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Report
Effect of Height of Bridge Above Water on Salt Deposition Levels

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Table of Contents

Page

1 INTRODUCTION

Maintenance of bridge structures is a major issue for the Queensland Department of Main Roads. In the previous phase of this CRC project an initial approach was made towards the development of a program for lifetime prediction of metallic bridge components. This involved the analysis of five representative bridge structures with respect to salt deposition (a major contributor to metallic corrosion) to determine common elements to be used as “cases” - those defined for buildings are not applicable.

The five bridges analysed included the Gladstone Port Access Road Overpass, Stewart Road Overpass, South Johnstone River Bridge, Johnson Creek Bridge and the Ward River Bridge. The locations of these bridges are shown in Figure 1.

Figure 1 Locations of the five bridges analysed

1.1 Analysis Methodology

The salt deposition on the five representative bridge structures was computed using computational fluid dynamics (CFD) and compared against the deposition on a salt candle at the same location.

Illustrative results for the Gladstone Port Access Road Overpass are shown. The Gladstone Port Access Road Overpass in Gladstone City is located at latitude 23°51’ and longitude 151°30’. It is on the Gladstone Port Access Road between Glenlyon

Road and the Port Precinct and passes over the top of Auckland Street and the railway lines. There is ocean to the North, North East and East of this bridge.

The bridge comprises twelve spans ranging in length from 28.4 metres to 37 metres. The superstructure consists of a reinforced concrete deck on rectangular prestressed concrete deck units for span 12 and on five T-ROFF trough-shaped prestressed concrete girders for spans 1 to 11. For these 11 spans the total width of the superstructure is 10.44 metres and the height is 2.81 metres, giving a height to width ratio of 1:3.7.

The salt deposition on a salt candle, extracted from the CSIRO GIS database at the location of Gladstone for a marine environment at the latitude and longitude given, is 13.3 mg.m^2/day. This does not take into account the bridge height.

The deposition on the superstructure was checked using three different aerosol release strategies. In one, aerosols were released directly upwind of the bridge, in the second they were released in bands above and below the bridge, in the third they were released over a broad area. Results for the Gladstone overpass are shown in Figure 2. The aerosol was diffused upstream due to turbulence.

Salt becomes trapped in the recirculation regions between the bridge girders, but although the concentration of the salt in the air between the girders is high, little is deposited on the girders and the underside of the deck.

The salt deposition on the bridge structure is summarized in Figure 3. The deposition is largest on upwind faces, intermediate on horizontal faces and least on downwind faces and in protected parts of the under bridge deck. The highest deposition rates are found on the bottom edges of the two downwind girders and on the upwind face of the upwind face of the upwind parapet.

