**COMMERCIAL-IN-CONFIDENCE**

# EXPERT REPORT ON DEATH OF SIMON BLAIR WARK

Report prepared and written by

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for

NSW SPECIAL COMMISSION OF INQUIRY INTO LGBTIQ HATE CRIMES

23/3/2023

# CONTENTS

**Page**

## QUALIFICATIONS AND EXPERTISE

1 I am a Professor and coastal geomorphologist in the School of Biological, Earth and Environmental Sciences, University of New South Wales (UNSW Sydney). I have been studying, researching and teaching aspects of coastal landforms and processes since 1988 (35 years).

2 My specific area of scientific expertise is in the field of coastal morphodynamics (involving mutual interactions between waves, currents, tides and nearshore topography) and coastal hazards. I have written 82 published scientific articles, 15 book chapters, and one book on these topics.

3 My broad area of scientific expertise relates to the action of waves, currents, tides and sediment transport that occur within the nearshore zone along coastlines. The nearshore zone extends from the upper beachface, which is impacted by waves and wind, seaward to where waves first start to interact with the bottom of the ocean, typically at depths of 10-20 metres. Both boundaries are variable at any given time depending on wave conditions.

4 My specific area of expertise involves the behaviour of rip currents, which are strong, narrow seaward flows of water which extend from the shoreline offshore through the surf zone to the extent of breaking waves, and at times, some distance beyond. The surf zone is the region dominate by breaking waves. Rip currents are primarily related to beaches and do not occur along long stretches of rocky coastlines, and or within bays and harbours.

5 Since 2001, I have run a beach safety community education program called the Science of the Surf (SOS), which is designed to educate the public on beach safety and coastal hazards. This program has been presented to over 50,000 members of the community, including thousands of primary and high school students. SOS has received significant mainstream media attention and both State (NSW) and National Community Safety related awards.

6 In January 2023 I was appointed as a Member to the Order of Australia (AM) for my service towards beach safety research and education. My full CV is attached as Appendix B.

7 I am a Life Member and former caretaker (resident member) of the Tamarama Beach Surf Life Saving Club.

8 I have previously been involved as an expert witness involving the death of Ross Warren which is part of this Special Commission. I provided a Statement on 1/8/2001, a report on 5/4/2002, a statement on 11/4/2002, gave oral evidence on 3/4/2003 and a further statement on 31/1/2017.

## EXECUTIVE SUMMARY

9 Simon Blair Wark was last seen at 2:00 pm on 9 January 1990 and his body was observed floating face down approximately 200-300 m north-east of Dobroyd Head in Sydney Harbour at 9:00 am on 10 January 1990. His clothes were found near the Gap Bluff on 11 January 1990.

10 This period of time was characterised by mild, rainy weather and calm to light winds with sporadic gusts from the south to south-east. Offshore wave heights were higher than normal and wave direction was estimated to be from the north-east or east.

11 This period was characterised by greater tidal ranges associated with spring tide conditions. Low tide (0.34 metres) occurred at 3:00 pm on 9 January 1990 with water levels rising towards high tide (1.76 metres) at 9:00 pm on 9 January 1990. The subsequent falling tide reached a low of 0.03 metres at 4:00 am on 10 January before rising again to a high tide at 10:00 am of 1.17 metres. Under these conditions, tidal currents within Sydney Harbour would have been stronger than normal, particularly during the falling tide between 9:00 pm on 9 January 1990 and 4:00 am on 10 January 1990.

12 It is my opinion that surface drift caused by wind and waves did not contribute greatly to the direction of travel of Mr Wark's body in the water, regardless of where his body entered the water.

13 It is my opinion that tidal currents and circulation between the entrance of Sydney Harbour and the location where Mr Wark's body was recovered are the dominant control on the movement of Mr Wark's body in the water, regardless of where his body entered the water.

14 It is my opinion that if Mr Wark's body entered the water in the vicinity of Gap Bluff, this most likely would have occurred between 9:00 pm on 9 January 1990 and 4:00 am on 10 January 1990. It should be acknowledged that given the reversals in tidal currents and the distances involved, there are a number of assumptions and unknowns involved in this opinion. However, water entry during this time period is consistent with known information about tidal currents associated with a falling tide during spring tide conditions and with anecdotal information provided in a memorandum to me on 3 March 2023 which describes the trajectory of human bodies entering the water near the Gap Bluff.

15 It is my opinion that it is also possible that Mr Wark's body could have entered the water in the vicinity of Reef Beach between 2:30 pm on 9 January 1990 and 4:00 am on 10 January 1990 and based on tidal conditions, it is more likely that this would have occurred between 9:00 pm on 9 January 1990 and 4:00 am on 10 January. However, much less is known about tidal movements in this region than between Gap Bluff and Dobroyd Head.

## INTRODUCTION

16 This report has been prepared at the request of the Special Commission of Inquiry into LGBTIQ hate crimes in relation to the death of Mr Simon Blair Wark.

17 Mr Wark was last seen alive at 2:00 pm on 9 January 1990 in Double Bay, Sydney. His body was sighted near Dobroyd Head in Sydney Harbour just after 9:00 am on January 10 1990.

18 I have been provided with a copy of the Uniform Civil Procedure Rules 2005 – Schedule 7 – Expert witness code of conduct.

19 I, Professor Robert Brander, acknowledge for the purpose of Rule 31.23 of the Uniform Civil Procedure Rules 2005 that I have read the Expert Witness Code of Conduct in Schedule 7 to the said rules and agree to be bound by it.

20 I have been asked to undertake an expert report in relation to Mr Wark's death to assist the enquiry and have been provided with the following materials:

21 On 11 December 2022: Items 1-14 (Report of Death to Coroner, Police Statements, SBS Media, Bureau of Meteorology weather synoptic and rainfall observations for Watsons Bay area, sea level observations at Fort Denison, Geoscience Australia sunrise, sunset and twilight times for The Gap, Manly Hydraulics Laboratory Sydney offshore wave data, USNO primary phases of the Moon) and an aerial map of the area of interest with specific points of interest labelled.

22 On 23 December 2022: Bureau of Meteorology weather and rainfall observations for the period January 1990.

23 On 6 February 2023: Bureau of Meteorology daily synoptic (meteorological) charts for the period 1-11 January 1990.

24 On 3 March 2023: A copy of a handwritten memorandum dated 16 January 1990 relating to Mr Wark's death. This memorandum appears to be authored by the forensic pathologist who conducted Mr Wark's autopsy and contains anecdotal information suggesting that the vicinity of Dobroyd Head is a common location for human bodies entering the water near The Gap to be found on a rising tide.

25 I have been asked to address the following matters in my report:

26 **1.** Following my review of the briefing material, please identify:

27 **a)** Any additional areas of expert opinion you consider would assist his Honour on the issues of Mr Wark's location, date and manner of death, and

28 **b)** If relevant, appropriate experts from whom his Honour may wish to seek further expert opinion.

