WARRINGAH COUNCIL

ATTACHMENT BOOKLET 5

ORDINARY COUNCIL MEETING

TUESDAY 24 SEPTEMBER 2013

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BMT WBM

A part of BMT in Energy and Environment

Manly Lagoon Flood Study

Mapping Compendium

Final
R.N2069.005.02.compendium .docx
August 2013

LIST OF MAP SERIES INCLUDED IN THIS COMPENDIUM

Design Catchment Flood Mapping

A1 - Inundation Extent Map (Multiple Events)

A2 - 20% AEP Peak Flood Water Level
A3 - 10% AEP Peak Flood Water Level
A4 - 5% AEP Peak Flood Water Level
A5 - 2% AEP Peak Flood Water Level
A6 - 1% AEP Peak Flood Water Level
A7 - 0.5% AEP Peak Flood Water Level
A8 - 0.2% AEP Peak Flood Water Level
A9 - 0.1% AEP Peak Flood Water Level
A10 - PMF Peak Flood Water Level

A11 - 20% AEP Peak Flood Water Depth
A12 - 10% AEP Peak Flood Water Depth
A13 - 5% AEP Peak Flood Water Depth
A14 - 2% AEP Peak Flood Water Depth
A15 - 1% AEP Peak Flood Water Depth
A16 - 0.5% AEP Peak Flood Water Depth
A17 - 0.2% AEP Peak Flood Water Depth
A18 - 0.1% AEP Peak Flood Water Depth
A19 - PMF Peak Flood Water Depth

A20 - 1% AEP Peak Flood Velocity
A21 - PMF Peak Flood Velocity

A22 - 20% AEP Hydraulic Categories
A23 - 5% AEP Hydraulic Categories
A24 - 1% AEP Hydraulic Categories
A25 - PMF Hydraulic Categories

A26 - 20% AEP Provisional Flood Hazard
A27 - 5% AEP Provisional Flood Hazard
A28 - 1% AEP Provisional Flood Hazard
A29 - PMF Provisional Flood Hazard

Design Ocean Flood Mapping

A30 - Inundation Extent Map (Multiple Events)

A31 - 20% AEP Peak Flood Water Level
A32 - 5% AEP Peak Flood Water Level
A33 - 1% AEP Peak Flood Water Level

A34 - 20% AEP Peak Flood Water Depth
A35 - 5% AEP Peak Flood Water Depth
A36 - 1% AEP Peak Flood Water Depth

