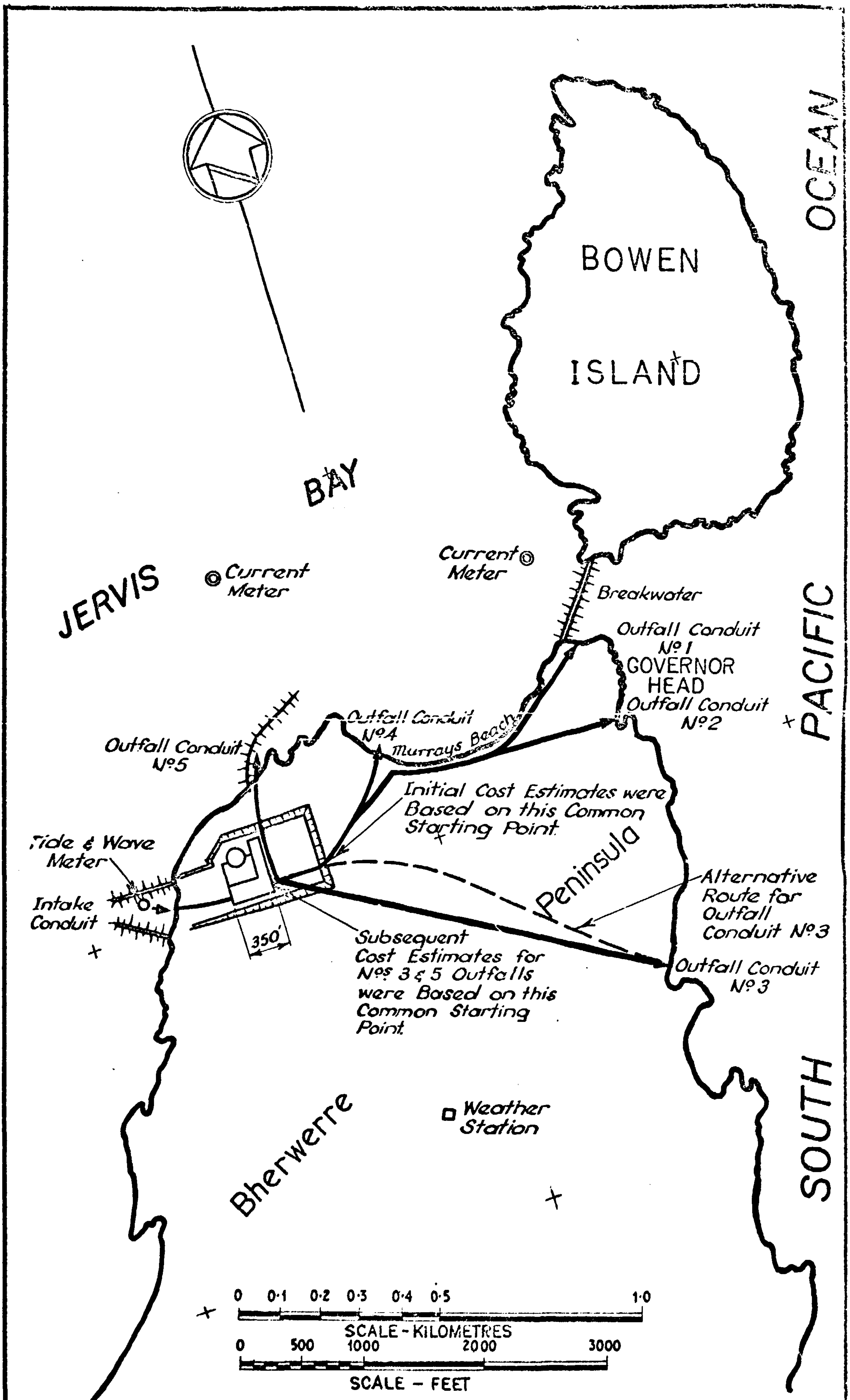


FIG. 2

THE ELECTRICITY COMMISSION OF N.S.W.

POWER & TRANSMISSION DEVELOPMENT DIVISION

DRN	C.K.McK.	JERVIS BAY P.S. — CIRCULATING WATER SYSTEM	APPROVED [signature] DATE 13/8/70
TCD	F.N.G.	ALTERNATIVE LAYOUT LOCATIONS	
CKD	C.McK.		C.I. 2864/1