29 **2.** Provide a summary of the prevailing weather, tidal, current and rip conditions at and around Gap Bluff and Dobroyd Head on 9 and 10 January 1990.

30 **3.** Identify variables that must be taken into account in any opinion provided as to the likely direction of travel of a human body entering the water at a particular coastal location or being found at a particular location.

31 **4.** Is the location where and time when Mr Wark's body was found consistent with it potentially having entered the water from the area in the vicinity of Gap Bluff at some point between 2:30 pm on 9 January 1990 and 9:00 am on 10 January 1990?

32 **5.** If the answer to the point above is 'Yes', can I indicate:

33 **a)** the time it would have taken for the body to float from Gap Bluff to Dobroyd Head; and

34 **b)** the likelihood of this having been the entry point and any matters that I consider are relevant to assessing the likelihood.

35 **6.** Is the location where and when Mr Wark's body was found consistent with it potentially having entered the water from the area in the vicinity of Reef Beach at some point between 2:30 pm on 9 January 1990 and 9:00 am on 10 January 1990?

36 **7.** If the answer to question 6 is yes, can I estimate:

37 **a)** the time that would have taken for the body to float from Reef Beach to Dobroyd Head; and

38 **b)** the likelihood of this having been the entry point and any matters that you consider are relevant to assessing the likelihood.

39 **8.** Any other matters arising from the circumstances of Mr Wark's death within my area of expertise on which I wish to express an opinion and which will be of assistance to his Honour

40 My knowledge, findings and opinions based on the material I have been provided with and the queries above are contained within this report.

41 In this report, I have made the following assumptions:

- The weather and Fort Denison tidal data provided by the Bureau of Meteorology provides an accurate estimate of weather conditions and tidal time and stage at the locations of relevance.

- The offshore wave data provided by the NSW Department of Environment and Planning Manly Hydraulics Laboratory from the Sydney offshore wave rider buoy provides an approximation only of wave condition in the locations of relevance.

- Meteorological synoptic charts from the Bureau of Meteorology (sourced from the Sydney Morning Herald) for the period of interest provide an approximation of wave direction along the Sydney coast based on my own interpretations.

## POINT 1: ADDITIONAL AREAS OF EXPERTISE

42 My area of expertise relates to nearshore processes. The area(s) of interest in this report deal with: i) a rocky coastline extending approximately 1 km from the Gap Bluff northwards to South Head; ii) the approximately 1.5 km opening into Sydney Harbour between South and North Head; iii) the northern portion of Sydney Harbour extending 1.6 km from the harbour entrance to the vicinity near Dobroyd Head where Mr Warks body was found; and iv) the approximately 300-400 metre distance in the northern Harbour between Reef Beach and the vicinity near Dobroyd Head where Mr Warks body was found.

43 This region is characterised by rocky coast morphodynamics, deeper water and tidal circulation within a drowned river valley estuary (Sydney Harbour).

44 It would be useful to consult with someone with experience in search and rescue in the region of the Gap Bluff as they may have an understanding of drift directions along that coastline under different wave conditions.

45 Additional areas of expertise that would be of assistance in these environments would be a geomorphologist familiar with rocky coast hydrodynamics or any oceanographers and estuarine coastal geomorphologist with expertise in tidal circulation and/or the ability to conduct numerical simulations of tidal flow within Sydney Harbour.

46 Some experts within these fields who may be able to provide further expert opinion and assistance in these matters include:

47 Professor David Kennedy (rocky coast geomorphology; University of Melbourne, [redacted])

48 Professor Moninya Roughan (oceanographer; UNSW Sydney, [redacted])

49 Professor Ana Vila-Concejo (estuarine geomorphologist; University of Sydney, [redacted])

50 It would also be recommended to consult with a medical expert with knowledge of what happens to deceased human bodies immersed in the ocean.

## POINT 2. SUMMARY OF PREVAILING ENVIRONMENTAL CONDITIONS AT AND AROUND GAP BLUFF AND DOBROYD HEAD ON 9 AND 10 JANUARY 1990.

### 51 2.1 Weather

52 Weather data and a summary of weather conditions for the period 9 and 10 January 1990 was provided to me in a Supplementary Letter on December 23 2022. The summary of weather conditions is repeated here with a focus on the time of interest between 3:00 pm on 9 January 1990 and 9:00 am on 10 January 1990.

53 The temperature at Sydney Observatory Hill at 3:00 pm on 9 January 1990 was 20.0 degrees Celsius, with a minimum of 18.1 degrees Celsius at 3:00 am on 10 January

1990 and an increase to 20.0 degrees Celsius at 9:00 am on 10 January 1990. Temperature conditions could be considered mild.

54 Between 3:00 pm on 9 January 1990 and 9:00 am on 10 January 1990, conditions were overcast with no sunshine hours. Visibility was between 800 and 10000 m. Rain and drizzle was present with 22.6 mm being recorded at the Rose Bay station in the 24 hours up to 9:00 am on 10 January 1990.

55 Between 3:00 pm on 9 January 1990 and 9:00 am on 10 January 1990, the wind at Sydney Observatory hill was between 0 and 11 km/hr (calm to light winds). The wind blew from a southerly direction (180 degrees from True North) with the exception of the period between 9:00 pm on 9 January 1990 and 12:00 am (midnight) on 10 January 1990 when it blew in a south-easterly direction (157 degrees from True North). Maximum wind gusts recorded on 9 January 1990 and 10 January 1990 at Observatory Hill were 35 km/hr (fresh) and 26 km/hr (moderate) from the south-east respectively, although these occurred outside of the time of interest. Hourly maximum wind gust data is not available.

56 ## 2.2 Tides

57 Tidal data was sourced from the Bureau of Meteorology tidal station at Fort Denison within Sydney Harbour. Tidal conditions recorded at Fort Denison are representative of tidal conditions in the area of interest, both within Sydney Harbour, at the harbour entrance between North and South Head, and outside of the Heads along the open ocean coast (Short, 2007).

58 Sea level observations at Fort Denison for the period of interest are as follows:

59 Low tide = 3:00 pm on 9 January = 0.34 metres

60 High tide = 9:00 pm on 9 January 1990 = 1.76 metres

61 Low tide = 4:00 am on 10 January 1990 = 0.03 metres

62 High tide = 10:00 am on 10 January 1990 = 1.17 metres

63 These tidal conditions occurred during a period of spring tides, where tidal ranges (the difference in sea level elevation between low and high tide) are maximised. During spring tides, high tides are higher than usual and low tides are lower than usual. Spring tides occur for several days around each full moon and new moon period. The full moon occurred on 11 January 1990.