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A42 - Increased Manning's by 25% - 1% AEP Catchment Event
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A44 - Higher Raintall Losses - 1% AEP Catchment Event
A45 - Lower Initial Berm Height - 1% AEP Catchment Event
A46 - Lower Initial Berm Height - 1% AEP Catchment + 5%AEP Ocean Event
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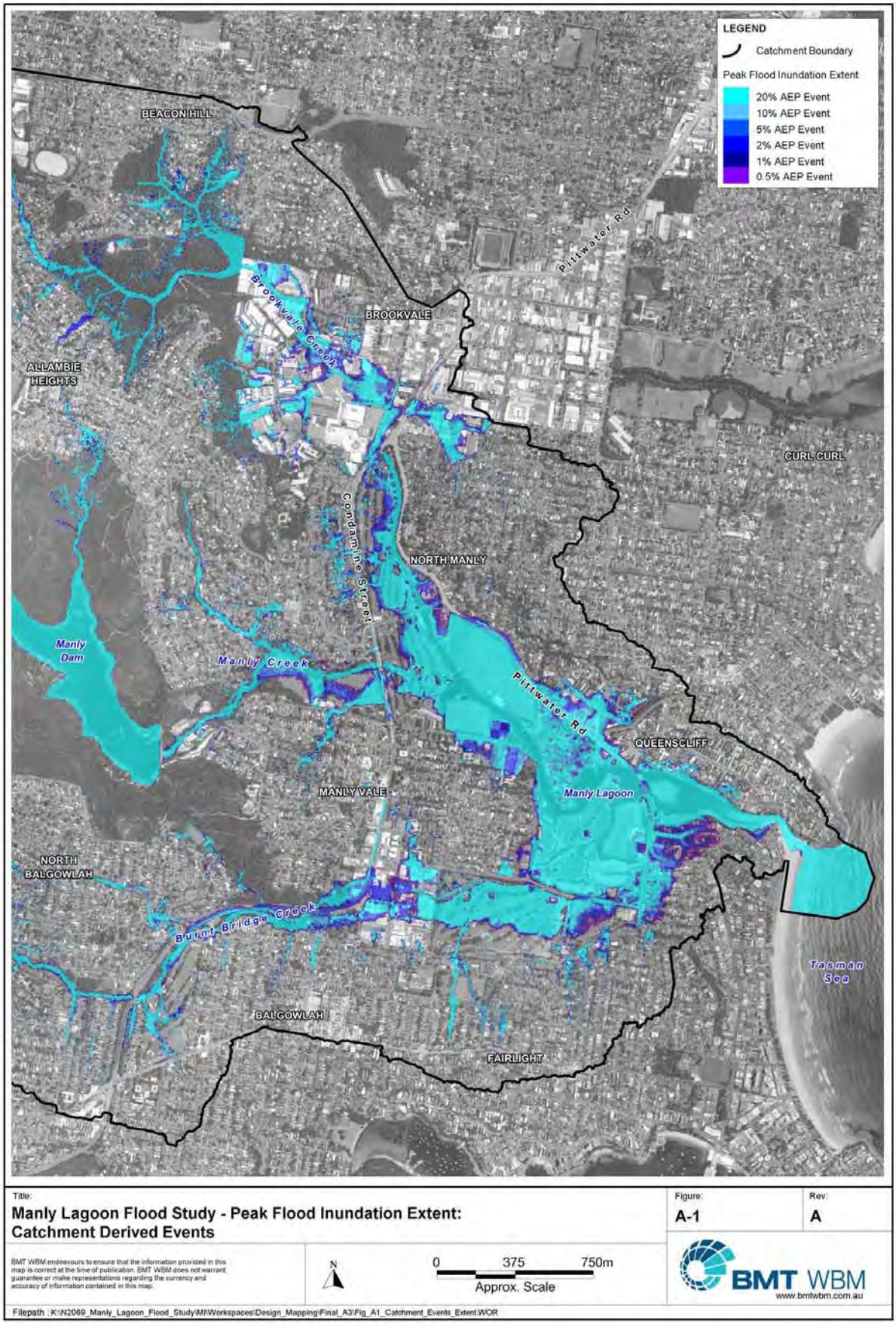
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Catchment Boundary
Peak Flood Inundation Extent
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10% AEP Event
5% AEP Event
2% AEP Event
1% AEP Event
0.5% AEP Event
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
QUEENSCLIFF
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Pittwater Rd
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Peak Flood Inundation Extent: Catchment Derived Events
Figure: A-1
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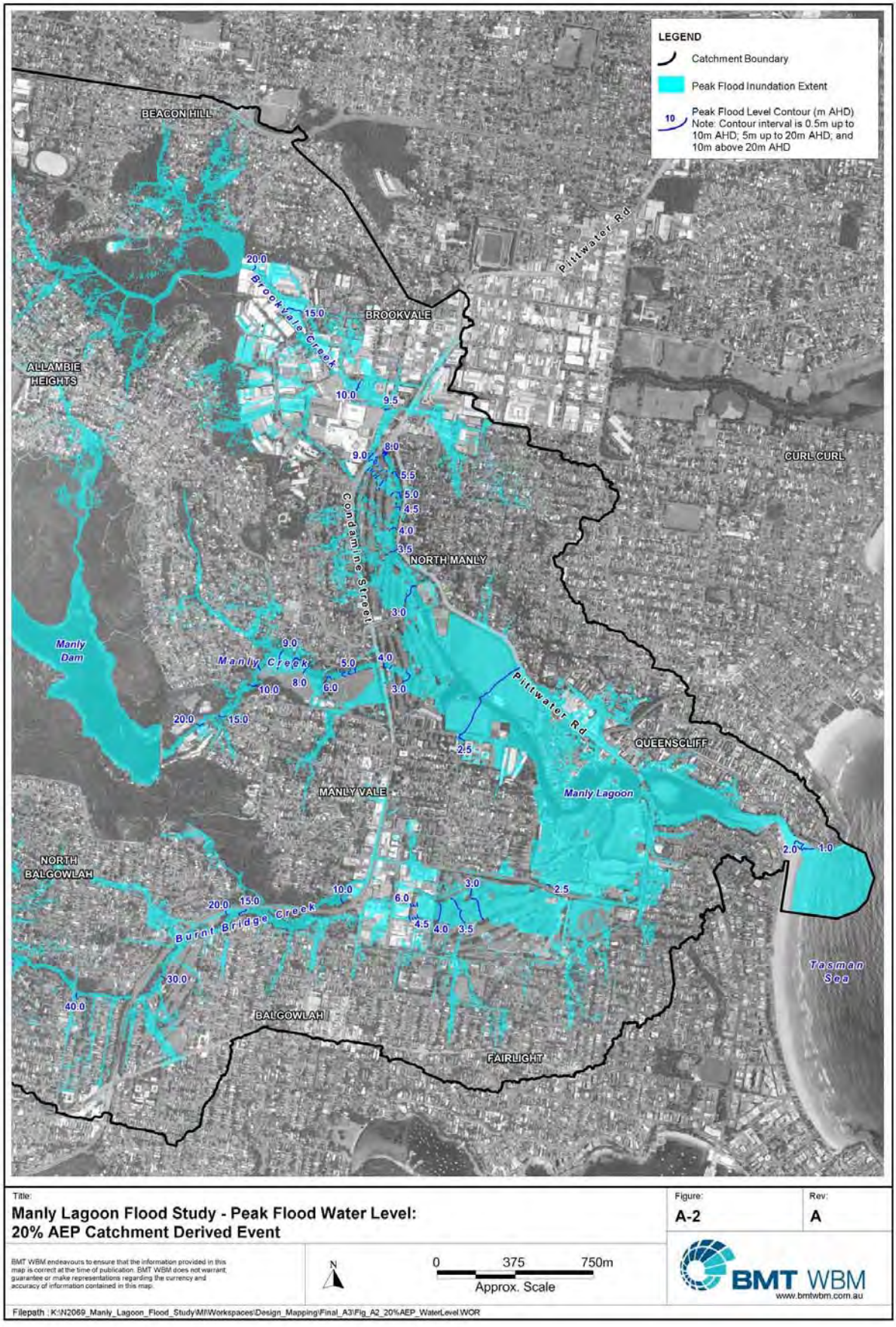
LEGEND
Catchment Boundary
Peak Flood Inundation Extent
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Peak Flood Level Contour (m AHD)
Note: Contour interval is 0.5m up to 10m AHD; 5m up to 20m AHD; and 10m above 20m AHD
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Manly Lagoon Flood Study - Peak Flood Water Level:
20% AEP Catchment Derived Event
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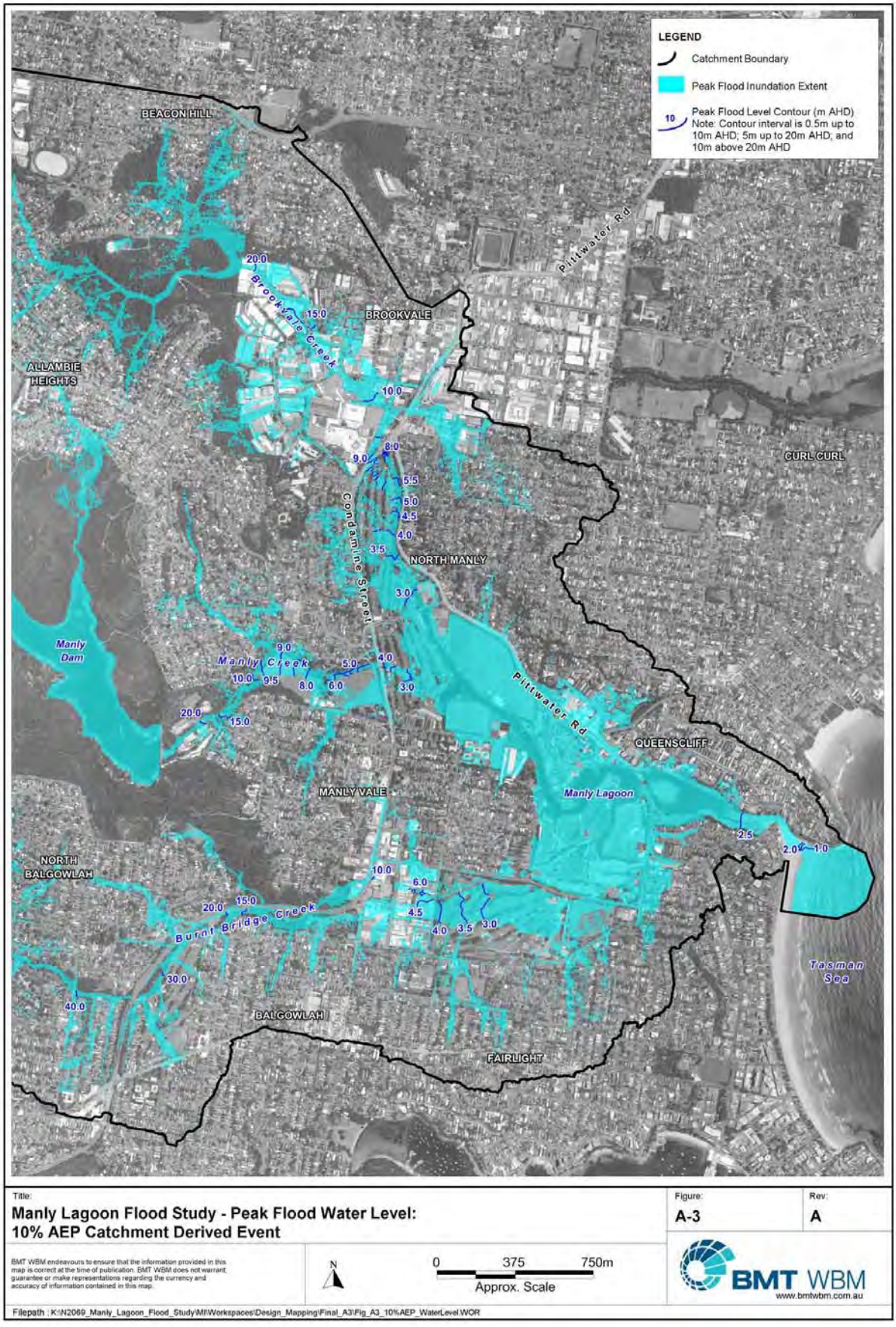
LEGEND
Catchment Boundary
Peak Flood Inundation Extent
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Peak Flood Level Contour (m AHD)
Note: Contour interval is 0.5m up to 10m AHD; 5m up to 20m AHD; and 10m above 20m AHD
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Manly Lagoon Flood Study - Peak Flood Water Level:
10% AEP Catchment Derived Event
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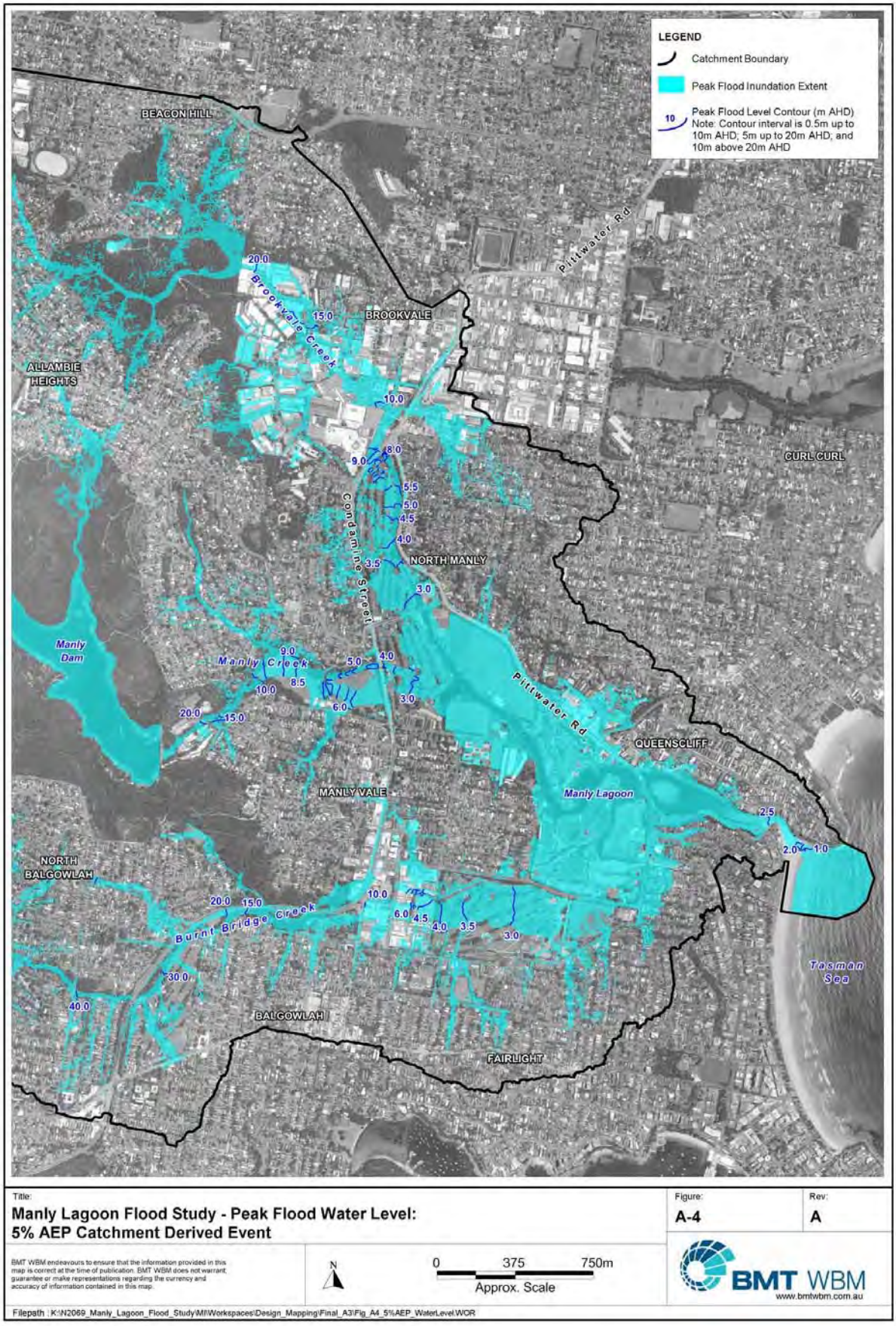
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Peak Flood Level Contour (m AHD)
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Manly Lagoon Flood Study - Peak Flood Water Level:
5% AEP Catchment Derived Event
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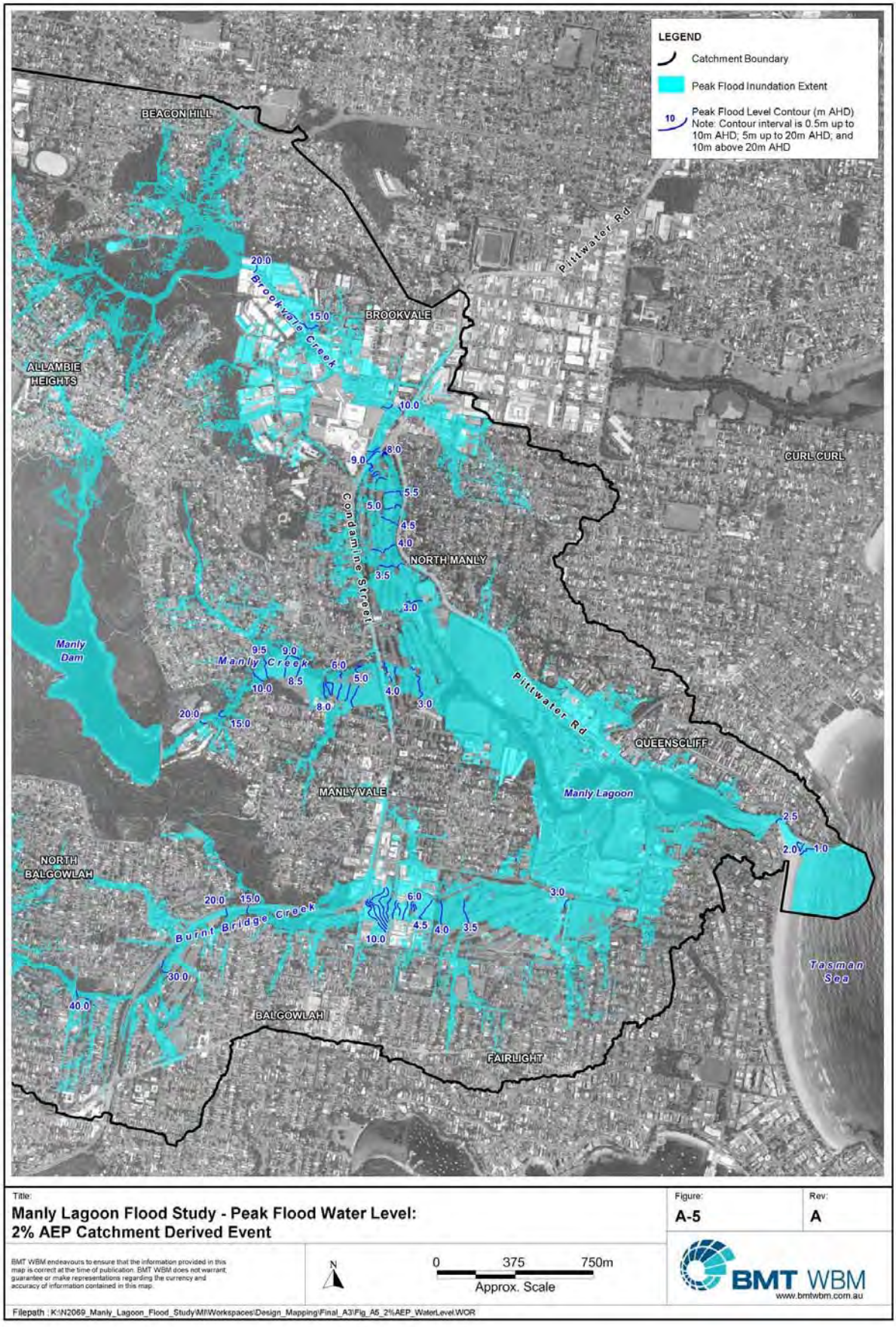
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Peak Flood Inundation Extent
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Peak Flood Level Contour (m AHD)
Note: Contour interval is 0.5m up to 10m AHD; 5m up to 20m AHD; and 10m above 20m AHD
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Manly Lagoon Flood Study - Peak Flood Water Level:
2% AEP Catchment Derived Event
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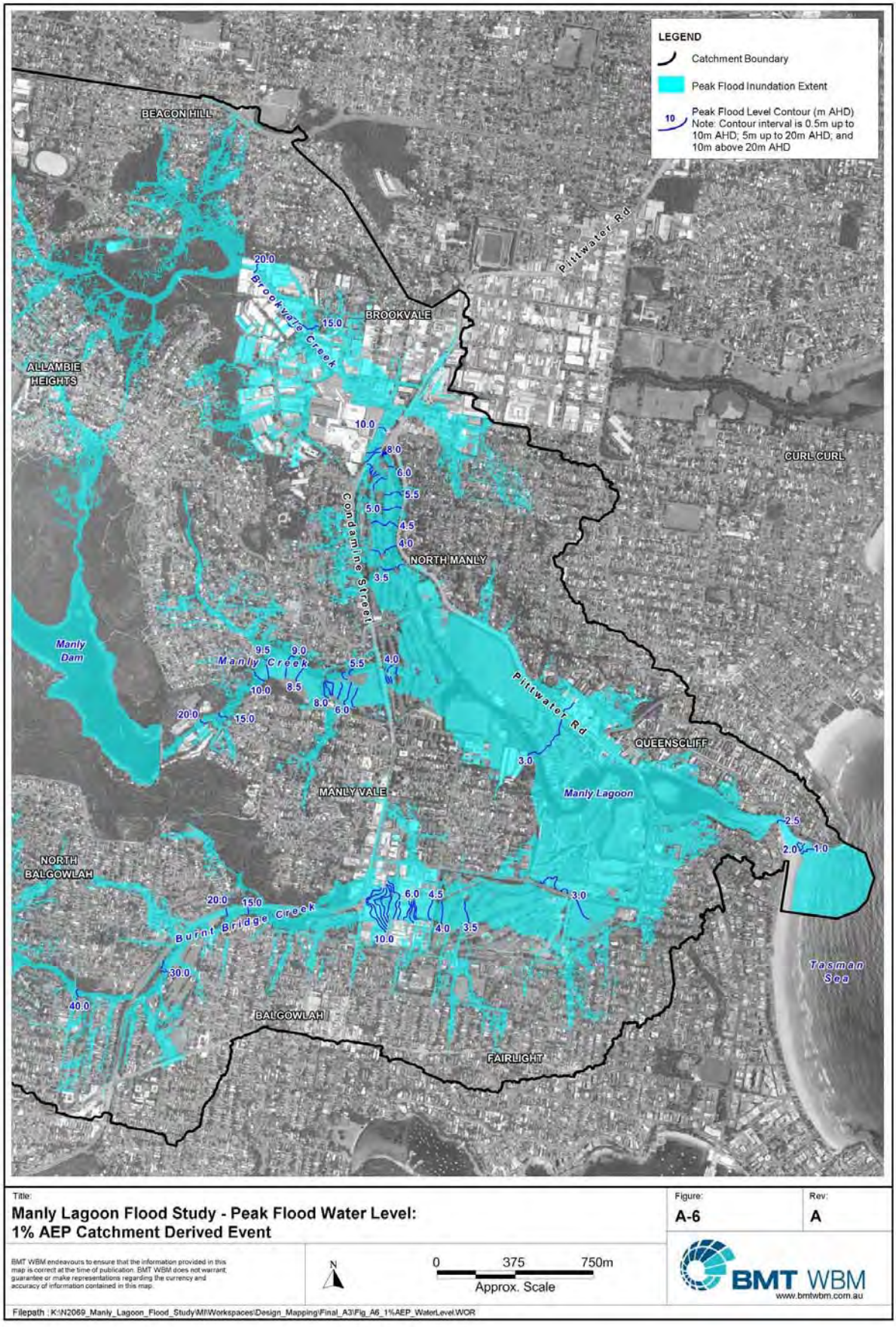
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Manly Lagoon Flood Study - Peak Flood Water Level:
1% AEP Catchment Derived Event
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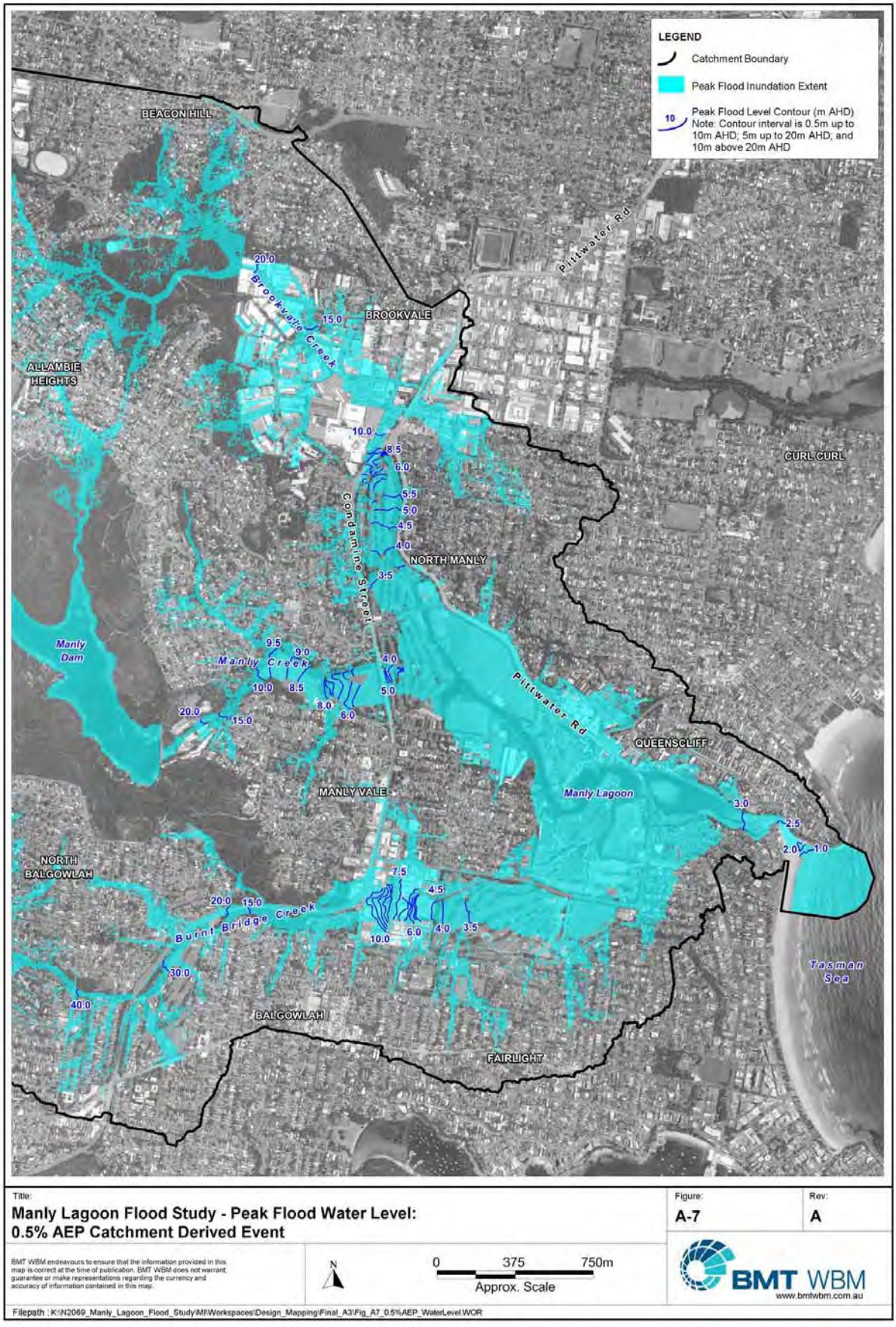
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Manly Lagoon Flood Study - Peak Flood Water Level:
0.5% AEP Catchment Derived Event
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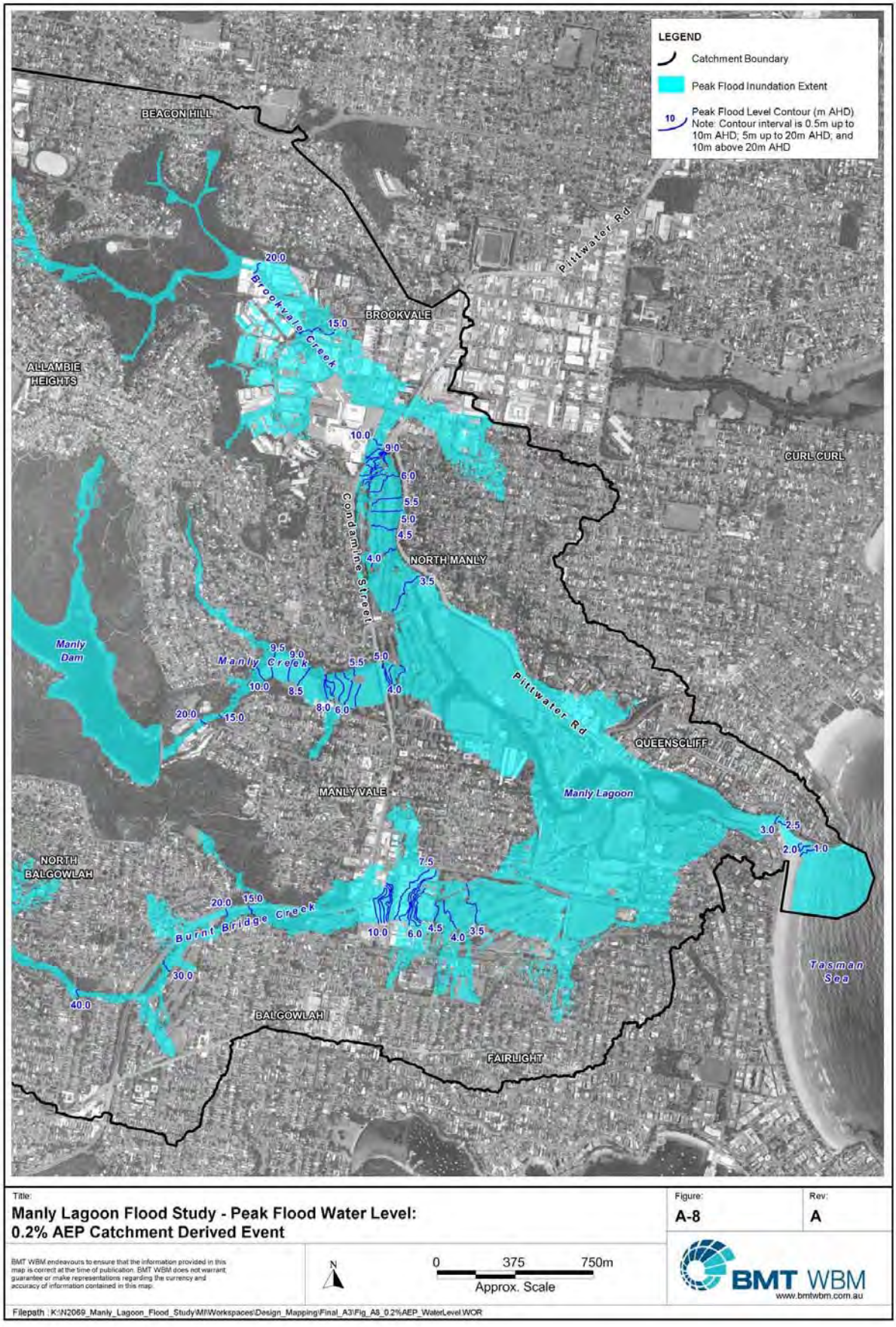
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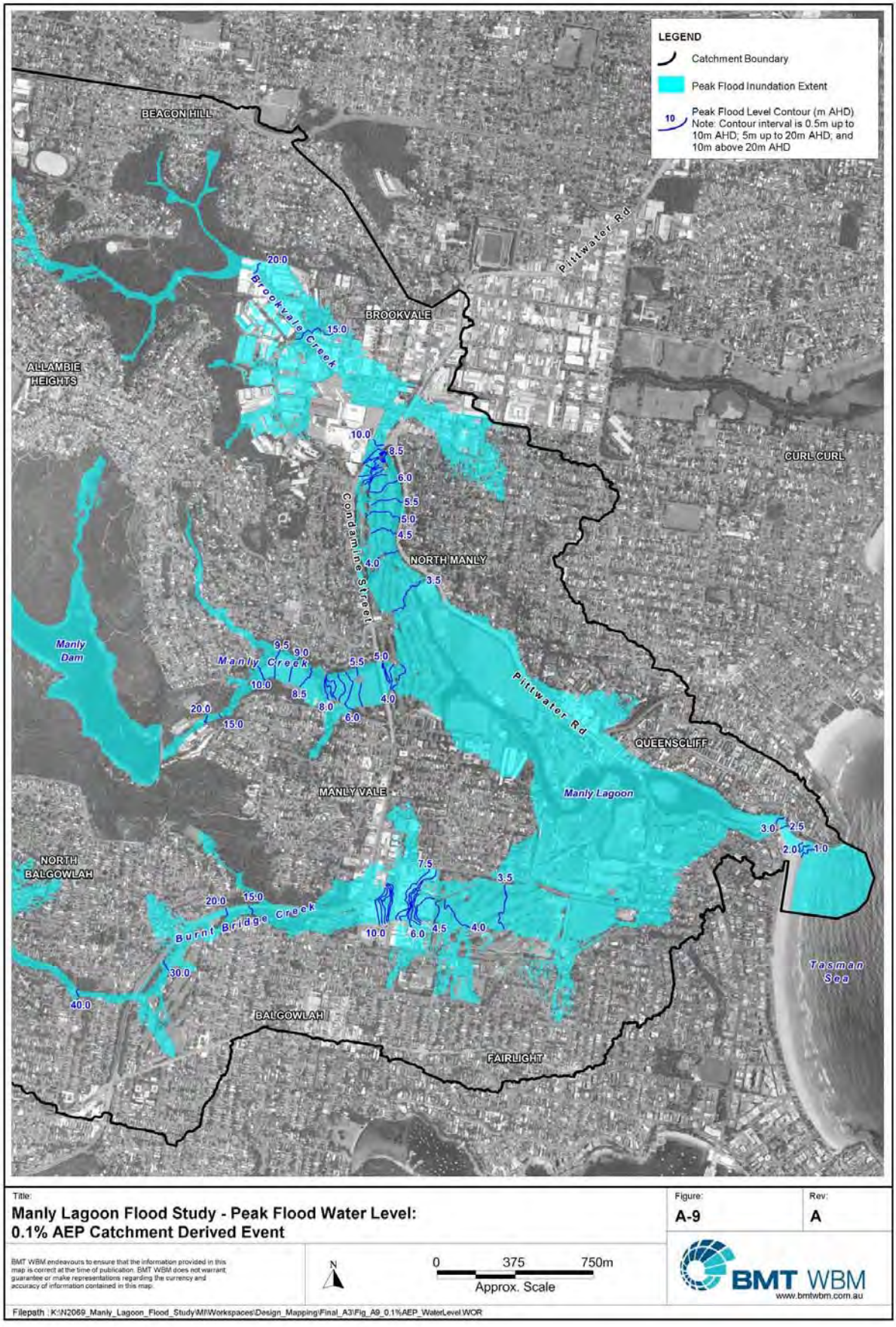
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Manly Lagoon Flood Study - Peak Flood Water Level:
0.1% AEP Catchment Derived Event
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750m
Approx. Scale
BMT WBM
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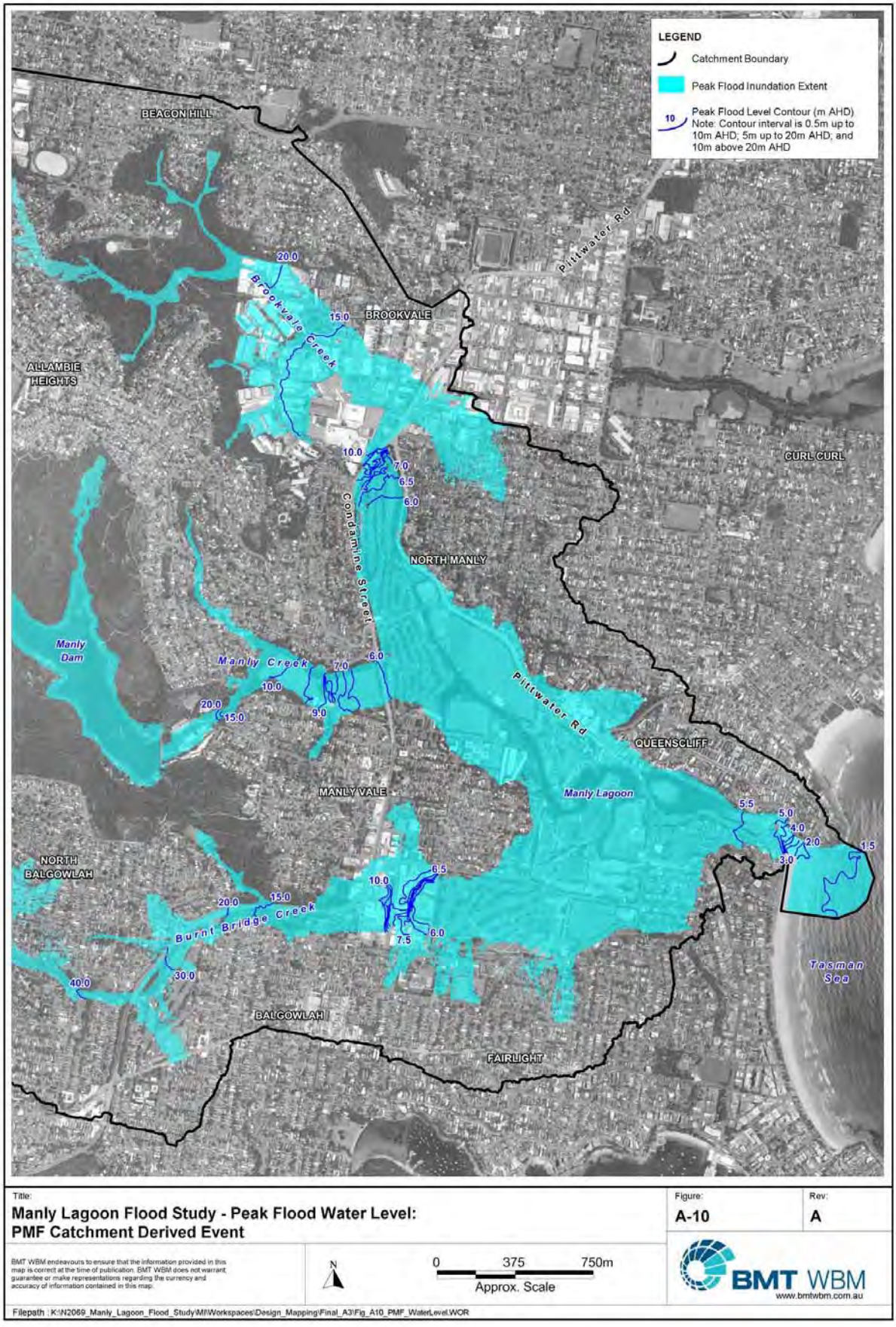
LEGEND
Catchment Boundary