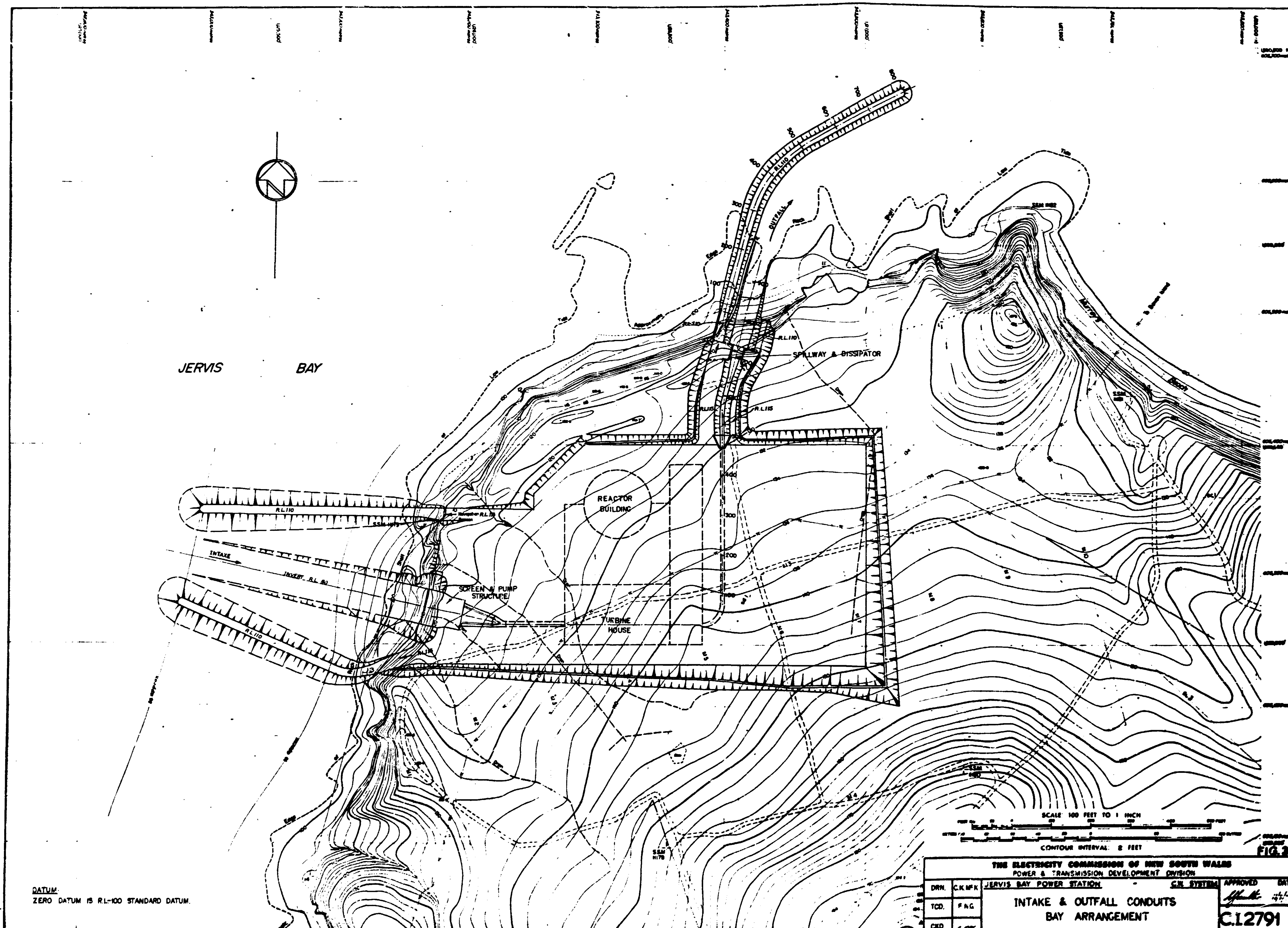
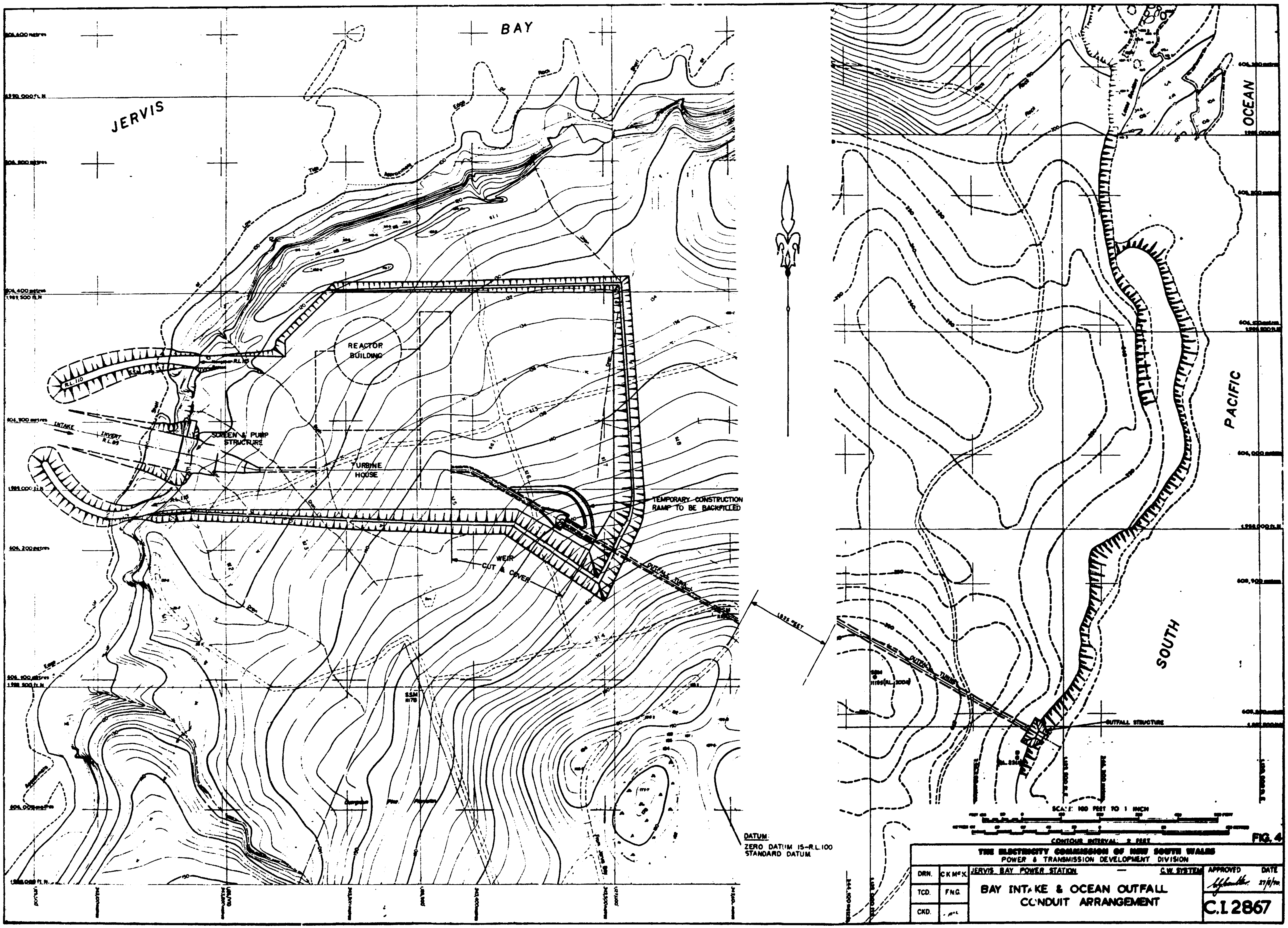