64 The mean tide range for Sydney is approximately 1 metre.

65 Phases of the tide (and tidal circulation) can be summarised as follows:

66 3:00 pm to 9:00 pm on 9 January 1990 = Rising (flood) tide

67 9:00 pm on 9 January 1990 to 4:00 am on 10 January 1990 = Falling (ebb) tide

68 4:00 am to 10:00 am on 10 January 1990 = Rising (flood) tide

69 The rising (flood) tide between 3:00 pm and 9:00 pm on 9 January 1990 was characterised by a tidal range of 1.42 metres (difference between 0.34 metres and 1.76 metres).

70 The falling (ebb) tide between 9:00 pm on 9 January 1990 and 4:00 am on 10 January 1990 was characterised by a tide range of 1.73 m (difference between 1.76 metres and 0.03 metres).

71 The subsequent rising (flood) tide between 4:00 am and 10:00 am on 10 January 1990 was 1.14 m (difference between 0.03 metres and 1.17 metres).

72 In general, a rising tide will generate tidal currents flowing into Sydney Harbour and the vicinity of the North Harbour in an approximately westerly direction (towards the west) and in the vicinity of the North Harbour, in a north-westerly direction (towards the north-west).

73 In general, a falling tide will generate tidal currents flowing out of Sydney Harbour in an easterly direction (towards the east) and the vicinity of the North Harbour in an approximately south-easterly direction (towards the south-east).

74 The velocity of tidal currents within an estuary such as Sydney Harbour is primarily determined by the tidal prism – the volume of water flowing into or out of an estuary. The larger the tidal range between a low and high tide, or between a high and low tide, the larger the tidal prism will be.

75 In general, the larger the tidal prism, the stronger (faster) the tidal currents will be.

76 During the period of interest, the tidal prism was greatest during the falling (ebb) tide between 9:00 pm on 9 January 1990 and 4:00 am on 10 January 1990 than it was

during the rising (flood) tides that occurred between 3:00 pm and 9:00 pm on 9 January 1990 and 4:00 am and 10:00 am on 10 January 1990.

77 This suggests that tidal currents would have been stronger on the falling (ebb) tide between 9:00 pm on 9 January 1990 and 4:00 am on 10 January 1990 than the previous rising (flood) tide between 3:00 pm and 9:00 pm on 9 January 1990 and the subsequent rising (flood) tide between 4:00 am and 10:00 am on 10 January 1990.

78 As no measurements of tidal current velocity within the region and time of interest exist (to my knowledge), the actual tidal velocities are unknown.

79 The only reference in the scientific literature to tidal currents in the vicinity of interest that I found were reported in publications by Johnston et al. (2015) and Middleton et al. (1997) – full details of these publications are provided in the Reference List.

80 Johnston et al. (2015) report unpublished data from Professor Moninya Roughan of UNSW Sydney that towards the mouth of the Harbour, depth-averaged tidal velocities typically range from 0.1 to 0.25 metres per second over the spring-neap tidal cycle. This was representative of currents in 15 metres water depth.

81 To place these velocities in perspective, speeds of 0.1 and 0.25 metres per second equate to distances travelled of a floating object of 360 metres and 900 metres per hour respectively.

82 Middleton et al. (1997) reports an example of tidal current measurements outside the entrance to Sydney Harbour near the peak of a falling (ebb) tide during a spring tide range of 1.6 metres. This outflowing tidal current is strongest on the northern side of the entrance and a clockwise eddy is formed with some inflow on the southern side.

83 More information on tidal currents is provided in Section 3.4.

84 ## 2.3 Rip Currents

85 Rip currents are a feature of sandy beaches characterised by waves breaking across a wide surf zone and would not have been present at any of the locations of relevance to this report.

86

87 ## 2.4 Waves

88 Offshore wave data was supplied from the Sydney offshore Waverider buoy by the NSW Department of Planning and Environment. At the time of the incident the buoy was located approximately 9 km offshore of Long Reef, on Sydney's Northern beaches, and was moored at a water depth of approximately 85 m. In January 1990, the buoy provided hourly measurements of : i) significant wave height ($H_s$), which is the average of the highest 1/3 of wave heights recorded during that hour; ii) maximum wave height ($H_{max}$), which is the highest wave recorded in that hour; iii) wave period ($T_p$), which is the mean of wave periods (time between two waves) over the hour. Wave direction was not available at the time.

89 It is acknowledged that wave conditions at this offshore location only provide an approximation of wave conditions occurring along the Sydney open ocean coastline or within Sydney Harbour. Wave heights (but not wave period) will vary between offshore deepwater locations and shallow water coastlines due to processes of wave shoaling (slowing down of the waves), wave refraction (bending of the wave crests and direction due to variable bathymetry and topography), and wave breaking. Headlands at North and South Head and promontories within Sydney Harbour will also create wave sheltering effects depending on wave direction.

90 Based on long-term determination of the Sydney wave climate (Short and Trenaman, 1990), the mean significant wave height in January is 1.58 m and the mean wave period is 7.4 s. These values are close to the yearly averages experienced in Sydney.

91 Significant wave heights recorded at the offshore buoy between 3:00 pm on 9 January 1990 and 9:00 am on 10 January 1990 ranged from 1.7 metres to 2.5 metres with an average significant wave height of 2.08 metres. Waves were highest (> 2 metres) between 3:00 pm on 9 January 1990 and 2:00 am on 10 January 1990. These wave heights are approximately 0.5 metres higher than normal.

92 The wave period was fairly consistent during the same time period, ranging from 7.2 seconds to 8.8 seconds with a mean of 7.9 seconds. These are indicative of swell wave conditions and were only slightly longer than the long-term average value for January, but similar to the long-term annual average wave period for waves offshore of Sydney. Of note, wave period does not change from deepwater to shallow water

and the values recorded at the offshore buoy would have been consistent with those experienced at the locations of interest.

93 Given the calm to light winds present, the waves would have been manifest as clean swell waves without wind chop/whitecapping present.

94 The wave rider buoy did not record direction and while winds were from the south and south-east at times, local winds do not determine the direction of swell waves.

## 95 2.5 Meteorological Synoptic Charts and Wave Direction

96 In the absence of directional wave data from the Sydney wave rider buoy, I have been provided with daily synoptics (both forecast and observed) created by the Bureau of Meteorology and printed in the Sydney Morning Herald. These synoptics cover the period 31 December 1989 to 10 January 1990.

97 Waves are generated by wind and waves with periods 7.2 seconds to 8.8 seconds as recorded offshore of Sydney between 3:00 pm on 9 January 1990 and 9:00 am on 10 January 1990 are indicative of low period swell waves. Swell refers to waves that have been formed by wind blowing across a long fetch (open water distance) for an extended period of time (days). In general, swell waves require wind to blow across a fetch of 1000 kilometres or more and are classified as having periods of 8 seconds to 20 seconds. Swell waves that reach the Sydney coast are formed significant distances away from Sydney (1000's of kilometres) and may take several days to reach the Sydney coastline.