Peak Flood Inundation Extent
10
Peak Flood Level Contour (m AHD)
Note: Contour interval is 0.5m up to 10m AHD; 5m up to 20m AHD; and 10m above 20m AHD
BEACON HILL
ALLAMBIE HEIGHTS
BROOKVALE
Brookvale Creek
Pittwater Rd
CURL CURL
NORTH MANLY
Condamine Street
Manly Dam
Manly Creek
QUEENSCLIFF
MANLY VALE
Manly Lagoon
NORTH BALGOWLAH
Burnt Bridge Creek
Tasman Sea
BALGOWLAH
FAIRLIGHT
20.0
15.0
10.0
7.0
6.5
6.0
9.0
5.5
5.0
4.0
2.0
1.5
3.0
7.5
40.0
30.0
Title:
Manly Lagoon Flood Study - Peak Flood Water Level:
PMF Catchment Derived Event
Figure:
A-10
Rev:
A
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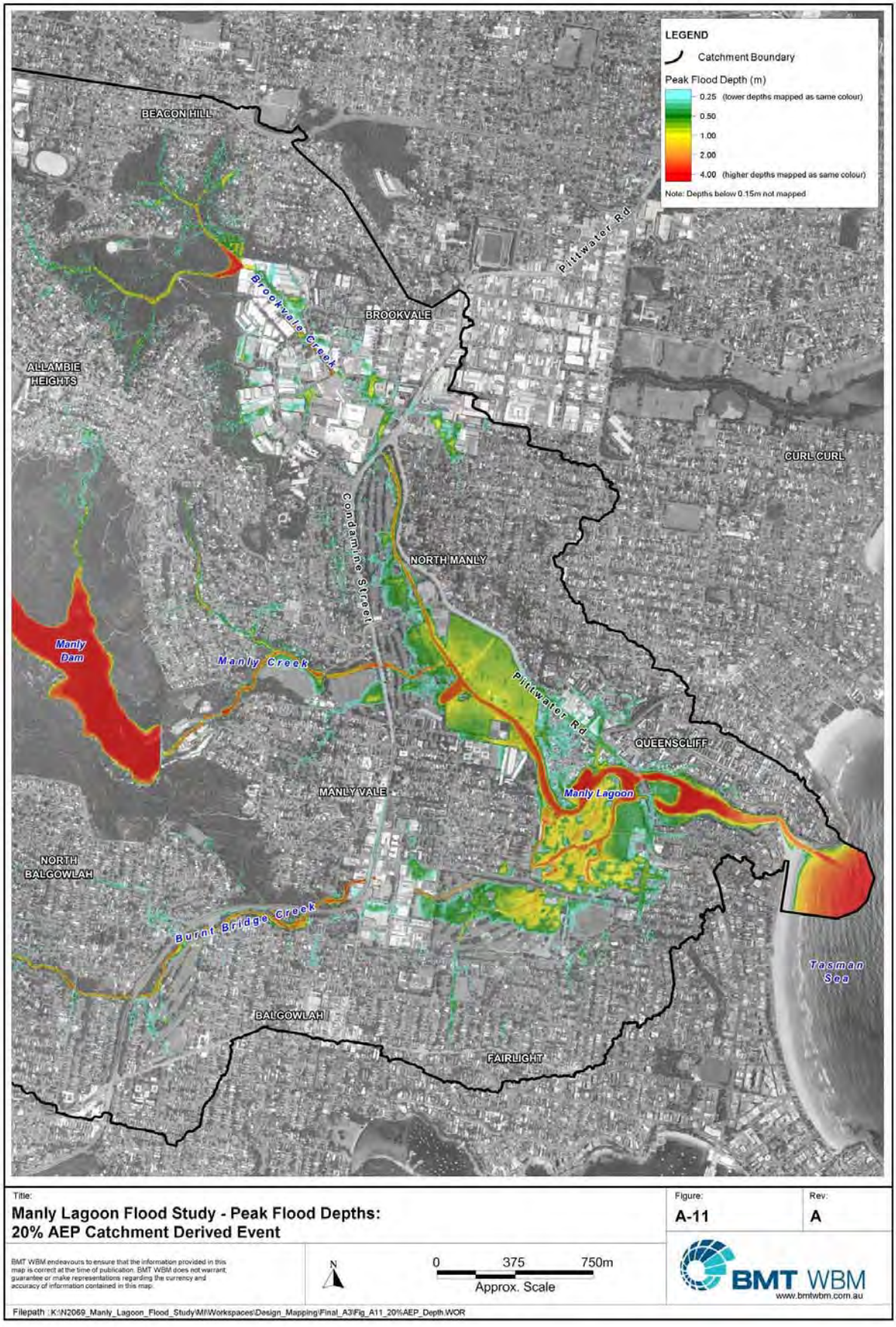
LEGEND
Catchment Boundary
Peak Flood Depth (m)
0.25 (lower depths mapped as same colour)
0.50
1.00
2.00
4.00 (higher depths mapped as same colour)
Note: Depths below 0.15m not mapped
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
MANLY VALE
QUEENSCLIFF
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Pittwater Rd
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Peak Flood Depths:
20% AEP Catchment Derived Event
Figure:
A-11
Rev:
A
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Approx. Scale
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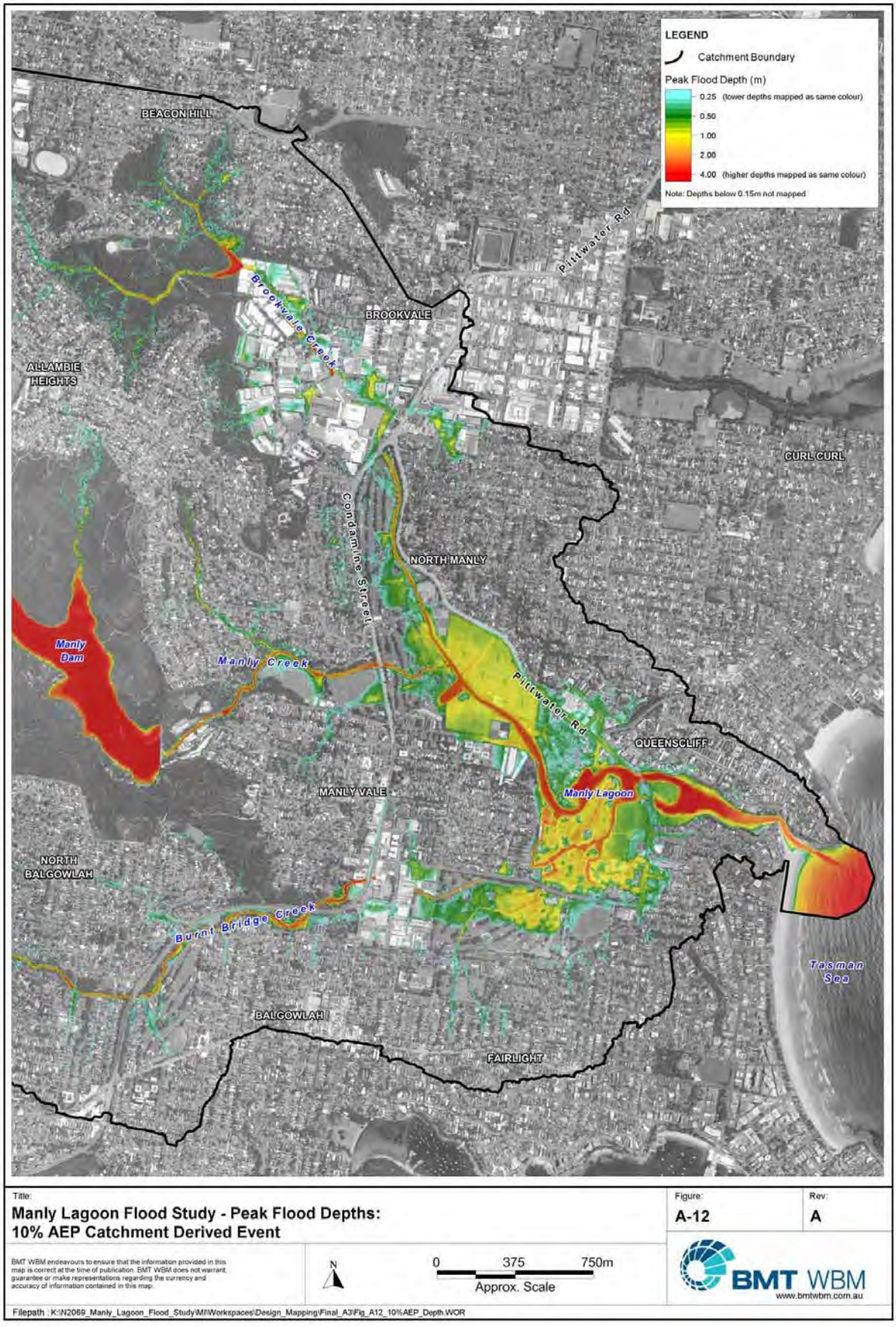
LEGEND
Catchment Boundary
Peak Flood Depth (m)
0.25 (lower depths mapped as same colour)
0.50
1.00
2.00
4.00 (higher depths mapped as same colour)
Note: Depths below 0.15m not mapped
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
QUEENSCLIFF
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Pittwater Rd
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Peak Flood Depths:
10% AEP Catchment Derived Event
Figure:
A-12
Rev:
A
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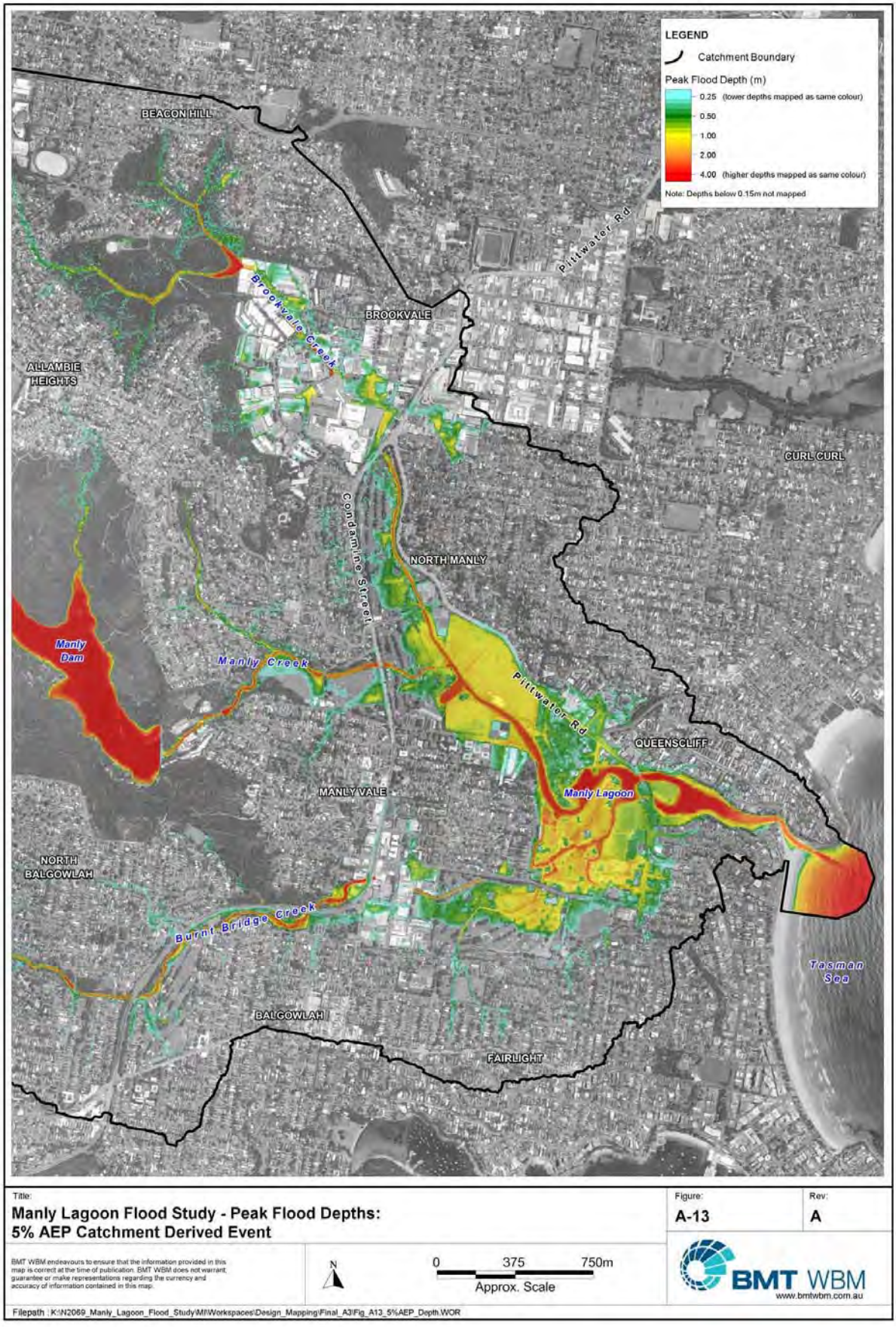