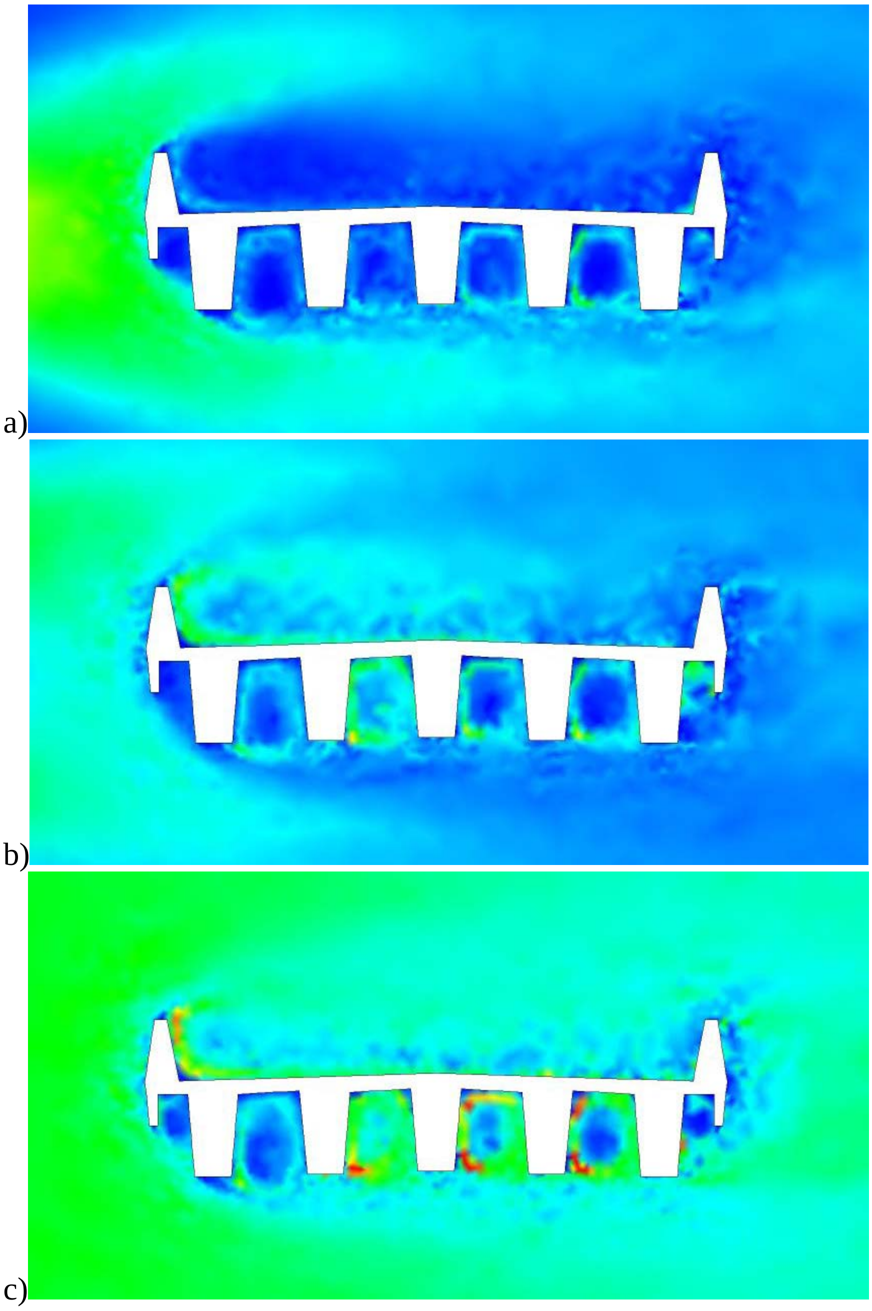

Figure 2 Volume fraction of salt around the superstructure of the Gladstone Port Access Road Overpass; a) particles released within 1.4 metres of the mid-height, b) particles were released between 1.4 and 2.8 metres of mid-height, c) all salt aerosol particles. Flow is from left to right. Red is high concentration and blue is low concentration