98 A summary of each daily synoptic in terms of swell wave direction is provided in Appendix A.

99 I acknowledge that while I do not have expertise in meteorology or interpreting synoptic charts, I understand the basic principles through my own university study and interest in waves and wave prediction. I believe that my interpretations provide a reasonable approximation of the deep water wave direction over the period of interest.

100 It is my opinion that a large southerly swell would have impacted the Sydney coastline on 4 January 1990. This is supported by the provided Sydney offshore wave buoy data. This swell would have quickly faded and been replaced by low period easterly or north-easterly swell between 7 January 1990 and 10 January 1990. Based on the provided Sydney offshore wave data these swell waves were higher than the average wave height experienced in this location.

101 It is my opinion that between 3:00 pm on 9 January 1990 and 9:00 am on January 10 1990 low period swell waves approached the Sydney open ocean coastline from an easterly or north-easterly direction.

102 More information on wave conditions is provided in Section 3.3.

## POINT 3. VARIABLES INFLUENCING DIRECTION OF TRAVEL OF A HUMAN BODY ENTERING THE WATER OR BEING FOUND AT A COASTAL LOCATION

103 There are several key variables to consider in regards to determining the direction of travel of a human body entering coastal waters or being found at a particular coastal location.

### 104 3.1 Rocky coast geomorphology

105 Rocky coasts are typically characterised by a cliff and may have a rock platform at the base. Rock platforms may be flat or sloped, wide or narrow, and may be partially covered with broken rock material from the eroding cliff. There is often a sub-tidal (i.e. always submerged) cliff at the seaward end of the rock platform that leads to the seabed. These sub-tidal cliffs are generally < 5 metres in height.

106 The rocky coast geomorphology between the Gap Bluff and South Head is characterised by a near vertical sandstone cliff face fronted by a discontinuous and irregular rock platform that, where it exists, is narrow in width, generally flat and covered with eroded sandstone cliff boulders at the base.

107 Rocky coasts generally face the full force of ocean waves and are energetic environments in terms of wave activity. Most rock platforms can become fully submerged at high tide and completely, or partially, exposed at low tide, although this depends on the tidal range. During periods of spring tides (such as the spring tides which occurred during the period of interest) rock platforms would be fully inundated by wave action around high tide and likely fully emerged around low tide. There is considerable water movement across rock platforms in all directions where, and whenever, the rock platform is covered by water and exposed to wave activity.

108 The region seaward of shore platforms is extremely energetic and turbulent, even during small wave conditions. This is largely due to a combination of waves breaking on the rock platform as well as the reflection of wave energy from the rock platform.

This area of turbulence does not necessarily move objects in a net direction parallel to the rock platform, but can induce a general drift in a direction perpendicular to the shore platform, which is generally offshore. However, if waves are approaching the rocky coastline and shore platform from a particular angle (direction), it is possible that a general drift may develop in the direction that the waves are moving.

109 Complex and turbulent wave, tide and drift conditions combined with irregular topography makes it very difficult to determine the direction of travel of a human body entering the water at a coastal location such as the rocky coastline between Gap Bluff and South Head.

110 These same conditions also make it difficult to conclude whether a human body on a rock platform, or in the water adjacent to a rock platform, would remain in those locations. A human body on a rock platform may be washed into the ocean by wave action or wedged between rocks by wave action. A human body in the water adjacent to a rock platform may remain in the water or may be washed back onto the rock platform. These are all potential scenarios as it is very difficult to determine or predict what would happen in such an energetic environment without direct observations of wave conditions.

111 **3.2 Bathymetry**

112 The bathymetry of Sydney Harbour, the area immediately outside of the harbour, and along the coast from South Head to the Gap Bluff can impact the wave height, direction and the circulation of ocean currents, including tidal currents.

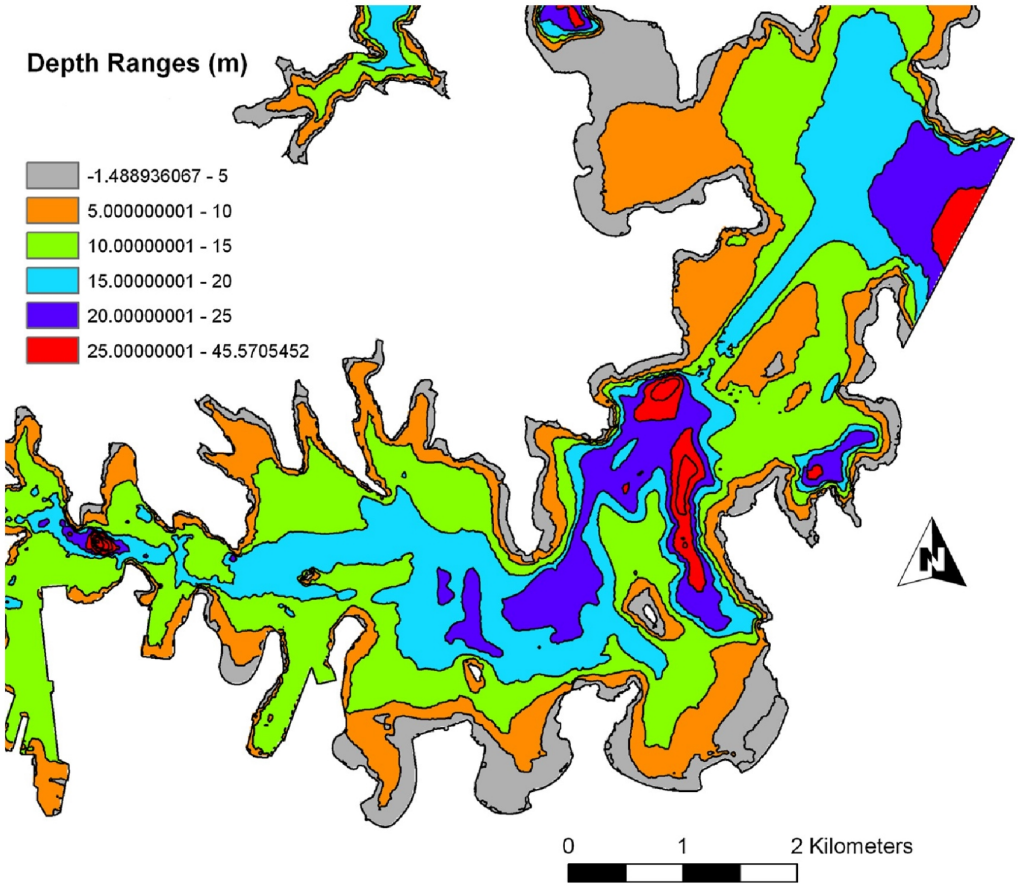
113 The bathymetry immediately offshore of the rock platform between the Gap Bluff and the entrance to Sydney Harbour is less than 5 metres in depth, increasing to 5-10 metres in depth further offshore (Figure 1).