Title:
Manly Lagoon Flood Study - Peak Flood Depths: 5% AEP Catchment Derived Event

Figure: **A-13**

Rev: **A**

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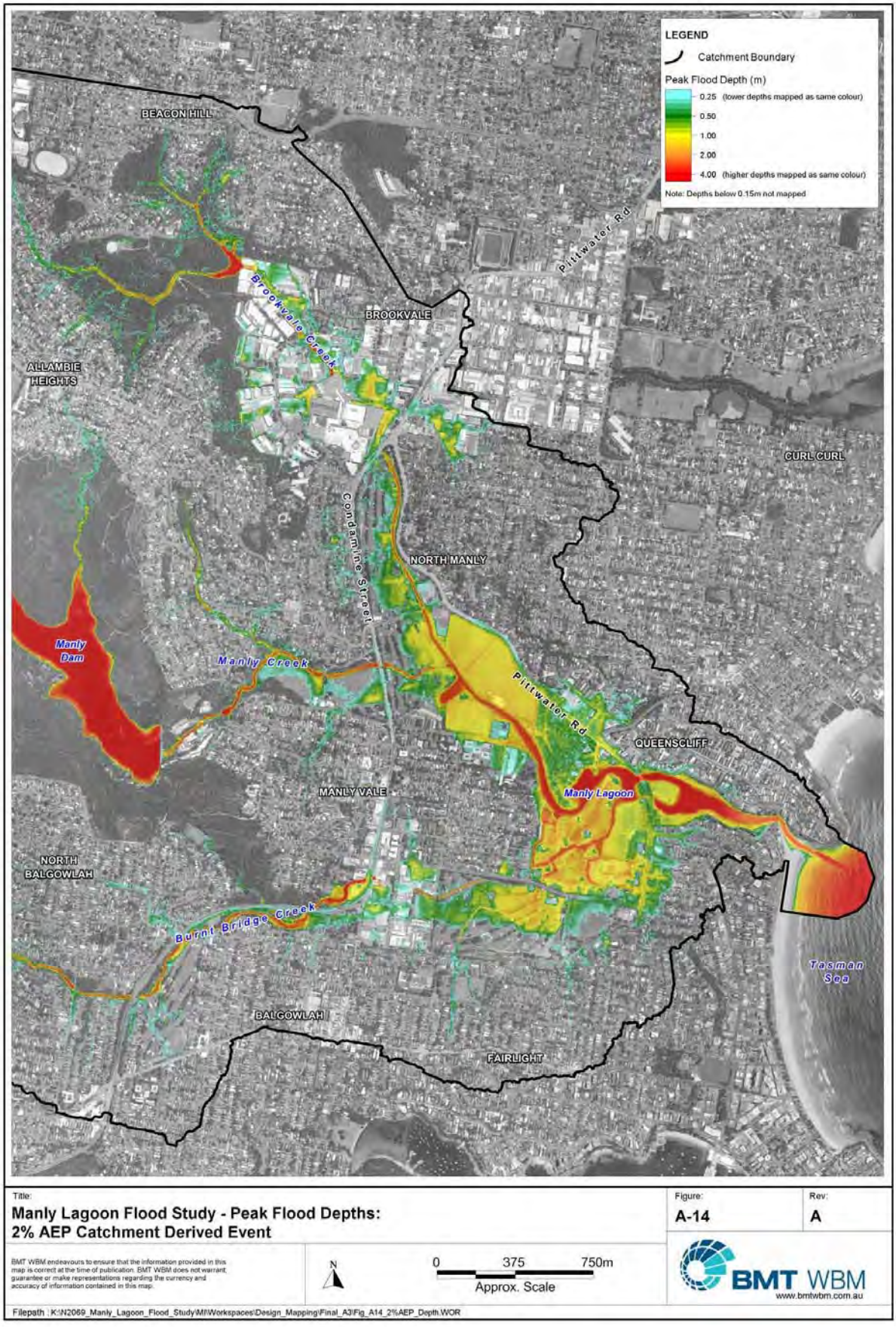
Filepath : K:\N2069_Manly_Lagoon_Flood_Study\MI\Workspaces\Design_Mapping\Final_A3\Fig_A13_5%AEP_Depth.WOR


