Fort Macquarie to Kirribilli Point.—This route is about the same length from shore to shore as the Dawes' Point to Milson's Point route, and offers the same advantages from the constructional standpoint. It would, however, necessitate the vehicular traffic from the business side of the City passing through the already congested streets, whereas by the Dawes' Point to Milson's Point route the vehicular traffic could be taken direct to the western side of the City.

Route Adopted.—The Dawes' Point to Milson's Point route was adopted, and Mr. David Hay, M.Inst.C.E., of the firm of Mott and Hay, who subsequently came from London, at the request of the New South Wales Government, to report on the traffic problem of the City of Sydney, upheld the Author's choice of route.

COMPARISON OF BRIDGE WITH SUBWAYS.

A bridge from Dawes' Point to Milson's Point will be compared with the subways recommended by the Royal Commission on "Communication between Sydney and North Sydney." Plan No. 3 shows the location of the Subways, and Plan No. 13 shows the location of the bridge.

Railway.—The railway, via bridge, would leave the existing Milson's Point railway to the south of Bay Road Station, and would connect with the proposed City Railway at Wynyard Square Station. After junctioning with the City Railway at Wynyard Square, passengers could reach the eastern side of the City, the Eastern Suburbs, the Show Ground, Cricket Ground, &c., without changing trains. On the northern side of the harbour, there would be two open-air stations, viz., "North Sydney," between Walker Street and Miller Street, parallel to Blue Street; and "Kirribilli," opposite the Town Hall, North Sydney, near Burton Street.

The railway, via subway, would leave the existing Milson's Point railway at the head of Lavender Bay, would connect with the proposed City Railway, and the traffic could go to the eastern or western side of the City as required. On the northern side of the Harbour there would be an underground station at Milson's Point, 75 feet below the surface, access to which would be by lifts and steps.

The railway, via bridge, would open up the thickly populated portions of North Sydney right down to Milson's Point, and would form the first section of a Northern Suburbs Railway, whereas the railway, via subway, would only be an extension of the Milson's Point railway into the City. This is clearly shown by the revenue anticipated by the Railway Department for the year 1911, viz.: £63,550 by bridge, and £22,323 by subway.

The length from Bay Road Station to Wynyard Square by bridge would be 2.6 miles, and the length by subway 3.3 miles. Mr. C. A. Hodgson, Superintendent of Lines, estimated that 238 trains each way per day would be required to cope with the traffic last year. The saving in train mileage by bridge would be 332.2 miles per day, or 121,816 miles per annum, and as the traffic increases the saving would be much greater.

The rise from Wynyard Square Station to the bridge is 137 feet, and the fall from the bridge to Bay Road Station is 74 feet. By subway the rise to Bay Road Station is 182 feet, and the fall from Wynyard Square to subway is 119 feet.

Mr. David Hay, in his report, stated that the severer grades and greater distance to be traversed by subway than by the bridge would add at least 15 per cent. to the cost of the electric current alone on the haulage of every ton taken over the line from Wynyard Square to Bay Road Station.

By bridge the railway would be at a higher lever than by subway, and the future extension to Neutral Bay, Mosman, the Spit, Manly, and eventually to Pittwater would be cheaper, the distance shorter, and the grades easier via bridge than via subway.

Tramway.—Although the tramway may not be taken across the harbour, the facilities via bridge and via subway will be compared.

The tramway, via bridge, would leave the existing North Sydney system at the intersection of Junction and Alfred Streets, and passing over the bridge would loop around Wynyard Square on the City side. Via subway, the tramway would leave the existing North Sydney system at the intersection of Junction and Arthur Streets, and would join with the existing system at Circular Quay.

By bridge, the tram could pick up and set down passengers as far as Fitzroy Street, North Sydney, and so serve the thickly populated district between Lavender Bay and Neutral Bay. By subway no passengers would be picked up after passing Arthur Street. On the City side, via bridge, the tram would run along a new roadway, whereas, via subway, the tram would run along George Street and add very much to the congestion in that already too congested street.