114 The bathymetry between South Head and North Head varies from less than 15 metres adjacent to the headlands to 20 to 25 metres across the middle of the entrance to Sydney Harbour (Figure 1).

115 From the entrance to Sydney Harbour, water depths decrease from 20-25 metres to 15 to 20 metres further into the Harbour and then to 10 to 15 metres approaching Dobroyd Head (Figure 1).

116 Water depths immediately adjacent to Dobroyd Head and Reef Beach are less than 5 metres and increase to 5 to 10 metres further offshore (Figure 1).

117 Based on Figure 1 and the map of Sydney Harbour provided to me showing the approximate location of where Mr Wark's body was recovered 200-300 m north-east of Dobroyd Head, it is likely that the water depth at this location was between 5 to 15 metres.




118

119 **Figure 1.** Bathymetry of Sydney Harbour. Contours are at 5 metre intervals (from Mulhearn, 2014).

120 **3.3 Wave action**

121 Unbroken ocean waves travelling through deep water do not generally cause a directional movement of water.

122 In shallower depths where waves are shoaling (interacting with the bottom) and breaking, there is a drift of surface water in the direction that waves are moving towards (e.g. southerly waves would create a drift moving northward). On a sandy shoreline, this results in a net surface drift of water towards the beach. On a rocky coastline, this tends to result in turbulent wave action across rock platforms and against cliffs causing backwash and reflection.

123 If waves approach any shoreline at an angle to the shoreline, there will generally be a net drift of water along the shoreline from that direction. For example, if a shoreline has a North-South orientation and waves approach from the North-East then there will be a drift along the shoreline to the south.

124 Based on my opinion that offshore deepwater waves were approaching the Sydney coastline from an easterly or north-east direction, this would suggest that any wave-generated drift from Gap Bluff to South Head would be negligible (if easterly swell) or to the south (if north-easterly swell).

125 This would also suggest that if the waves were easterly, they could enter Sydney Harbour and create a wave-generated drift towards the west. It is not possible to comment on the potential speed or exact direction of any such drift.

126 Deepwater waves entering Sydney Harbour are then subject to the processes of attenuation (reduction in energy) and refraction (bending of the wave crests) and while Dobroyd Head may be subject to breaking wave activity due to its exposure to incoming swell, Reef Beach is protected by the headland and can be considered to be a low-wave energy environment.

127 Due to this protection and absence of significant wave breaking at Reef Beach, it is unlikely that any wave-generated drift would have been present between Reef Beach and Dobroyd Head.

128 Any existing wave-driven drift would transport a human body at the surface in the direction of that drift.

## 129 3.4 Tidal currents

130 Tidal currents along the open ocean Sydney coastline are negligible due to the microtidal tide range (less than 2 metres).

131 Circulation within, and near the entrance to, Sydney Harbour is tidally dominated with some influence from prevailing winds (Johnson et al., 2015).

132 It is not known how far this tidal circulation influence extends along the open ocean rocky coastline to the south and north of the entrance to Sydney Harbour.

133 Tidal currents are periodic, reversing approximately every 6 hours and vary in magnitude both spatially and over a tidal period (from low to high tide, or high to low tide; Johnson et al., 2015).

134 According to Johnston et al. (2015), depth-averaged tidal current velocities near the entrance of Sydney Harbour typically range from 0.10 to 0.25 metres per second across a spring-neap tidal cycle with the higher range of these velocities to be expected during a spring tide cycle.

135 Depth-averaged refers to the average velocity from the surface to the bottom.

136 According to Middleton et al. (1997), during spring tides, the ebb flow (outgoing flow from high to low tide) is strongest near the northern side of the Harbour Entrance and a clockwise eddy (current) is formed with some inflow on the southern side of

the Harbour Entrance. This scenario is evident in Figure 2, which shows measurements of surface currents at the Entrance during a spring tide range of 1. 6 metres.

137 Of note, the spring tide range between 9:00 pm on 9 January 1990 and 4:00 am on 10 January 1990 was 1.73 m so conditions could be considered to be similar to the patterns shown in Figure 2.

138 Figure 2 also indicates that offshore of the vicinity of the Gap Bluff there is a tidal current flowing to the south-west.

139 Tidal currents within Sydney Harbour and close to the entrance of Sydney Harbour would be the dominant variable likely to determine the direction of travel of a human body entering the water in these regions and also where a body would be found. These tidal currents would act on a body at the surface and submerged at depth.

140 It should be noted that the observations of tidal circulation shown in Figure 2 based on Middleton et al. (1997) represent one specific set of measurements over a spring tidal cycle and may not be representative of general tidal circulation in these regions over all time periods and tidal cycles.

141 **3.5 Wind**

142 The action of wind blowing across water can move floating objects on the surface, such as a human body, in the direction that the wind is blowing.

143 If wind were to exert a significant impact on the direction of travel of a body floating on the surface, the wind would have to be strong and of sustained duration.

144 Winds in the region during the time of interest were calm to light and from the south to south-east, with some fresh to moderate gusts from the south-east winds. While these conditions were not sustained or likely to cause significant surface drift,

any surface drift within the harbour caused by wind alone would have been in a north or north-west direction.