LEGEND
Catchment Boundary
Peak Flood Depth (m)
0.25 (lower depths mapped as same colour)
0.50
1.00
2.00
4.00 (higher depths mapped as same colour)
Note: Depths below 0.15m not mapped
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
QUEENSCLIFF
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Brookvale Creek
Pittwater Rd
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Peak Flood Depths:
2% AEP Catchment Derived Event
Figure:
A-14
Rev:
A
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BMT WBM
www.bmtwbm.com.au
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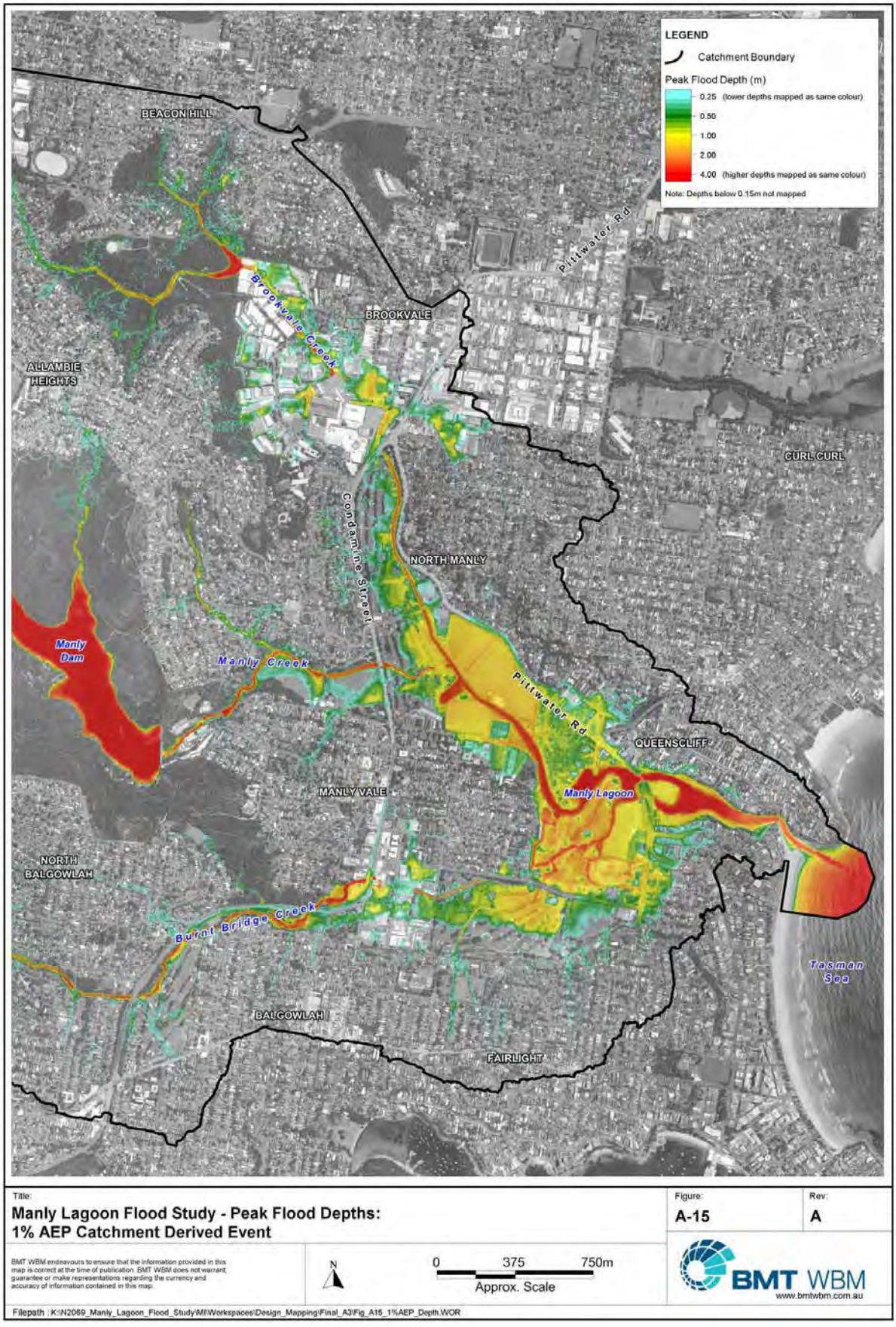
LEGEND
Catchment Boundary
Peak Flood Depth (m)
0.25 (lower depths mapped as same colour)
0.50
1.00
2.00
4.00 (higher depths mapped as same colour)
Note: Depths below 0.15m not mapped
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
MANLY VALE
QUEENSCLIFF
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Brookvale Creek
Condamine Street
Pittwater Rd
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Peak Flood Depths:
1% AEP Catchment Derived Event
Figure:
A-15
Rev:
A
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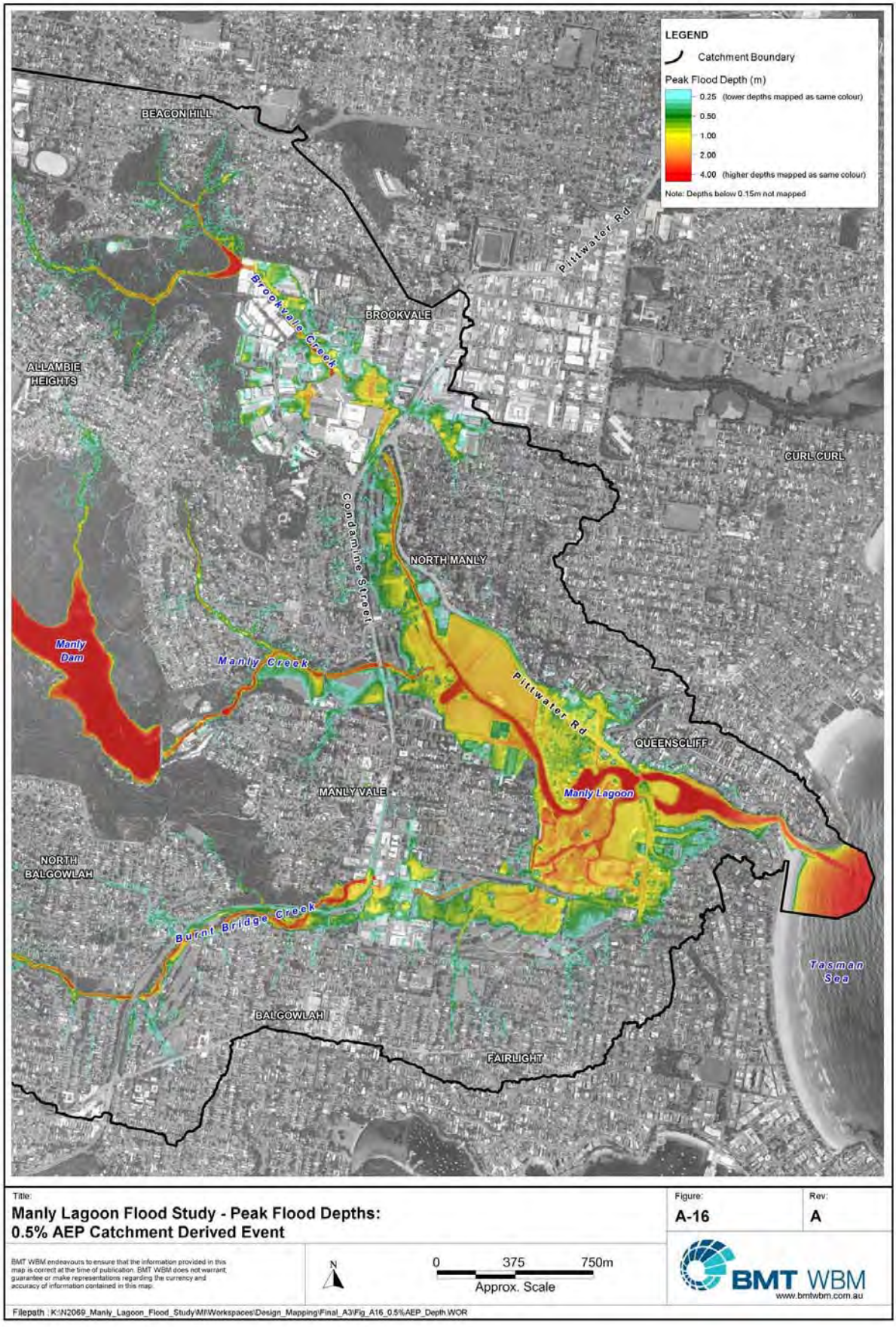
LEGEND
Catchment Boundary
Peak Flood Depth (m)
0.25 (lower depths mapped as same colour)
0.50
1.00
2.00
4.00 (higher depths mapped as same colour)
Note: Depths below 0.15m not mapped
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
MANLY VALE
QUEENSCLIFF
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Brookvale Creek
Condamine Street
Pittwater Rd
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Peak Flood Depths:
0.5% AEP Catchment Derived Event
Figure:
A-16
Rev:
A
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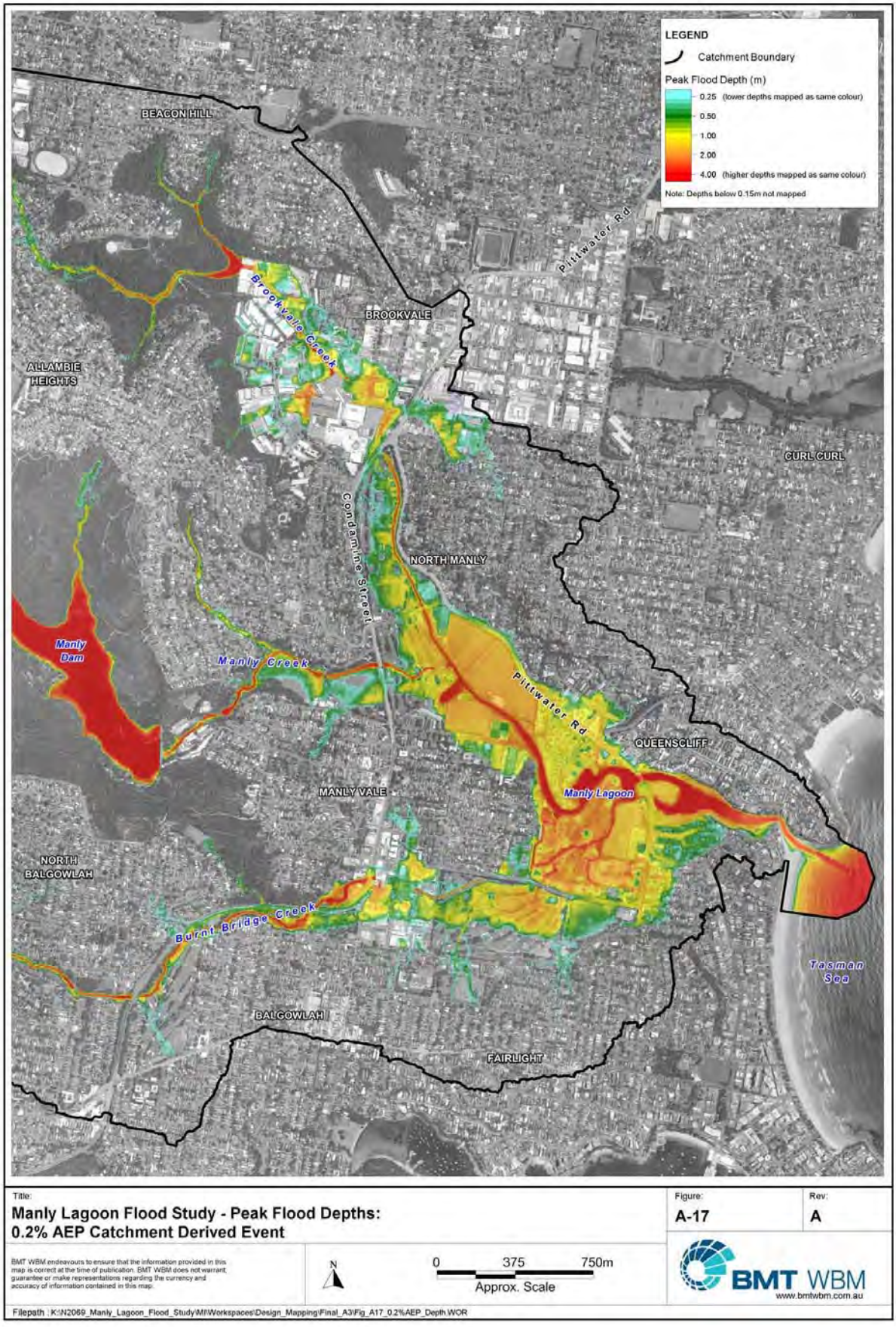
LEGEND
Catchment Boundary
Peak Flood Depth (m)
0.25 (lower depths mapped as same colour)
0.50
1.00
2.00
4.00 (higher depths mapped as same colour)
Note: Depths below 0.15m not mapped
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
MANLY VALE
QUEENSCLIFF
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Pittwater Rd
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Peak Flood Depths:
0.2% AEP Catchment Derived Event
Figure:
A-17
Rev:
A
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Approx. Scale
BMT WBM
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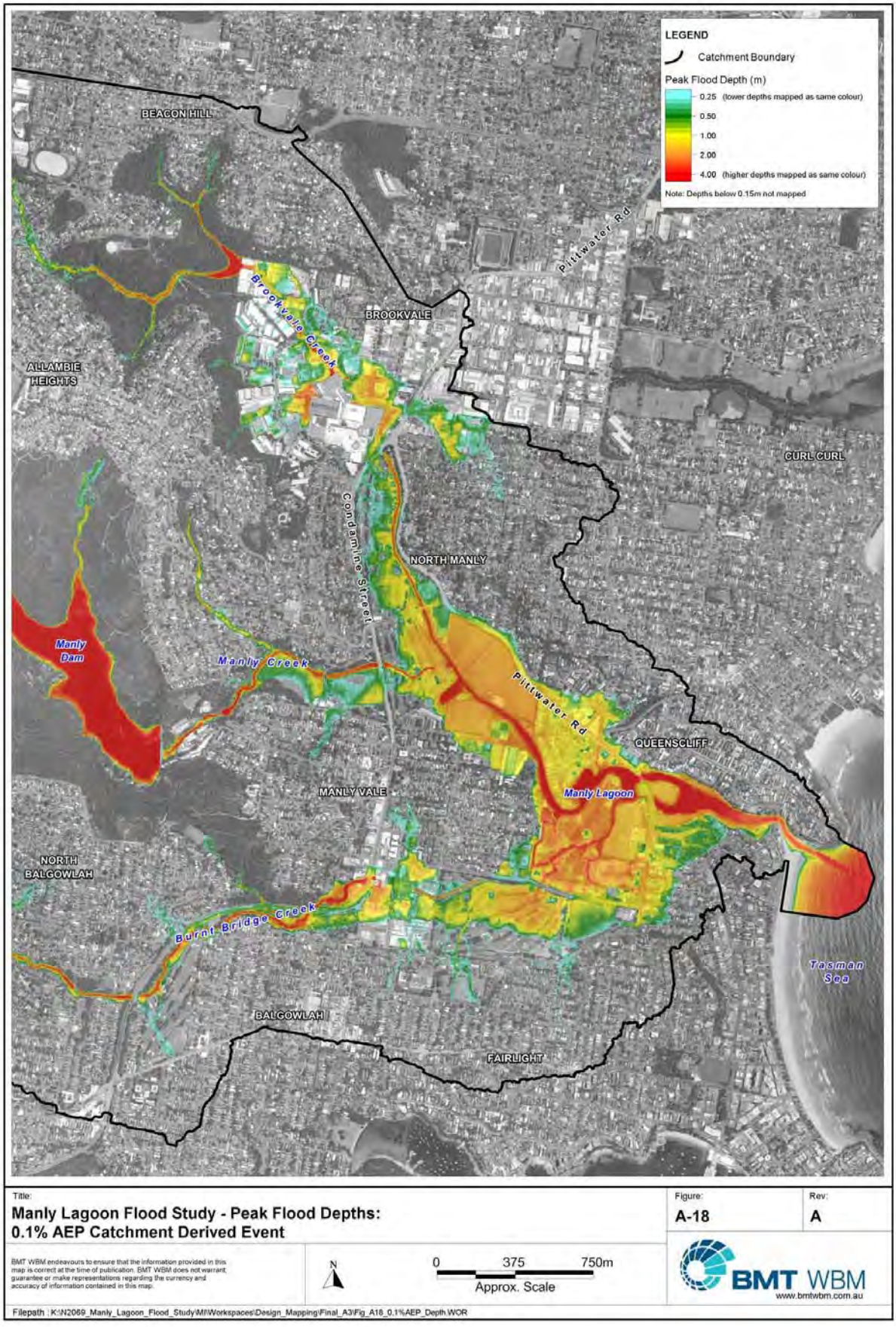
LEGEND
Catchment Boundary
Peak Flood Depth (m)
0.25 (lower depths mapped as same colour)
0.50
1.00
2.00
4.00 (higher depths mapped as same colour)
Note: Depths below 0.15m not mapped
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
QUEENSCLIFF
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Pittwater Rd
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Peak Flood Depths:
0.1% AEP Catchment Derived Event
Figure:
A-18
Rev:
A
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www.bmtwbm.com.au
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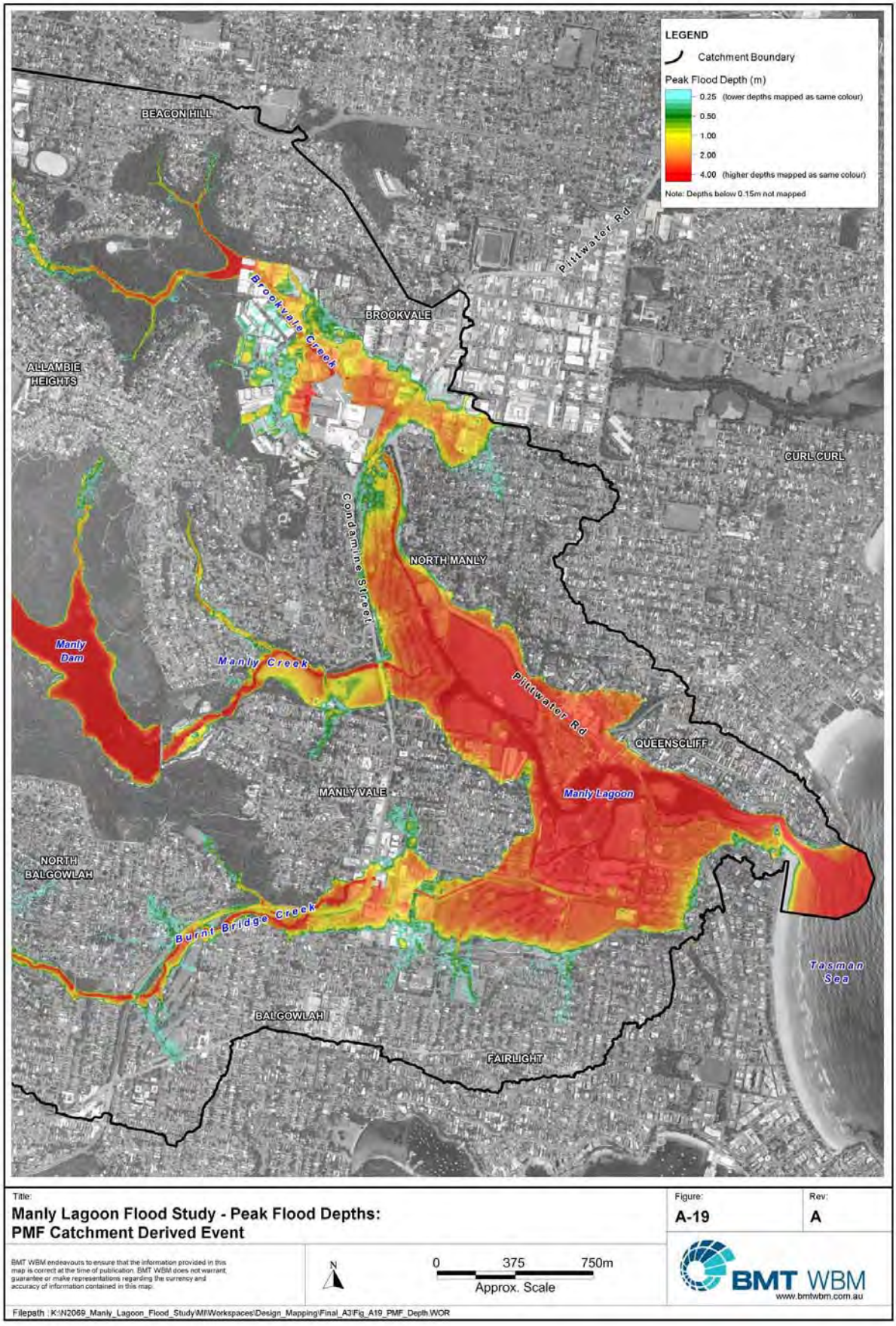