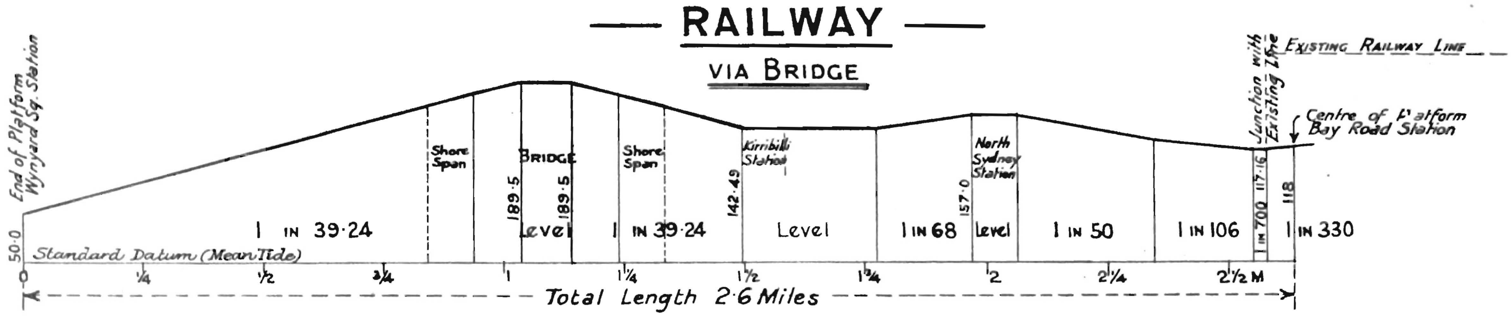
The distance from George Street, opposite the General Post Office, Sydney, to the intersection of Arthur and Junction Streets, North Sydney, is two miles by bridge or subway. The rise from the General Post Office to the bridge is 138 feet, and the fall from the bridge to Arthur Street 52 feet. The rise by subway to Arthur Street is 200.7 feet, and the fall from the General Post Office to subway is 115 feet.

Plan No. 3a.

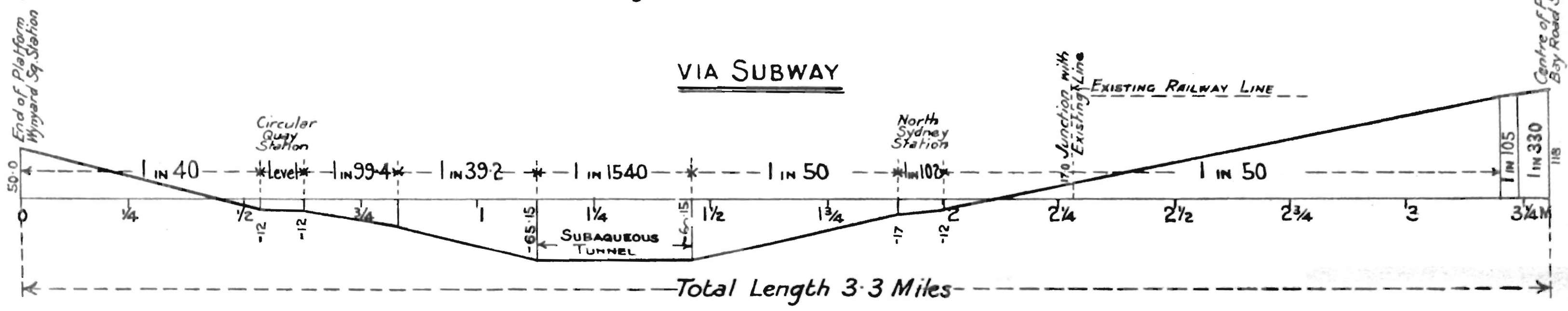
DIAGRAM SHEWING COMPARISON OF LENGTHS AND GRADES VIA BRIDGE AND VIA SUBWAY.