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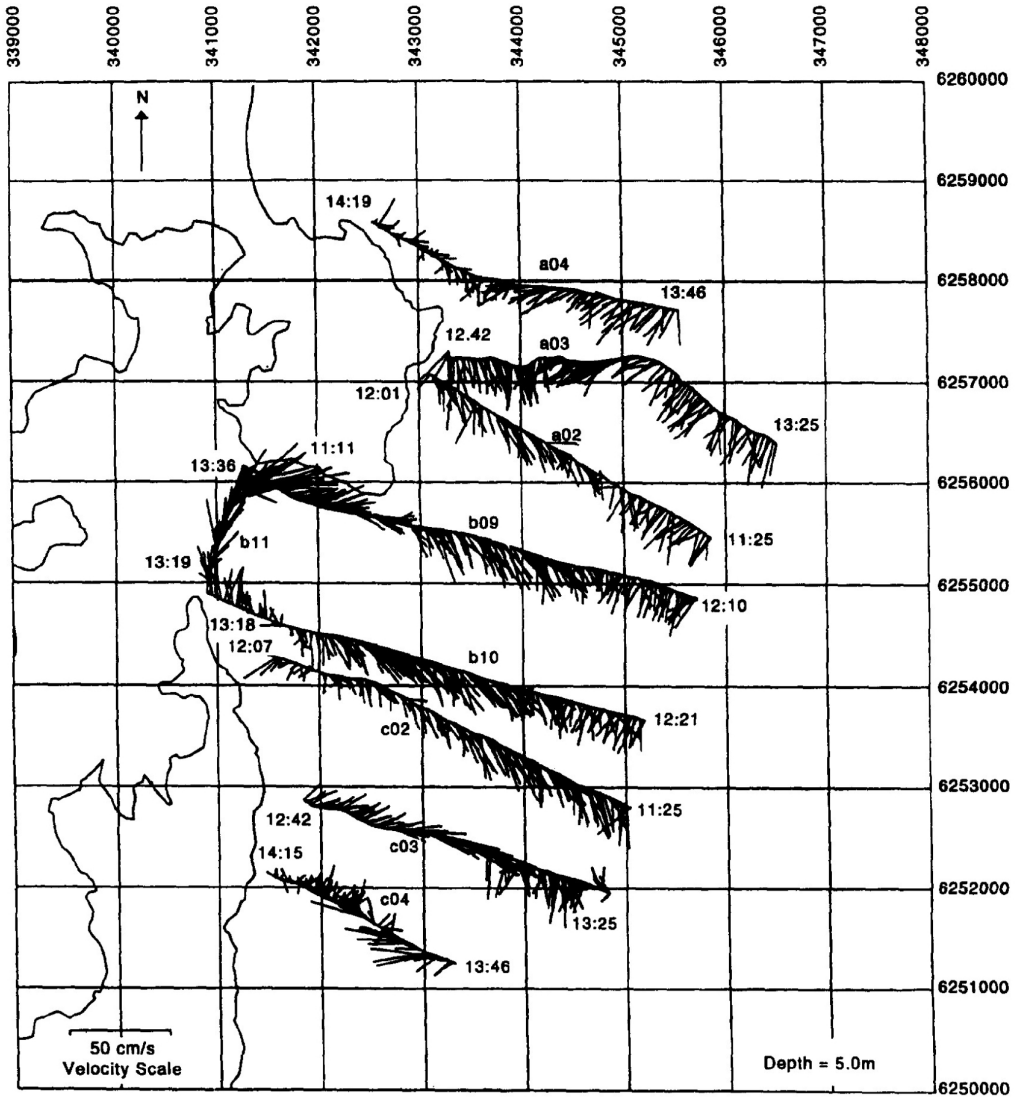


**Figure 2.** Ocean surface currents measured by a vessel-mounted Acoustic Doppler Current Profiler, showing outflow currents near Sydney Harbour (from Middleton et al, 1997).

146 **3.6 Post-Mortem Buoyancy**

147 Although I am not an expert, it is my understanding that immediately after death in water, either due to drowning or other factors, a human body (corpse) will sink to the bottom.

148 It is my non-expert understanding that this is more likely to occur during a drowning event where the lungs of a person will fill with water. If a corpse falls into the water in a manner where oxygen remains in the lungs, the corpse may remain floating for longer (although I don't know how long this may be).

149 The point above is supported by the memorandum provided to me on 3 March 2023 which states that 'If found up to 10-12 hours following a fall, bodies may appear fairly fresh and show little in the way of immersion'.

150 It is my non-expert understanding that if a human corpse sinks to the bottom, putrefaction and bacterial decomposition begins to occur, creating internal gases which will eventually make the body buoyant again although a number of variables will contribute to how long this process takes.

151 The direction that a human body floating on the surface of the water would travel and end up would be influenced by the action of tidal currents, wind and wave action as described previously.

152 The direction that a human body at the bottom of the ocean would travel and end up would be influence by tidal currents and post-mortem buoyancy.

## POINT 4/5. GAP BLUFF ENTRY AND DOBROYD HEAD RECOVERY

153 It is my opinion that there is a possibility that Mr Wark's body may have entered the water in the vicinity of Gap Bluff between 2:30 pm on 9 January 1990 and 9:00 am on 10 January 1990.

154 It should be acknowledged that this possibility is difficult to determine with complete confidence given the complex nature of wave and tide interactions in the vicinity of Gap Bluff and Sydney Harbour and the lack of specific knowledge of the actual time and location where Mr Wark's body may have entered the water in the vicinity of Gap Bluff.

155 It is furthered complicated by the fact that Mr Wark's body may not have entered the water immediately, but may have been on the rock platform for a period of time before entering the water.

156 The information below is therefore based on a number of assumptions and opinions and I have provided a number of scenarios based on the possibility of entry at the Gap Bluff during the various tidal cycles which occurred during the time of interest.

157 **4.1 Scenario 1- Entry near Gap Bluff between 3:00 pm and 9:00 pm on 9 January 1990 (Rising Tide)**.

158 This time period was characterised by a rising (flood) tide, waves travelling from the east or north-east and calm to light winds from the south to south-east.

159 Based on tidal conditions, the rock platforms in the vicinity of The Gap would have likely been fully exposed during low tide conditions between 2:30 pm and approximately 4:00 pm on 9 January 1990.

160 If Mr Wark's body was lying on exposed rocks, it would most likely have entered the water during higher water levels around high tide between approximately 7:00 pm and 9:00 pm on 9 January 1990 when wave action would have inundated the rock platform.

161 For Mr Wark's body to enter the harbour during this time period and eventually reach the vicinity of Dobroyd Point, it would first require Mr Wark's body to travel from the vicinity of the Gap Bluff northward towards South Head and the Harbour entrance, a distance of approximately 1 to 1.2 kilometres.

162 There is little evidence to support the presence of a northward drift of water from the Gap Bluff due to the action of waves and wind during this time period. The presence and characteristics of any tidal currents along this rocky coast during a rising tide is also unknown to me. If a northward drift of water did exist, this would likely have been slow and it would have taken Mr Wark's body several hours to reach the Harbour entrance in the vicinity of South Head.

163 Assuming that a northward drift from the vicinity of the Gap Bluff to the Harbour entrance did exist and Mr Wark's floating body reached the entrance to the Harbour, it would then be subject to tidal currents and would travel in the direction of any tidal currents that were present. The direction and speed of tidal currents in this area during a rising tide are unknown to me.

164 Using the range of tidal current velocities in the Harbour reported by Johnson et al. (2015) of 10 metres/second to 25 metres/second as an example, this would suggest that a floating body within the Harbour could potentially travel a distance ranging from 360 metres to 900 metres over an hour at those velocities respectively - in the direction that the tidal currents were flowing.

165 The approximate distance between the opening of the Harbour and Dobroyd Head where Mr Wark's body was recovered is approximately 2 kilometres.

166 If Mr Wark's body had reached the entrance to the Harbour between 3:00 pm and 9:00 pm on 9 January 1990 it would have moved further into the harbour during the remainder of the rising (flood) tide during this time.