Title:
Manly Lagoon Flood Study - Peak Flood Depths: PMF Catchment Derived Event

Figure: **A-19**

Rev: **A**

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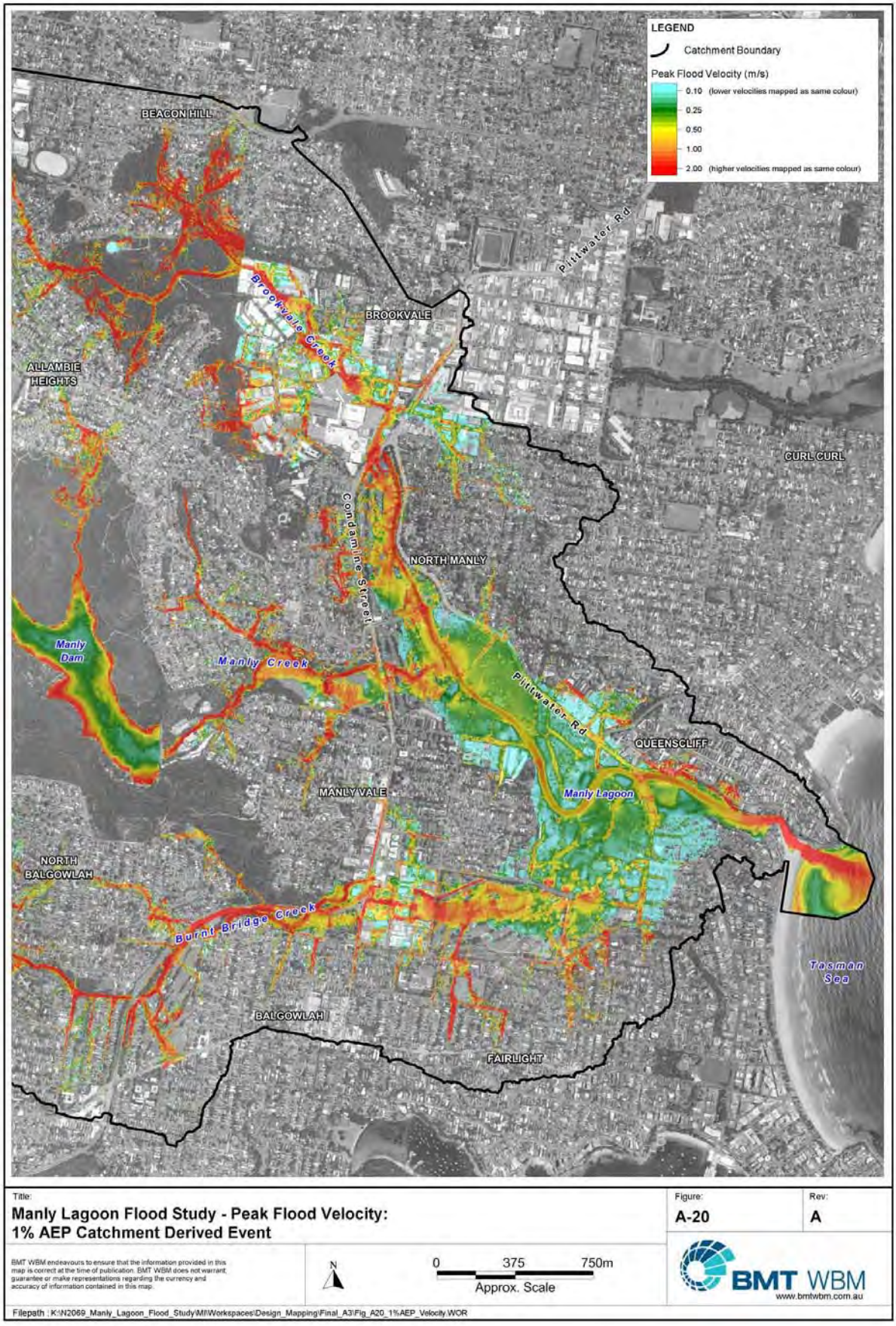
LEGEND
Catchment Boundary
Peak Flood Velocity (m/s)
0.10 (lower velocities mapped as same colour)
0.25
0.50
1.00
2.00 (higher velocities mapped as same colour)
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
QUEENSCLIFF
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Pittwater Rd
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Peak Flood Velocity:
1% AEP Catchment Derived Event
Figure:
A-20
Rev:
A
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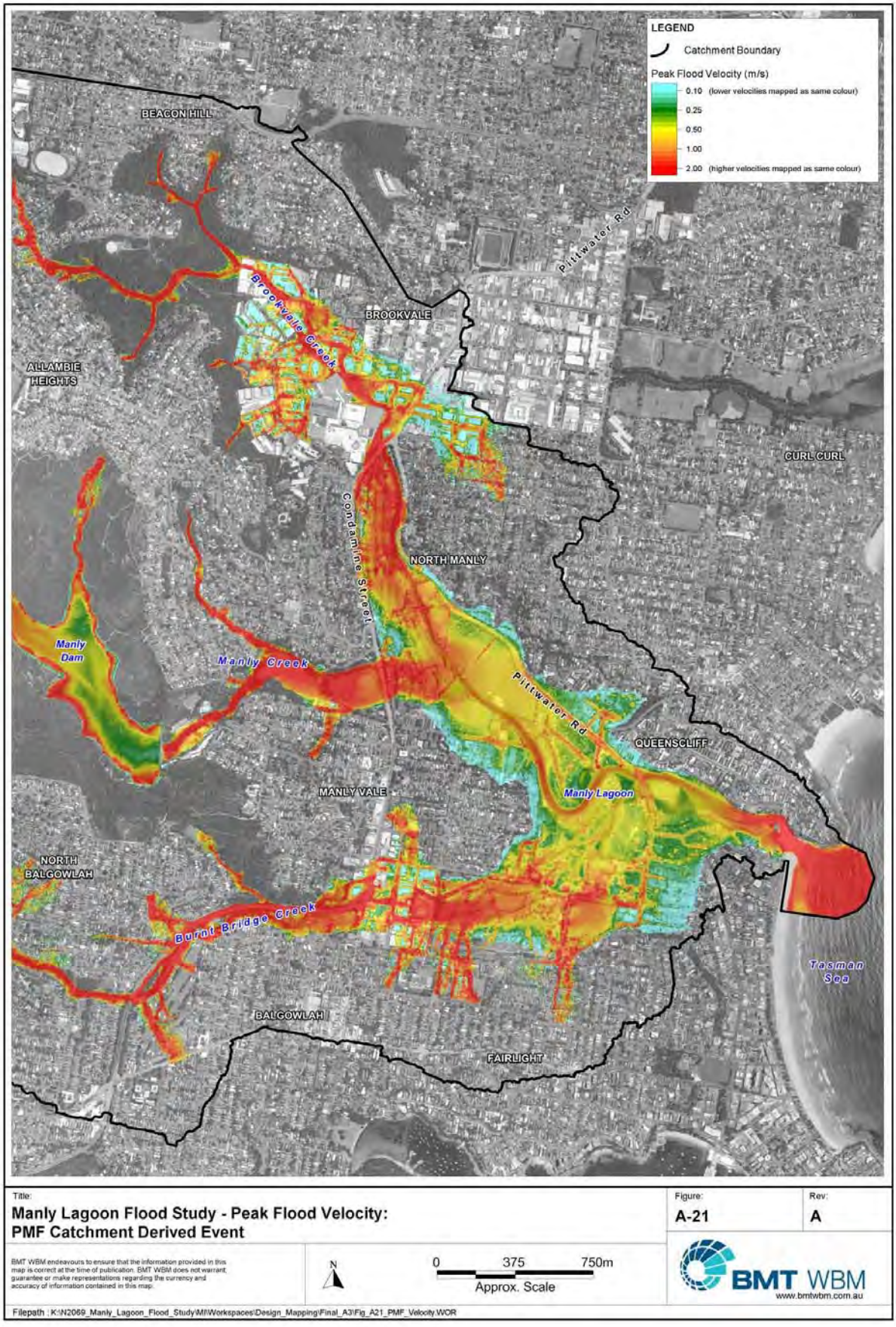
LEGEND
Catchment Boundary
Peak Flood Velocity (m/s)
0.10 (lower velocities mapped as same colour)
0.25
0.50
1.00
2.00 (higher velocities mapped as same colour)
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
QUEENSCLIFF
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Brookvale Creek
Pittwater Rd
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Peak Flood Velocity:
PMF Catchment Derived Event
Figure:
A-21
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
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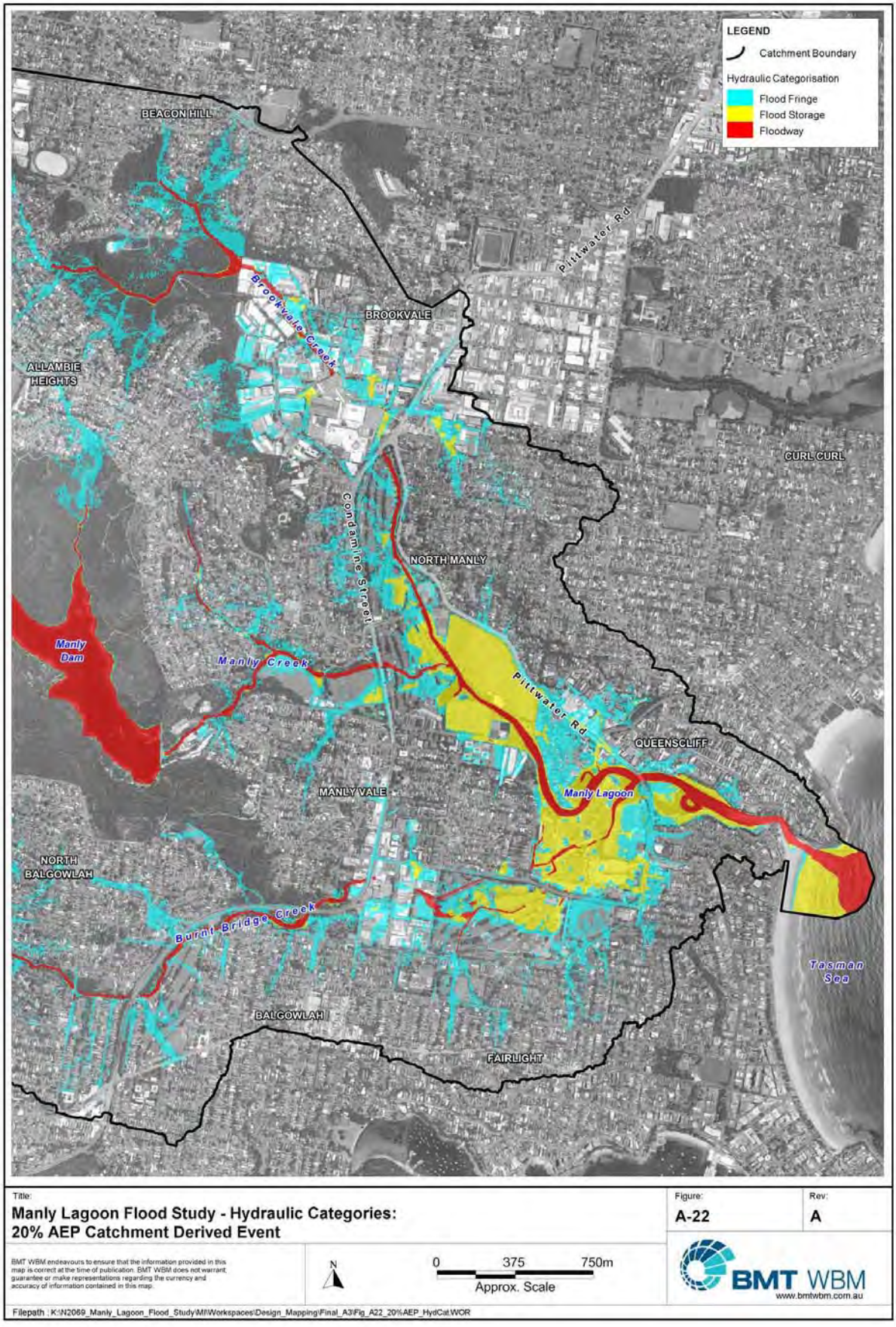
LEGEND
Catchment Boundary
Hydraulic Categorisation
Flood Fringe
Flood Storage
Floodway
BEACON HILL
Pittwater Rd
Brookvale Creek
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
Condamine Street
NORTH MANLY
Manly Dam
Manly Creek
Pittwater Rd
QUEENSCLIFF
MANLY VALE
Manly Lagoon
NORTH BALGOWLAH
Burnt Bridge Creek
Tasman Sea
BALGOWLAH
FAIRLIGHT
Title:
Manly Lagoon Flood Study - Hydraulic Categories:
20% AEP Catchment Derived Event
Figure:
A-22
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
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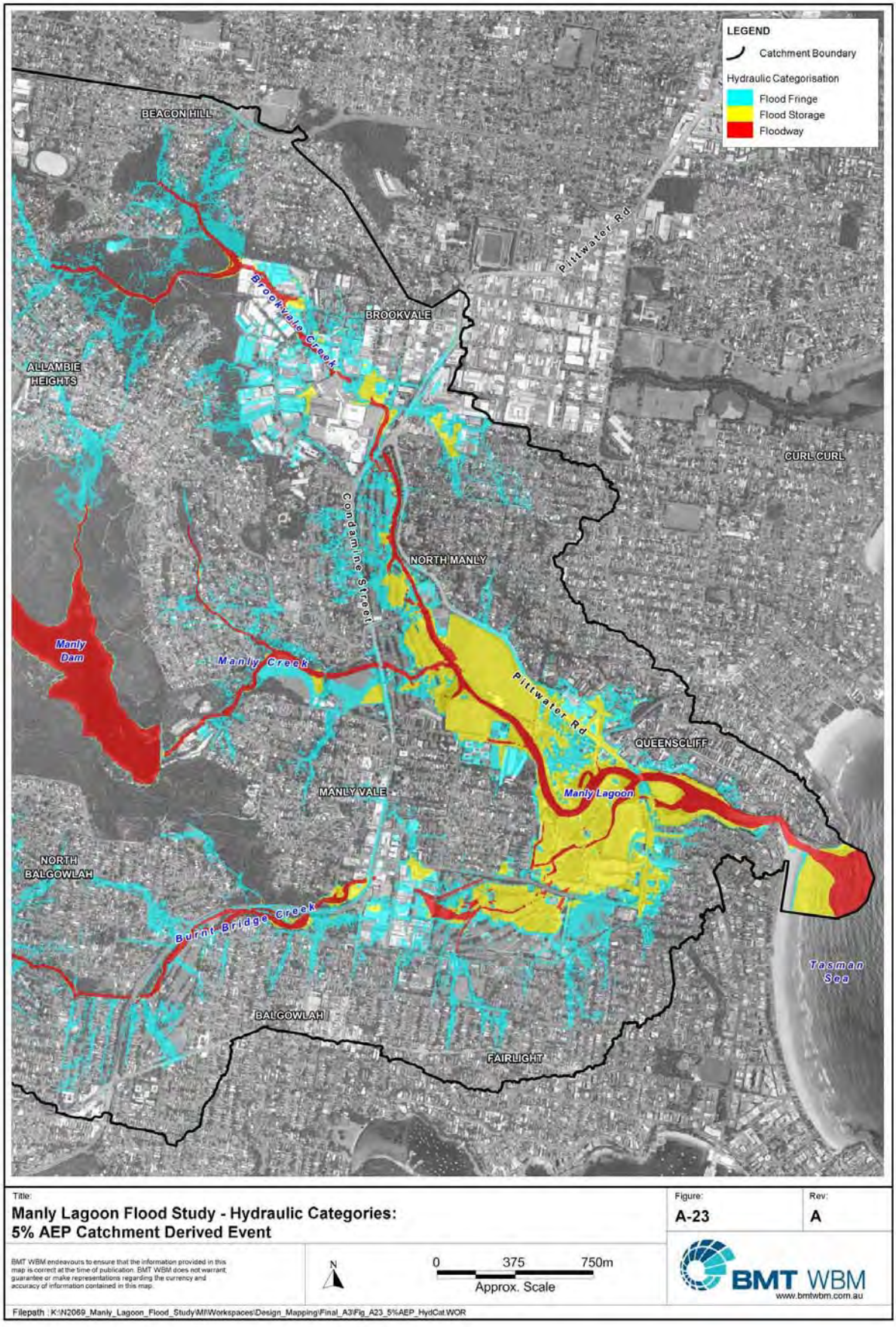
LEGEND
Catchment Boundary
Hydraulic Categorisation
Flood Fringe
Flood Storage
Floodway
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
MANLY VALE
QUEENSCLIFF
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Pittwater Rd
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Hydraulic Categories:
5% AEP Catchment Derived Event
Figure:
A-23
Rev:
A
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Approx. Scale