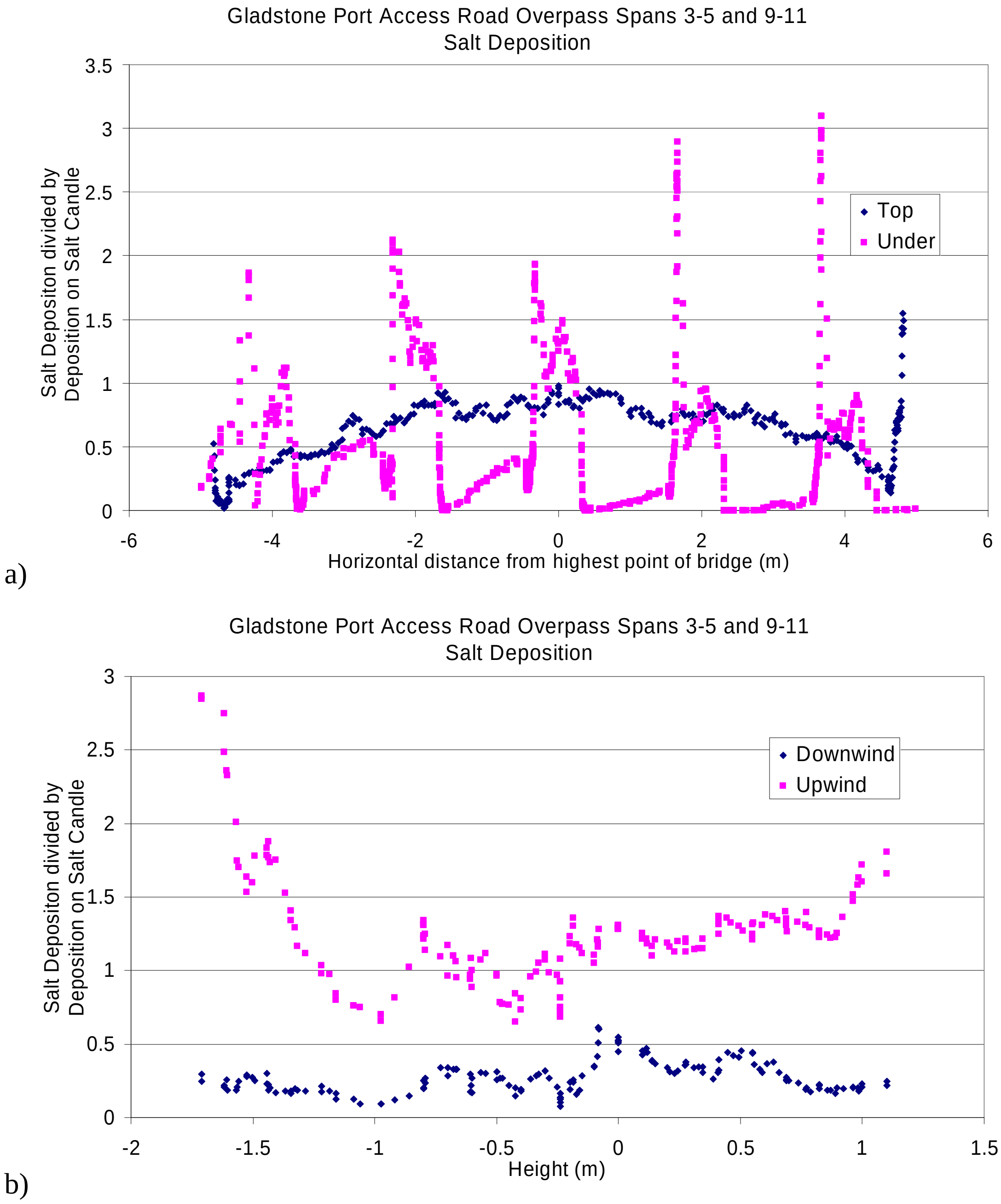

Figure 3. Salt deposition on the Gladstone Port Access Road overpass measured relative to the salt candle deposition

As mentioned earlier, the computations carried out for the five bridges took no account of the height of the bridge above the water level. A subsequent analysis of the effect of bridge height has been carried out.

2 EFFECT OF BRIDGE HEIGHT

2.1 Calculation of Salt Concentration

The effect of bridge height is considered in two separate parts: close to the coast and further inland. This is because the salt levels vary quite rapidly close to the coast.

The computed variation of atmospheric salt concentration with height is shown in Figures 4 and 5.