167 Mr Wark's body would then have been subject to tidal currents associated with the falling (ebb) tide between 9:00 pm on 9 January and 4:00 am on 10 January 1990. These currents would have moved a floating object towards the Harbour entrance and potentially into the open ocean.

168 Mr Wark's body would then have been subject to tidal currents associated with the rising (flood) tide between 4:00 am and 9:00 am on 10 January 1990. These currents would have moved a floating object back into the Harbour.

169 Given the absence of evidence for a northward drift from the Gap Bluff to the entrance of the Harbour, multiple reversals in tidal current direction and unknown actual tidal current velocities, it is difficult to determine the timing and trajectory for Mr Wark's body to reach the recovery location near Dobroyd Head in this scenario.

## 170 4.2 Scenario 2 - Entry near Gap Bluff between 9:00 pm on 9 January 1990 and 4:00 am on 10 January 1990 (Falling Tide)

171 This time period was characterised by a falling (ebb) tide associated with a large spring tide range with tidal currents in general flowing out of Sydney Harbour. Waves were likely approaching from the east or north-east and calm to light winds from the south to south-east were present.

172 If Mr Wark's body had entered the water during this time, it is more likely to have occurred during higher water levels between 9:00 pm and approximately 12 pm on 9 January 1990 when wave action would have inundated most, if not all, of the rock platforms.

173 Given the extreme low tide (0.03 metres) at 4:00 am on 10 January 1990, if Mr Wark had fallen from Gap Bluff, he most likely would have landed on exposed rocks between approximately 2:00 am to 4:00 am on 10 January 1990.

174 There is little evidence to support a northward drift from the Gap Bluff region to the entrance to Sydney Harbour due to the action of waves and wind. Figure 2 also suggests that a south-westerly flowing tidal current may be present in the southern vicinity of the Gap Bluff.

175 According to Figure 2 and Middleton et al. (1997) there is some evidence that a clockwise eddy of the tidal current is formed near the southern side of the Harbour Entrance during spring tide conditions during a falling tide – conditions similar to this time period. If these tidal currents existed in the vicinity of the Gap Bluff, it is possible that Mr Wark's body may have been transported towards South Head and into the Harbour by these currents, which would have been stronger than usual due to the large tide range during this tidal phase.

176 Once in Sydney Harbour, Mr Wark's body would then have been subject to tidal currents in this area, which generally show movement in a north-westerly direction according to Figure 2.

If Mr Wark's body had entered Sydney Harbour during this time, it is possible that it was also subject to some element of outflowing tidal currents associated with the falling (ebb) tide although these circulation patterns are unknown to me. However, it would then also have been subject to incoming tidal currents associated with the rising (flood) tide between 4:00 am and 9:00 am on 10 January 1990, which could have resulted in his body being found near Dobroyd Head.

177 Given that the distance between the Harbour Entrance and the vicinity of Dobroyd Head is approximately 2 kilometres and reported tidal current velocities between 0.1 and 0.25 metres per second would move a floating object between 360 metres and 900 metres an hour, it is possible that Mr Wark's body could have reached Dobroyd Head. However, actual tidal current velocities and trajectories in this region are unknown to me.

178 It is possible that Mr Wark's body could have entered the water off Gap Bluff during this time period. This scenario also supports the memorandum I received on 3 March 2023 which sats that 'If tide is running in it (Dobroyd Head) is a common place for "Gap" bodies to be found'. However, while this scenario seems more plausible than Scenario 1, it is still difficult to determine if this was the period of water entry with confidence.

179 **4.3 Scenario 3 - Entry near Gap Bluff between 4:00 am and 9:00 am on 10 January 1990 (Rising Tide)**

180 This time period was characterised by a rising (flood) tide with tidal currents flowing into Sydney Harbour. Waves were likely approaching from the east or north-east and calm to light winds from the south to south-east were present. This is similar to Scenario 1 with the main difference being that the tide range for this rising tide was smaller (1.14 metres compared to 1.42 metres). This suggests that tidal current velocities would have been lower than those experienced between 3:00 and 9:00 pm on 9 January 1990 (Scenario 1).

181 If Mr Wark's body had fallen at Gap Bluff between 4:00 am and approximately 6:00 am on 10 January 1990 there is a strong possibility it would have landed on exposed rocks due to the extreme low tide at 4:00 am (0.03 metres). If this was the case, water levels may have been high enough between approximately 6:00 and 9:00 am on 10 January 1990 for wave action to inundate the platform and move Mr Wark's body into the ocean.

182 Given that the distance from the vicinity of Gap Bluff to Dobroyd Head where Mr Wark's body was found is approximately 3.2 kilometres, if Mr Wark's body had entered the ocean at any time after 6:00 am, it is unlikely that currents associated with the rising tide moving north-west would have had sufficient time to move a floating object this distance.

183 If Mr Wark's body had entered the ocean from a fall from Gap Bluff between 4:00 am and 6:00 am on 10 January 1990, and assuming a range of tidal current velocities moving north-west at speeds of 0.1 to 0.25 metres per second, it would have taken approximately 3.5 to 8.5 hours respectively for Mr Wark's body to reach the recovery location.

184 In my opinion, there is only a very low possibility that Mr Wark's body entered the ocean in the vicinity of Gap Bluff after 4:00 am on 10 January 1990.

185 **4.4 Summary**

186 Ocean currents and drift directions in the vicinity of rocky coasts and tidal circulation in Sydney Harbour are complex and largely unknown. With the data provided to me and the prevailing wave direction conditions estimated from the synoptics, it is difficult to easily explain how Mr Wark's body would have travelled north from the vicinity of Gap Bluff to the entrance of Sydney Harbour unless tidal currents as shown in Figure 2 were present. This is a critical piece of information required because once in Sydney Harbour, tidal currents would dominate the direction of travel of a human body, either floating or submerged. However, anecdotal information provided in a memorandum on 3 March 2023 suggests that human bodies that enter the water near The Gap are commonly found near Dobroyd Point.

187 Another complicating factor is that in the time of interest between 3:00 pm on 9 January 1990 and 9:00 am on 10 January 1990, three tidal cycles occurred (low-high to high-low and low-high) of varying tidal stages and with two reversals of tidal current direction. Without knowing exactly when and where Mr Wark potentially entered the water around Gap Bluff, it is difficult to state distances and time of any travel associated with tidal currents with a high degree of accuracy.

188 If Mr Wark's body did enter the water near Gap Bluff, drift north towards the entrance to Sydney Harbour and then towards Dobroyd Head, it is my opinion that this would have been most likely to occur during the period between 9:00 pm on 9 January 1990 and 4:00 am on 10 January 1990 (Scenario 2).