RAILWAY

VIA BRIDGE

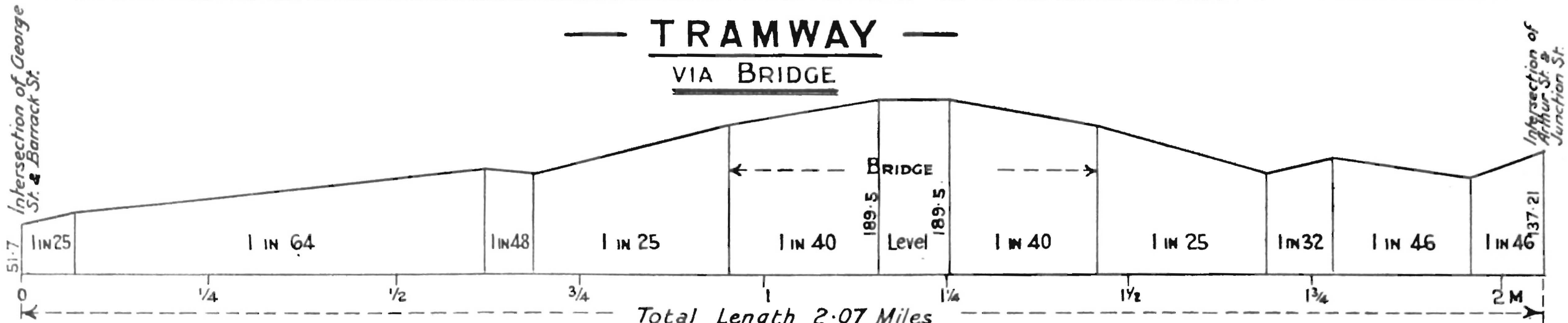


VIA SUBWAY

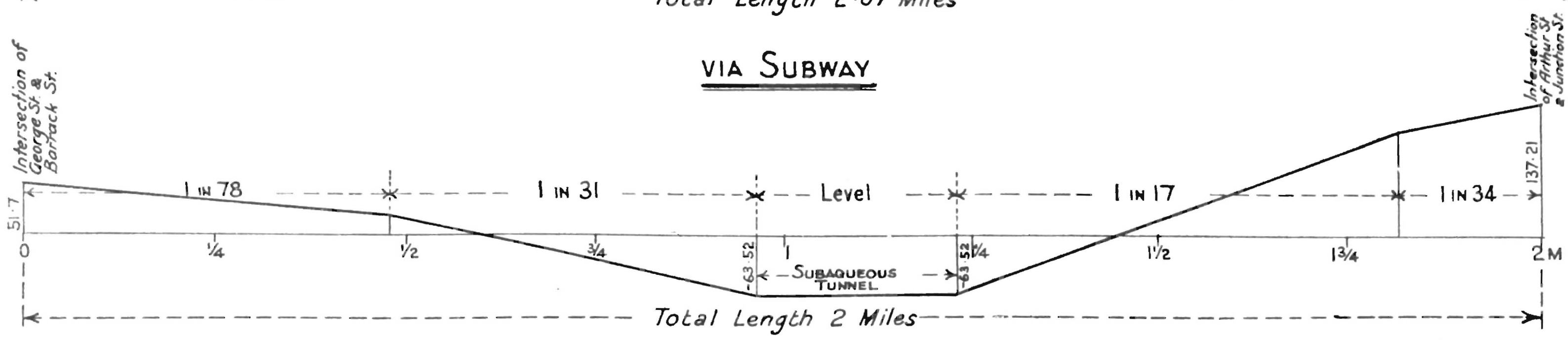


TRAMWAY

VIA BRIDGE

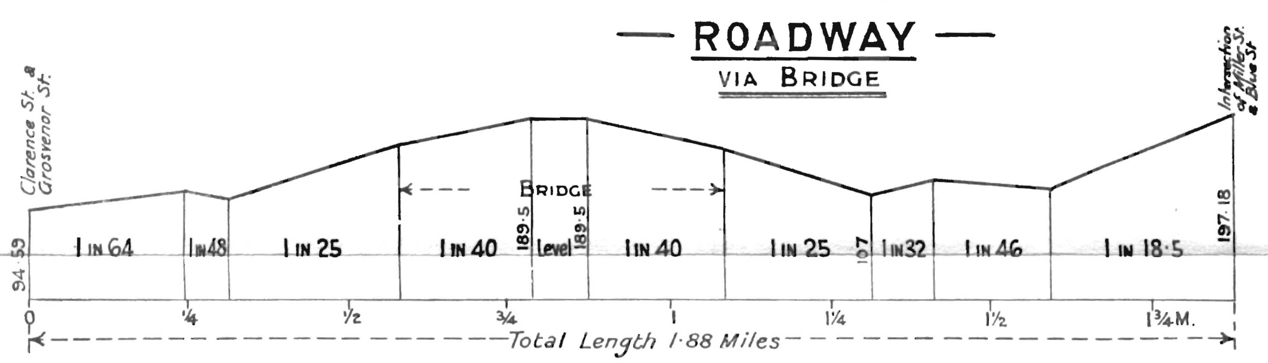


VIA SUBWAY

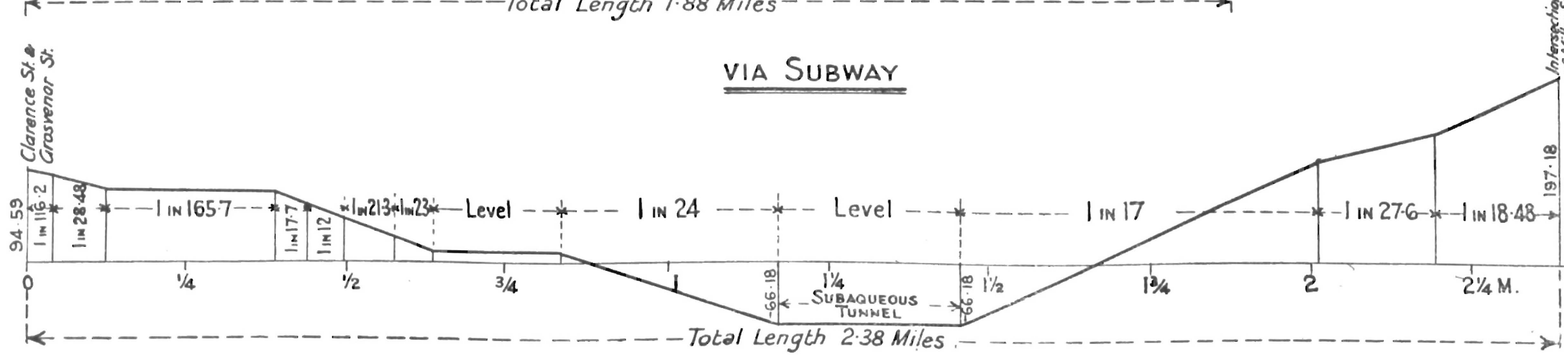


ROADWAY

VIA BRIDGE



VIA SUBWAY



Roadway.—Taking as common points the intersection of Grosvenor Street and Clarence Street, Sydney, and of Blue Street and Miller Street, North Sydney, the length, via bridge, is 1.88 miles, and via subway 2.38 miles, i.e., half a mile less by bridge than by subway. The rise from Grosvenor Street to the bridge is 95 feet, and from bridge to Miller Street 7 feet. The fall from Grosvenor Street to subway is 161 feet, whilst the rise from the subway to Miller Street is 263 feet. On the City side the vehicular traffic rises or falls only 95 feet by bridge as against 161 feet by subway. On the North Sydney side the rise or fall is 7 feet by bridge, as against no less than 263 feet by subway.

The grades via the subway are 1 in 12 for 330 feet and 1 in 17 for 300 feet on the City side, and 1 in 17 for 3,000 feet on the North Sydney side. The worst grade via the bridge is 18.5 for a length of 1,700 feet on North Sydney side.

Cost.—A bridge to accommodate four lines of railway, two of which may be used for tramway purposes, a 35ft. main roadway, an 18ft. motor roadway, and a 15ft. footway is estimated to cost £2,750,000.

The bridge provides for railway connection from Wynyard Square to Bay Road Station, tramway connection from Wynyard Square to the intersection of Alfred and Junction Streets, North Sydney, and for roadway connection from Prince's Street at Argyle Street, Sydney, to Alfred Street, North Sydney.

To provide equal facilities by subways there would be required:—

One double track railway subway from Wynyard Square to Lavender Bay.

One double track tramway subway from Circular Quay, Sydney, to Arthur Street, North Sydney.

Three vehicular subways from Pottinger Street, Sydney, to Arthur Street, North Sydney.

COST OF SUBWAYS.

Railway subway	£1,198,000
Tramway subway	537,000
Roadway subway (3 at £626,000 each)	1,878,000
Total	3,613,000
Cost of bridge	2,750.000
Difference in favour of bridge ..	£863,000

VENTILATION, NOISE, DRAINAGE AND LIGHTING.

With a bridge the problem of ventilation, noise, and drainage do not arise, and the lighting is confined to the night time.