JERVIS BAY
REACTOR BUILDING
TURBINE HOUSE
SCREEN & PUMP STRUCTURE
SPILLWAY & DISSIPATOR
OUTFALL
INTAKE
INVERT R.L. 80
R.L.110
R.L.115
100
200
300
400
500
600
700
800
SCALE: 100 FEET TO 1 INCH
CONTOUR INTERVAL: 2 FEET
DATUM:
ZERO DATUM IS R.L.-100 STANDARD DATUM.
THE ELECTRICITY COMMISSION OF NEW SOUTH WALES
POWER & TRANSMISSION DEVELOPMENT DIVISION
JERVIS BAY POWER STATION - C.N. SYSTEM
DRN. C.K.McK
TCD. F.N.G.
CKD.
APPROVED
DATE
INTAKE & OUTFALL CONDUITS
BAY ARRANGEMENT
C.I.2791

FIG.2


JERVIS
BAY
REACTOR BUILDING
INTAKE
INVERT R.L.89
SCREEN & PUMP STRUCTURE
TURBINE HOUSE
TEMPORARY CONSTRUCTION RAMP TO BE BACKFILLED
WEIR
CUT & COVER
OUTFALL TUNNEL
OUTFALL STRUCTURE
R.L.110
OCEAN
PACIFIC
SOUTH
DATUM:
ZERO DATUM IS-R.L.100 STANDARD DATUM.
SCALE: 100 FEET TO 1 INCH
CONTOUR INTERVAL: 2 FEET
FIG. 4
THE ELECTRICITY COMMISSION OF NEW SOUTH WALES
POWER & TRANSMISSION DEVELOPMENT DIVISION
DRN. C K McX
TCD. F.N.G.
CKD.
JERVIS BAY POWER STATION — C.W. SYSTEM
BAY INTAKE & OCEAN OUTFALL
CONDUIT ARRANGEMENT
APPROVED
DATE 27/8/70
C.I. 2867