189 **POINT 6/7. REEF BEACH ENTRY AND DOBROYD HEAD RECOVERY**

190 Reef Beach is located approximately 300 to 400 metres away (to the northwest) from the location where Mr Wark's body was recovered. This section of coastline consists of a small protected sandy beach (Reef Beach), with exposed sandstone rocks and a poorly developed rock platform continuing along the shoreline to Dobroyd Head.

191 In my opinion, it is possible that the location and time where and when Mr Wark's body was found is consistent with it potentially having entered the water from the area in the vicinity of Reef Beach at some time between 2:30 pm on 9 January 1990 and 10 January 1990.

192 It is my opinion that if Mr Wark's body had entered the water near Reef Beach between 3:00 pm and 9:00 pm on 9 January 1990 it would have remained in that area or moved further to the north-west due to the rising (flood) tide during that time. It may then have subsequently travelled towards the northern part of the Harbour by strong tidal currents associated with the falling (ebb) tide between 9:00 pm on 9 January 1990 and 4:00 am on 10 January 1990 and then again back towards the west by tidal currents associated with the rising (flood) tide between 4:00 am and 9:00 am on 10 January 1990. It is possible that Mr Wark's body could have ended up in the recovery location in this scenario although with multiple tidal reversals, it is difficult to state this with confidence.

193 It is my opinion that if Mr Wark's body had entered the water near Reef Beach between 9:00 pm on 9 January 1990 and 4:00 am on 10 January 1990, it would have travelled south-east towards the northern part of the harbour and harbour entrance due to strong tidal currents associated with the falling (ebb) tide. It would then have travelled back towards the north-west in the Harbour due to tidal currents associated with the rising (flood) tide between 4:00 am and 9:00 am on 10 January 1990. It is possible that Mr Wark's body could have ended up in the recovery location in this scenario.

194 It is my opinion that if Mr Wark's body had entered the water near Reef Beach after 4:00 am on 10 January 1990, it would have travelled north-west into North Harbour due to tidal currents associated with the rising (flood) tide which began around 4:00 am on 10 January 1990.

195 It is difficult to estimate tidal current velocity in this region without actual data, but assuming a range of 0.10 to 0.25 metres per second as per Johnston et al. (2015), this would equate to a distance travelled at a rate between 360 metres to 900 metres per

hour in the direction the tidal current is moving. It is my opinion that tidal currents in this area would likely have been present, but possibly not as strong as those reported by Johnston et al. (2015). However, even a current speed of 0.05 metres per second would equate to a distance travelled of 180 metres in an hour.

196 It is my opinion that if Mr Wark's body had entered the water in the vicinity of Reef Beach, this was most likely to have occurred between 9:00 pm on 9 January 1990 and 4:00 am on 10 January 1990.

197 ## 8. OTHER MATTERS ARISING

198 It is important to acknowledge that the opinions expressed in this report are not concluded opinions. There are several important reasons for this.

199 First, a critical determination of drift direction in the vicinity of Gap Bluff is wave direction, which was not available from the offshore wave rider buoy. I have therefore based estimates of wave direction on my own (non-expert) interpretation of meteorological synoptic charts. These interpretations may not be completely accurate.

200 Second, rocky coastlines are highly dynamic environments where the action of waves, tides, and associated drift (currents) are poorly understood and difficult to measure.

201 Third, despite conducting my own research into the scientific and grey literature around tidal circulation and tidal currents within Sydney Harbour, I was only able to source a paucity of information that was relevant to the regions of interest. These sources provided estimates of circulation that were generalised and/or based on a small number of site-specific measurements. It is therefore very difficult to estimate the actual patterns of tidal circulation and velocities of tidal currents that occurred during the period of interest.

202 Tidal circulation and tidal current velocity within an estuary such as Sydney Harbour are highly variable in space and time, both within an individual tidal cycle (e.g. from

low tide to high tide) and between tidal cycles (e.g. from a low-high tide followed by high-low). Without actual field measurements, it is impossible to state with a high degree of accuracy what tidal circulation patterns and current velocity would be at various locations in the Harbour.

203 I have used estimates of tidal current velocity found in the scientific literature, but these are not necessarily indicative of the actual velocities that were present in the period of interest.

204 The presence of three reversals in tide (low to high to low to high) during the period of interest make it extremely difficult to determine the potential time and trajectory of Mr Wark's body if it had entered the water at either Gap Bluff or Reef Beach.

205 For these reasons, the findings and opinions expressed in the Concluding section below are not to be treated as conclusive.

206 I would also like to note that the high tide sea level of 1.76 meters at 9 pm on 9 January 1990 was quite high due to spring tide conditions and likely would have inundated most, if not all, of the rock platform in the vicinity of Gap Bluff for several hours around 9 pm. The subsequent low tide sea level at 4:00 am on 10 January was 0.03 m. While periods of spring tides are associated with higher and lower water levels than normal, this was an exceptionally low water level and the rock platform in the vicinity of Gap Bluff would have been fully exposed for several hours around 4:00 am.

## 207 CONCLUDING FINDINGS AND OPINIONS

208 I am a coastal scientist with expertise in coastal morphodynamics, the rip current hazard and beach safety.

209 It is my opinion that weather and wind conditions during the period of interest would not have influenced the direction of travel of Mr Wark's body in the water.

210 It is my opinion that the assumed wave direction would not have generated a drift of water northwards from the Gap Bluff towards the entrance to Sydney Harbour. However, it is possible that complex interactions between wave breaking and the irregular coastline in this area could have generated a northward drift.

211 It is my opinion that wave conditions would not have influenced any drift of water between Reef Beach and Dobroyd Head.

212 It is my opinion that the dominant control on the direction of a human body in the water are the turbulent reflection of wave energy along the rocky coastline between Gap Bluff and the entrance to Sydney Harbour and the tidal circulation and currents present along this coast and within Sydney Harbour, particularly in the vicinity of Gap Bluff and South Head and the North Harbour region. However, without actual measurements the patterns of tidal circulation and currents can only be estimated.

213 It is my opinion that while it is possible that Mr Wark's body may have entered the water in the vicinity of Gap Bluff at any time during the period of interest, this would have been more likely to have occurred between 9:00 pm on 9 January 1990 and 4:00 am on 10 January 1990. It should be acknowledged that there are a number of assumptions and unknowns involved in this opinion.

214 It is my opinion that it is possible that Mr Wark's body entered the water in the vicinity of Reef Beach between 2:30 pm on 9 January 1990 and 4:00 am on 10 January 1990, based on tidal conditions, it is more likely that this occurred between 9:00 pm on 9 January 1990 and 4:00 am on 10 January.

215 Based on physical environmental conditions alone and the assumptions involved therein, it is easier to explain how Mr Wark's body entered the water near the vicinity of Reef Beach rather than Gap Bluff, although the latter is certainly possible, particularly given information provided in the memorandum I received on 3 March 2023 in relation to the movement of human bodies in the water near Gap Bluff to Dobroyd Head.

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