Artificial ventilation can be successfully applied to the railway and tramway subways where electricity will be the motive power, but the successful ventilating of the roadway subways would present greater difficulties. The dampness and unpleasant odours from both horse and motor traffic could never be entirely eliminated. The cost of ventilation would be a constant annual charge.

In subways the noise caused by the traffic is very great, and lighting would be a constant source of expense.

All tunnels are more or less subject to leakage. The following table, taken from the Proceedings of the Institution of Civil Engineers, Vol. 185, page 90, gives the leakage in various subways.

Location.	River or Harbour.	Leakage in gallons per twenty-four hours per 1 in. foot Single Bore.
New York ...	North River Pennsylvania R.R.	0.15
Detroit	Detroit River	0.85
Boston	Harbour	1.35
New York ...	East River, Pennsylvania R.R.	1.00 to 2.00
Sarnia	St. Clair River	2.46
New York ..	East River, Battery	1.68
New York ...	North River, Hudson-Manhattan ...	2.28

To the leakage in the subaqueous portion of the tunnel under Sydney Harbour would have to be added the seepage from the high ground on either shore. The leakage and seepage would have to be pumped out—a continual source of expense.

Mr. Hay reported: "In this connection I may mention the Blackwall and Rotherhithe tunnels under the Thames, two tunnels for vehicular traffic in London with which I am familiar. In these two cases the noise caused by the traffic and the difficulty in securing efficient ventilation, providing artificial light, drainage, &c., are highly detrimental factors."

The following extract from an article in the "London Magazine," by Mr. Foster Fraser, is of interest:—

"There are several tunnels for carts and pedestrians under the Thames, and one morning I spent in traversing two of them —Blackwall and Rotherhithe. There is something majestic about the tunnels. What, however, impressed me as strange, both in the Blackwall tunnel, and later, as I walked back through the Rotherhithe tunnel, was how little either of the tunnels is used. Considering the millions of money spent in their construction, they seem almost deserted."

OBSTRUCTION BY BRIDGE.

The bridge offers no obstruction whatever to shipping, except that the height of masts are limited to 170 feet at high water.

The masts of sailing ships, steamships, and motor ships require consideration.

Sailing Ships.—The following table gives the height of the masts of the largest sailing vessels which have traded to Sydney or Newcastle:—

Vessel.	Tonnage.	Height from Truck to Load Line.
Ship "S. D. Carlton"	1,788	187 feet
Four-masted barque "Ville due Havre"	2,446	187 ,,
Ship "Great Admiral"	1,406	184 ,,
Ship "Cumberland"	1,740	176 ,,
Ship "Glenelvon"	1,890	175 ,,
Ship "St. Nicholas"	1,688	168 ,,
Ship "Cambuskenneth"	1,785	166 feet 6 ins.
Four-masted barque "Waterloo" ...	1,792	165 ,,
Four-masted barque "Fort George" ...	1,608	164 ,,
Barque "Melanope"	1,608	155 ,,
Four-masted barque "Inverness-shire"	2,147	158 ,,

With a fixed headway of 170 feet, some of these vessels would have had to strike their top-masts, but this could be done without much trouble, and is frequently done at sea.

Mr. J. McAusland Denny, of the firm of Denny Bros., shipbuilders, Dumbarton, Scotland, in giving evidence before the Royal Commission on "Communication between Sydney and North Sydney," stated that it might cost £5 to £10 to strike a mast, but the cost would not have to be paid by the authorities here, whereas the bridge would. He considered 160 feet headway sufficient.

Steamships.—On July 1st, 1912. there were 7,564 steamships of 2,000 tons and over registered at Lloyds; of these three only require consideration, viz., the "Lusitania," "Mauretania" and "Olympic." The masts of the "Lusitania" and "Mauretania" are 175 feet above water level when flying light, but as there would always be some cargo and coal in these steamers, they could pass under the bridge. The "Olympic," whose masts are 202 feet high, would require telescopic masts to pass under the bridge. This year, the "Imperator" and "Aquitania," with masts about 210 feet above water level, will be in commission, and would also require telescopic masts.

The "Ceramic," "Nestor," "Otway," "Medina," "Mongolia," and "Kanowna" are the largest oversea and interstate steamships trading to Sydney; all of these could pass under the bridge without telescopic masts. The height of their masts above load line is as follows:—"Ceramic," 162ft.; "Nestor," 152ft. 8in.; "Otway," 137ft.; "Medina," 137ft. "Mongolia," 137ft.; "Kanowna," 129ft.