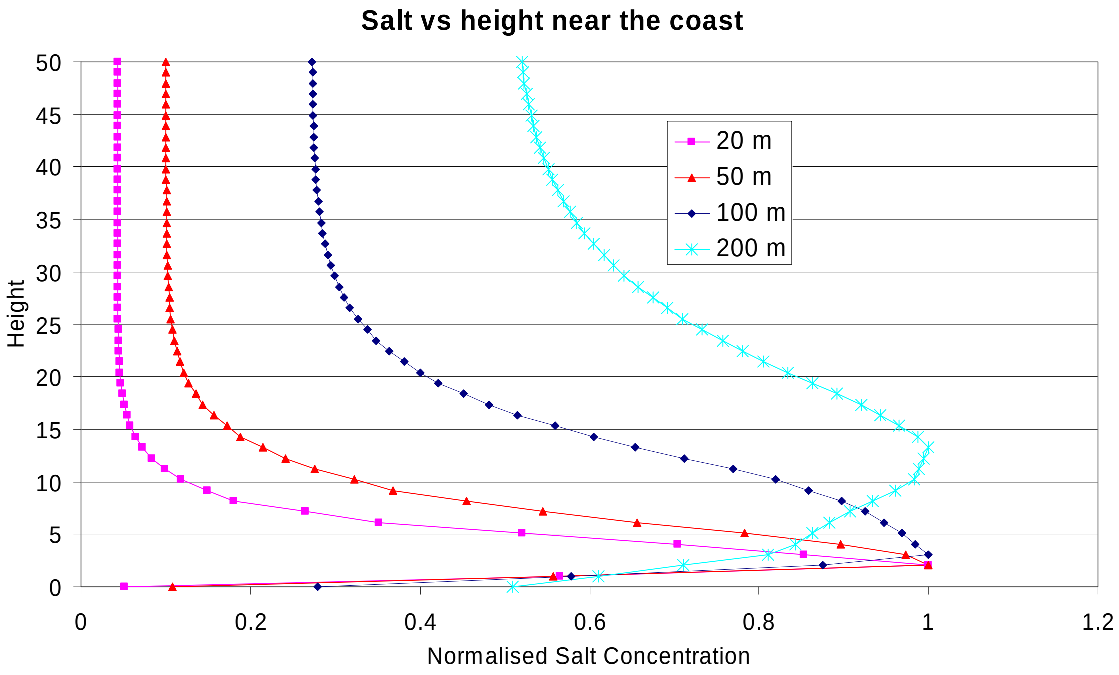

Figure 4. Atmospheric salt concentration near the coast

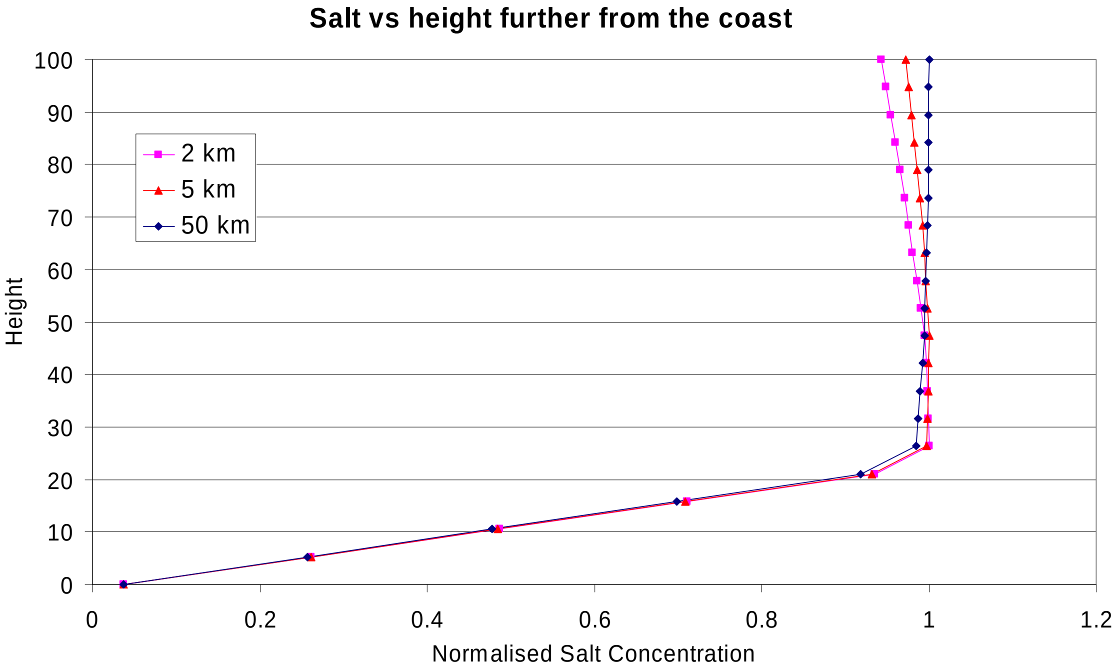

Figure 5. Atmospheric salt concentration 2-50km from the coast

Figure 4 shows the computed salt concentration as a function of height near the coast, at distances of 20, 50, 100 and 200 metres from the high water mark. Figure 5 shows the computed salt concentration as a function of height further from the coast, at distances of 2, 5 and 50 kilometres from the coast. Salt concentration profiles even further from the coast resemble those at 50 km. Salt concentrations below a height of 20 m in Figure 5 are not reliable because of the limitations of CFD grid resolution.

In Figure 5, the drop-off in salt concentration at heights below 25 metres is due to the effects of vegetation and topographic roughness but this decrease in concentration cannot be accurately computed. An average roughness calculated from topographic, urban and vegetation roughnesses is used. Vegetation and urban structures remove salt from the air and the combination of steep terrain and vegetation can remove even more.

Above 25 metres, the variation with height is due to a balance between gravity and air turbulence. Gravity brings salt-containing aerosols down towards the ground. This leads to a high concentration at lower heights. On the other hand, air turbulence tends to even out concentration and does so by reducing the concentration at lower levels and increasing them at upper levels. The result is a balance between gravity and turbulence that leads to an exponential decay of salt concentration with height (up to cloudbase) for each aerosol size.

By 50 km from the coast, all the coarser aerosols have already settled out, leaving only the fine aerosols that are almost unaffected by gravity so, above the influence of the vegetation and topography, the air turbulence gives these a concentration that is independent of height. At 2 km from the coast, some larger aerosols remain and gravity drags these downward resulting in a higher concentration at 25 to 50 metres high.