Mr. Denny stated in evidence: "In connection with steamers, we build ships with what are called telescopic masts; for example, vessels trading to New Zealand for the New Zealand Shipping Company not only have telescopic masts, but also removable tops on their funnels."

Motor Ships.—Ships driven by Diesel oil engines are now being constructed. In the future motor ships may displace steamships, as steamships have displaced sailing ships, though it will be difficult to surpass the efficiency of the marine steam engine.

The greater space available for cargo, the lesser cost of the stokehold staff, and other advantages, may make motor ships more economical than steamships. If so, the tendency will be for masts to diminish in height, as the altitude of the wireless apparatus will be determined by the height of the boat deck, and not by the height of the tops of the funnels, as is to some extent the case at present.

One of the largest motor ships afloat, the "Selandia," of 10,000 tons, is about the size of the mail steamers trading to Sydney; her masts are about 120 feet above water, or 17 feet lower than those of the mail steamers trading here.

Wireless Telegraphy.—For effective maritime working the aerials of the wireless apparatus require to be about 70 feet above the operating room, which is usually placed on the boat deck. It is this height, aerials to operating room, which affects the efficiency of the plant. A height greater than 70 feet does not give consistently better results. This height, 70 feet, will give a night range of 1,750 miles at least with a 2-Kilowatt plant—the maximum power allowed in the vicinity of land stations.

The Australian Wireless Company and the Marconi Company, Australia, were asked by the Department if a headway of 140 feet above water level would be ample provision to make for the aerials for all time.

The Resident Engineer of the Marconi Company, Mr. Fisk, replied: "I think 160 feet would be a much safer estimate; but it might be possible for ships requiring aerials of greater height to make use of telescopic masts. I do not foresee any difficulty in this so far as the wireless telegraphic apparatus is concerned."

The Technical Superintendent of the Australian Wireless Company, Mr. Leverrier, replied: "If the aerials are not less than 70 feet above the operating room (boat deck) then 140 feet above water level is ample."

Mr. Leverrier also stated that the average height of the aerial above sea level when a ship is loaded is 115 feet, though he had installed the aerials on four steamers at a height of 130 feet above sea level.

Mr. Hay made inquiries in London from the Marconi Company, and discussed the matter with Captain Sankey, R.E., a Director of the Company.

Mr. Hay reports: "I understand there is no doubt whatever that 170 feet would clear all except such vessels as the "Olympic," and some of the larger battleships of the British Navy. The latter are fitted with telescopic masts, and there would be no difficulty in so equipping any vessel wishing to trade with Sydney."

Headway Under Existing Bridges.—The headway under existing bridges is as follows:—

Brooklyn Bridge	East River, New York	135 feet headway
Williamsburgh Bridge ..	,, ,,	135 ,, ,,
Manhattan Bridge ..	,, ,,	135 ,, ,,
Queensborough Bridge ..	,, ,,	135 ,, ,,
Forth Bridge	Firth of Forth, Scotland	150 ,, ,,
Quebec Bridge (in course of construction) ..	St. Lawrence River, Quebec	150 ,, ,,

Two important bridges have been recently proposed, viz.: a suspension bridge for road traffic across the Mersey, connecting Liverpool and Birkenhead—headway proposed, 150 feet; and a suspension bridge to carry railway and road traffic across the Hudson River, New York—headway proposed, 170 feet.

OBSTRUCTION BY SUBWAYS.

In 1881 the maximum draught of the largest steamships afloat was 24 feet; at present it has increased to 35 feet.

To increase the draught of vessels beyond 35 feet would necessitate extensive alterations to existing harbours. Still, it is impossible to forecast what the draught of vessels will be 20 years hence. Should circumstances require the draught to be increased, the depth of harbours will have to be increased accordingly, and judging by the past, the draught will increase.

In the Culebra Cut—the most expensive work in the Panama Canal—the depth of water is 45 feet. The tunnels constructed under the Hudson River, New York, have a minimum depth of 70 feet of water from mean sea-level to top of tunnel, whilst those under the East River, New York, have a minimum depth of 79 feet of water from mean sea-level. These rivers accommodate the largest vessels afloat.