In Figure 4, the salt concentration profile 20 metres from the high water mark (pink data series) indicates the peak salt concentration is at a height of only 2 metres or so. This is because the salt is generated by ocean waves and these are not very high. The salt from the coastal waves has not yet diffused up to higher levels of the atmosphere. However, there is some salt at heights above 20 metres, and that is the salt that was generated way out at sea, independently of the waves at and near the coast.

Several things happen as the salt aerosol travels further distances from the coast. At 200 metres from the high water mark (light blue data series in Figure 4), the vegetation, urban and topographic roughness have strained salt from the lower 10 metres of the atmosphere. Salt from the coast has diffused upwards. The heaviest salt aerosol particles have settled out, leading to a more uniform variation of concentration with height.

Also, as the heaviest salt aerosol particles have settled out, so the relative proportion of the salt from the open ocean has increased, and this accounts for most of the increase in salt concentration at a height of 50 metres in Figure 4.

Local variations in vegetation, urban usage and topography will affect the salt variation with height at any given location. In smooth terrain with stunted vegetation and no urban development the height of peak salt will be lower. In rough terrain or with high-rise buildings or dense forest the height of peak salt will be higher. The one exception to that second statement is when the location is on the side of or top of an escarpment facing the ocean, then the height of peak salt will be lower.

2.2 Comparison with Salt levels on Gateway Bridge

The project partner, Queensland Department of Main Roads, was able to provide some chloride measurements taken at different heights on the Gateway Bridge over the Brisbane River. These measurements are listed in Table 1. The chloride concentration is in kg/m^3.

Table 1 Chloride levels on the Gateway Bridge

Core number	Height (m)	Chloride at 15 mm deep (kgm^{-3}).
7-6	1.40	0.69
6-4	1.425	0.57
6-2	1.50	0.54
7-4	4.65	0.26
6-6	4.95	0.29
6-8	8.97	0.30
7-2	9.80	0.22

Other relevant parameters include the distance from the coast (7.1km) and the type of terrain between the bridge and the coast: smooth, with no major obstructions.

Unfortunately, no direct comparison with computed results for this distance from the coast for the low ground roughness appropriate for the Gateway Bridge is feasible because it isn’t possible to easily compute salt concentrations below a height of 20 metres at distances further than 1 km from the coast, see Figure 6.

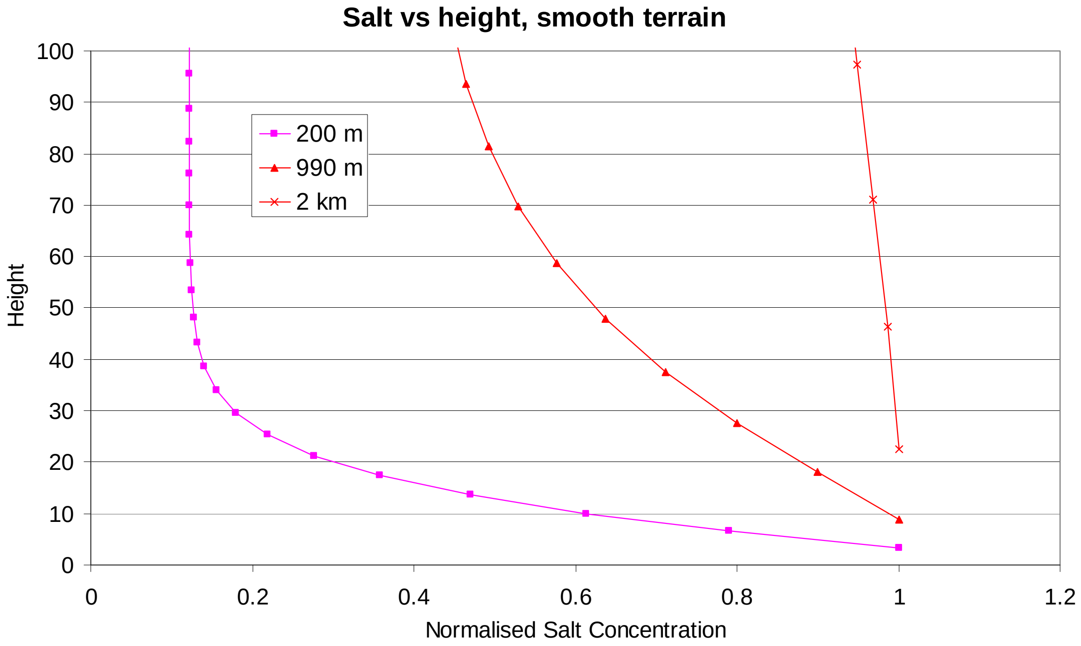

Figure 6. Salt variation with height for flow over smooth terrain.

Computed results for this location suggest that salt concentration in the air only decreases a small amount with height, no more than about 2% in 10 metres of height. This is consistent with the salt readings at heights of 4.65 metres and above. The significantly larger salt concentrations at 1.4 to 1.5 metres on the bridge are most probably due to splash and the bursting of bubbles created by ship propulsion systems. There is a significant amount of water traffic on the Brisbane River at this point, and the affects of this are not factored into the original calculations.

3. CONCLUSIONS

Adjacent to the coast, the salt concentration is largest at heights below 5 metres, unless salt at this height is blocked by high vegetation, rough terrain or urban development.

Under conditions of typical roughness (vegetation, terrain and urban), this height of peak salt concentration has moved up to about 14 metres at 200 m from the coast, and about 25 metres further than 2 km from the coast. The variation of salt concentration with height in the atmosphere gets less as the distance from the coast increases and the large droplets of salt water generated by salt spray at the coast settle out.

Under conditions of fairly low roughness, as in the area between the Gateway Bridge and the coast, it is not easy to say at what height the peak salt concentration is except to say that it is at a height of less than 22 metres at the position of the Gateway Bridge. At that distance from the coast the salt concentration is fairly constant with height.

Measurements of the salt concentration on the Gateway Bridge suggest that at heights of about 1.5 metres the salt spray from the river is increasing the amount of salt deposited above the ambient levels in the atmosphere.

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