The Suez Canal has largely controlled the draught of vessels trading to Sydney, but with the advent of boats trading, via the Cape, the draught of vessels has increased. In 1912 the deepest-laden merchant vessel left Sydney with a draught of 29 feet; this year the "Ceramic" has a loaded draught of 34 feet 6 inches, and the "Nestor" of 32 feet 10 inches.

A depth of 40 feet at low water over the top of the subway was adopted by the Royal Commission on "Communication between Sydney and North Sydney." Allowing for "squat" when under weigh and 2 feet of water under the keel, this would limit the draught of vessels to about 37 feet at low water.

As it is impossible to forecast what the draught of vessels will be in the future, it would not be advisable to construct a concrete steel bar across the harbour, limiting the depth of water to 40 feet at low water for all time by constructing subways. The harbour can be deepened to 60 feet and over right up from the Heads. A depth of 45 feet at least is advisable, preferably 50 feet, as it is possible that vessels which could pass over the subway with 40 feet of water in normal conditions may require to be taken up to the docks and repair shops when disabled and partly sunken, and would require a greater depth than 40 feet.

Dr. Corthell, in his report to the 11th International Congress of Navigation, Philadelphia, 1912, considers provision should be made for ships 1,100 feet long, 110 feet beam, and 40 feet draught, requiring a depth of water of at least 45 feet.

To quote Dr. Corthell: "The size of merchant ships is determined by the inexorable laws of commerce, trade, economy of transportation and the demands of passengers for room and comfort."

"The Panama Canal provides for a depth of 45 feet at the lock entrances. The German Government have radically enlarged the Kaiser Wilhelm Canal, providing a minimum depth of water of 45 feet at the lock entrances."

Regarding the Suez Canal, Dr. Corthell "believes that within a few years this Canal will necessarily have to be deepened, in order to retain its traffic, to 13 metres (42.6ft.) at least, allowing for a draught of 12 metres (39.4ft.) with corresponding width to allow for the passage, in two lines, of vessels of 25,000 tons. Note the gradual and evidently reluctant concessions to the steamships in the matter of draught. The company authorised, in 1869, 24.6ft. draught; 1890, 25.5ft.; 1898 it widened the Canal from 72ft. to 121ft; 1902, 26.2ft. draught was authorised; 1906, 26.3ft.; 1908, 28ft., the canal having been deepened to 31.2ft., and 28ft. was the authorised draught in January, 1911."

The Suez Canal Company requires a vessel to have at least 3 feet of water under her keel. A vessel with a certain draught when stationary at a wharf requires more water when under weigh. The following observations of the S.S. "Mauretania," made by Mr. Henry N. Babcock, U.S. Assistant-Engineer, New York, are interesting. The conditions and results are given following—the general rule being based mostly on forty observations made in 1904.

Due to leave pier ....9 a.m.
Passed Robbin's Reef, Bow..... 9 41 22 a.m. } 30 sec.
Stern.... 9 41 52 a.m.
Passed Romer Lighthouse—hour not reported 30 sec.
Length overall 790ft.—Flood current at Robbin's Reef, 1 mile
" " Romer 0.5 "

Speed passing Robbin's Reef, 17.4 stat. miles; speed through water, 18.4 miles.

	M.L.W. Depth.	Tide.	Wind	Sea.
At Robbin's Reef	40	5.0	Light N.W.	0.3
At Romer	45	5.0	—	—

Observed Draught.

	At Pier.	At Robbin's Reef.	At Romer.
Forward ...	34.75	37.6	38.6
Aft.	34.75	38.6	39.4

"Density of sea water at Romer would tend to make draught about 0.1 to 0.2 less than at pier.

"The observations generally show that the amount of 'squat' increases:—

"1. Inversely with depth of water under the keel.
" 2. Directly with speed.
" 3. Directly with fineness of ship's lines.

"I have not yet been able to get any definite ratio of variations other than the crude one (gotten up for pilots) that when a ship is near the bottom, her 'squat' in feet may be about one-fifth of her speed in statute miles per hour."

"The sinking of the ship was equal to 4.65ft. (1.41 m.) at Romer, with about 15ft. (4.6. m.) under her keel, when stationary."

If subways are constructed, a depth of 45ft. of water is at least advisable—preferably 50ft. Subways at this latter depth