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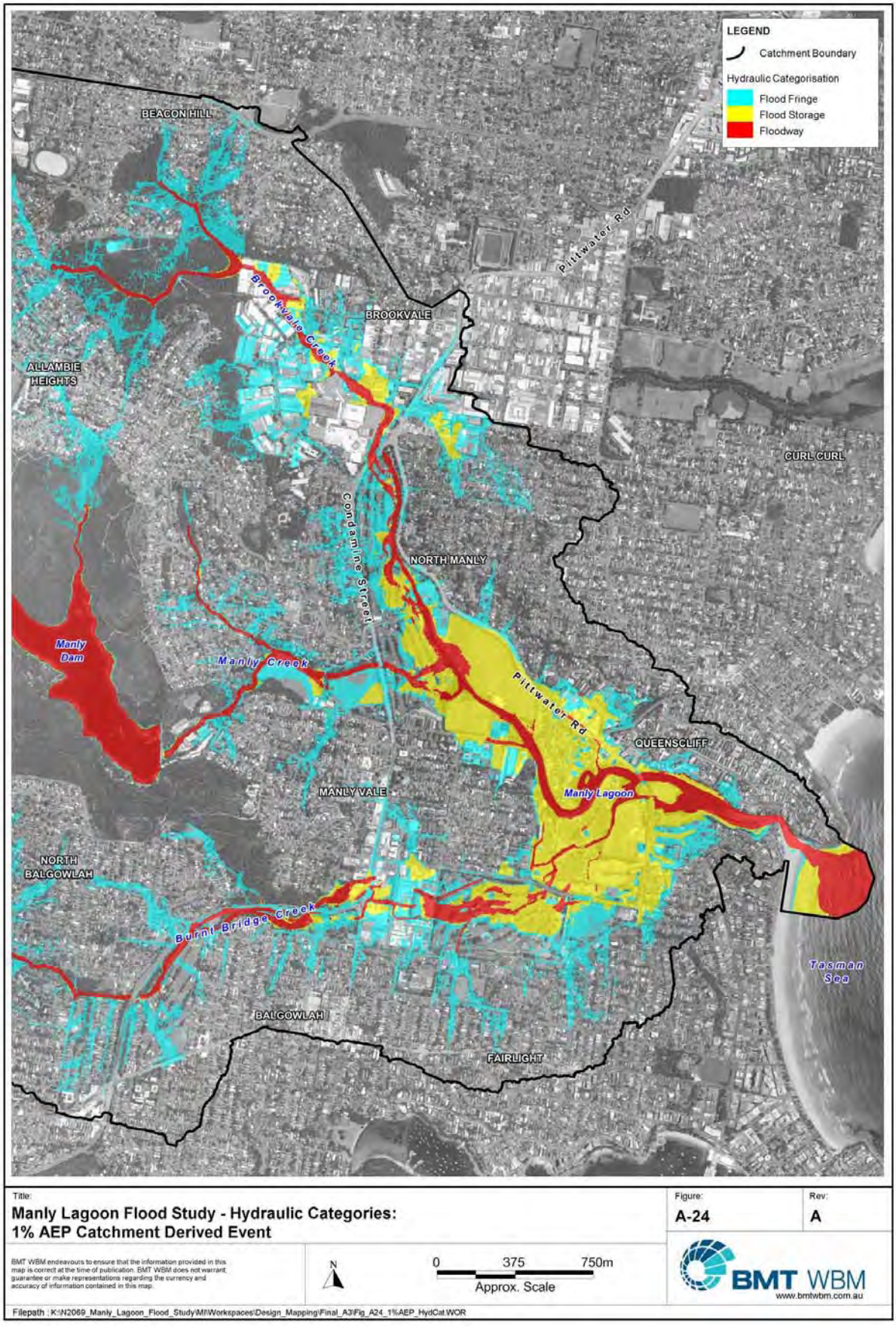
LEGEND
Catchment Boundary
Hydraulic Categorisation
Flood Fringe
Flood Storage
Floodway
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
QUEENSCLIFF
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Pittwater Rd
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Hydraulic Categories:
1% AEP Catchment Derived Event
Figure:
A-24
Rev:
A
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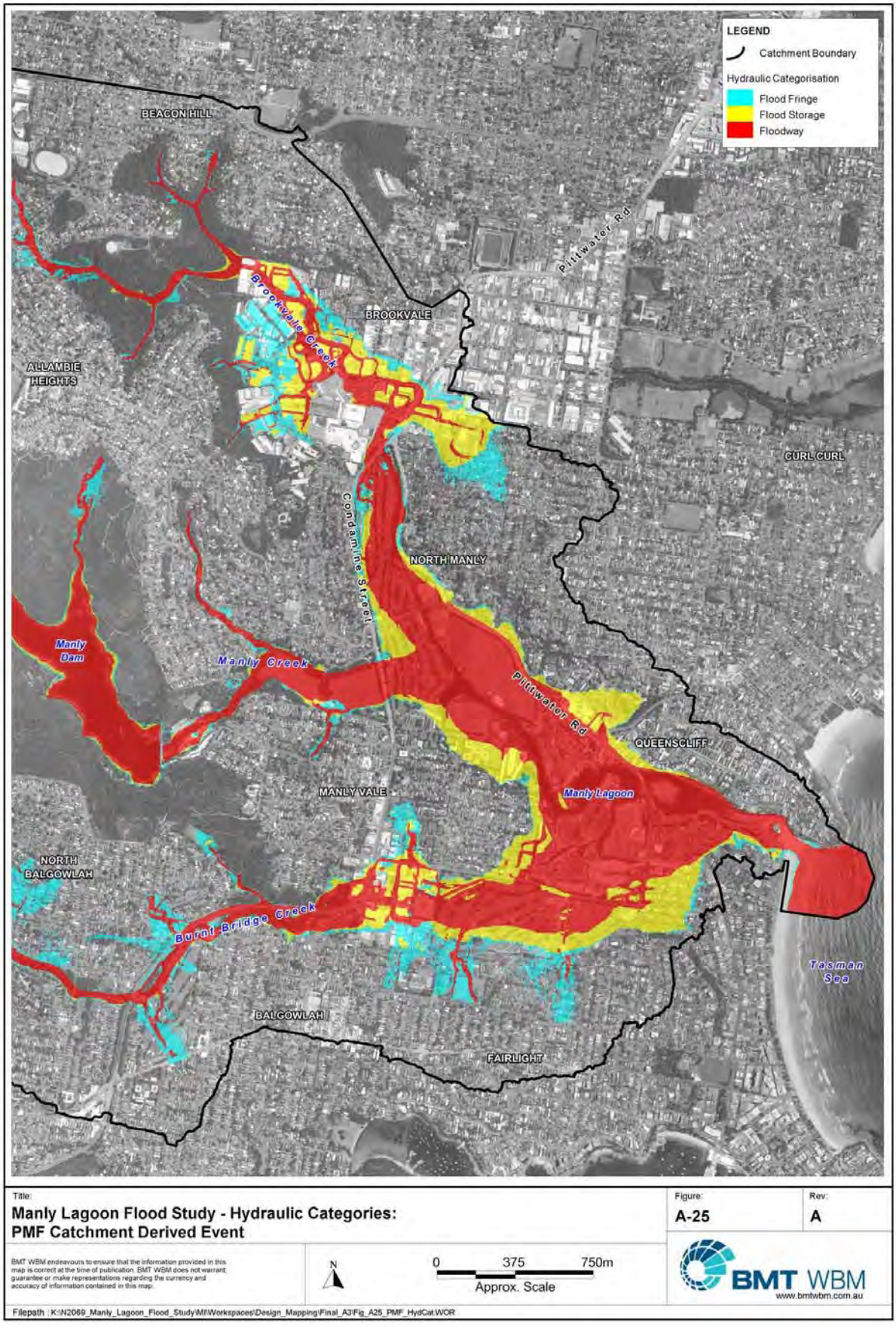
LEGEND
Catchment Boundary
Hydraulic Categorisation
Flood Fringe
Flood Storage
Floodway
BEACON HILL
Pittwater Rd
Brookvale Creek
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
Condamine Street
NORTH MANLY
Manly Dam
Manly Creek
Pittwater Rd
QUEENSCLIFF
MANLY VALE
Manly Lagoon
NORTH BALGOWLAH
Burnt Bridge Creek
Tasman Sea
BALGOWLAH
FAIRLIGHT
Title:
Manly Lagoon Flood Study - Hydraulic Categories:
PMF Catchment Derived Event
Figure:
A-25
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
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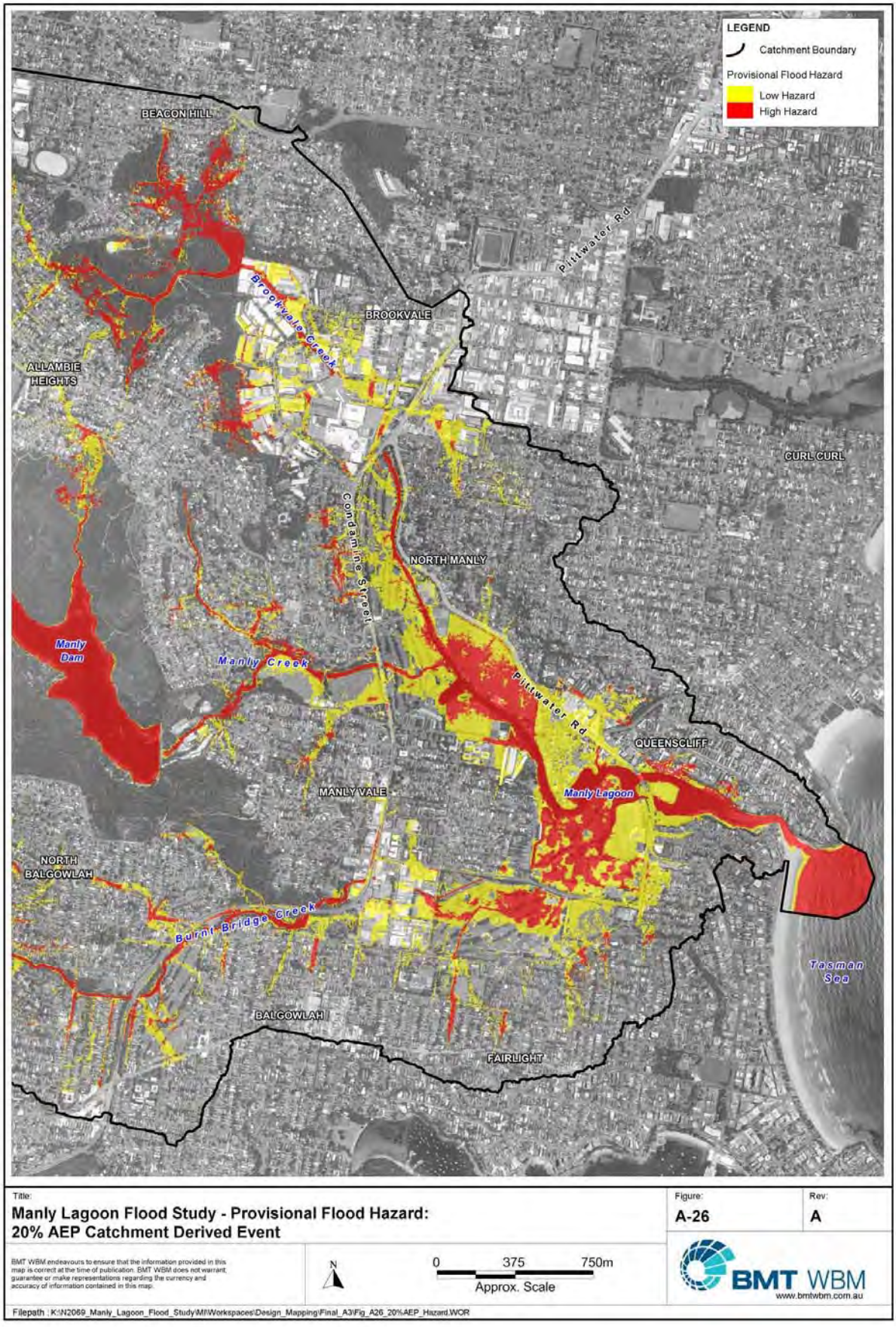
LEGEND
Catchment Boundary
Provisional Flood Hazard
Low Hazard
High Hazard
BEACON HILL
ALLAMBIE HEIGHTS
BROOKVALE
Brookvale Creek
Pittwater Rd
CURL CURL
Condamine Street
NORTH MANLY
Manly Dam
Manly Creek
Pittwater Rd
QUEENSCLIFF
MANLY VALE
Manly Lagoon
NORTH BALGOWLAH
Burnt Bridge Creek
Tasman Sea
BALGOWLAH
FAIRLIGHT
Title:
Manly Lagoon Flood Study - Provisional Flood Hazard:
20% AEP Catchment Derived Event
Figure:
A-26
Rev:
A
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Approx. Scale
BMT WBM
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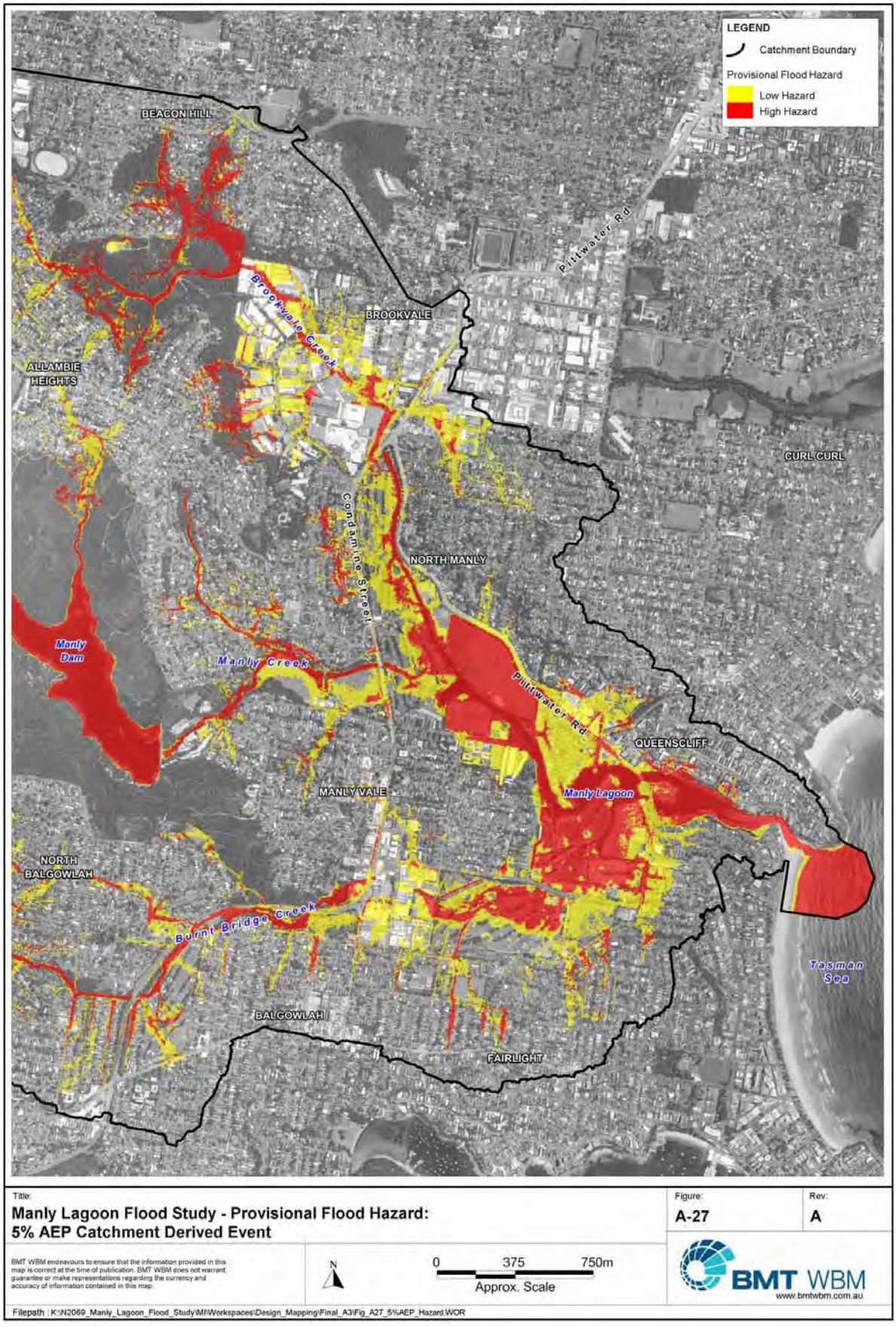
LEGEND
Catchment Boundary
Provisional Flood Hazard
Low Hazard
High Hazard
BEACON HILL
ALLAMBIE HEIGHTS
BROOKVALE
Brookvale Creek
Pittwater Rd
CURL CURL
Condamine Street
NORTH MANLY
Manly Dam
Manly Creek
QUEENSCLIFF
MANLY VALE
Manly Lagoon
NORTH BALGOWLAH
Burnt Bridge Creek
Tasman Sea
BALGOWLAH
FAIRLIGHT
Title:
Manly Lagoon Flood Study - Provisional Flood Hazard:
5% AEP Catchment Derived Event
Figure:
A-27
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
N
0
375
750m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
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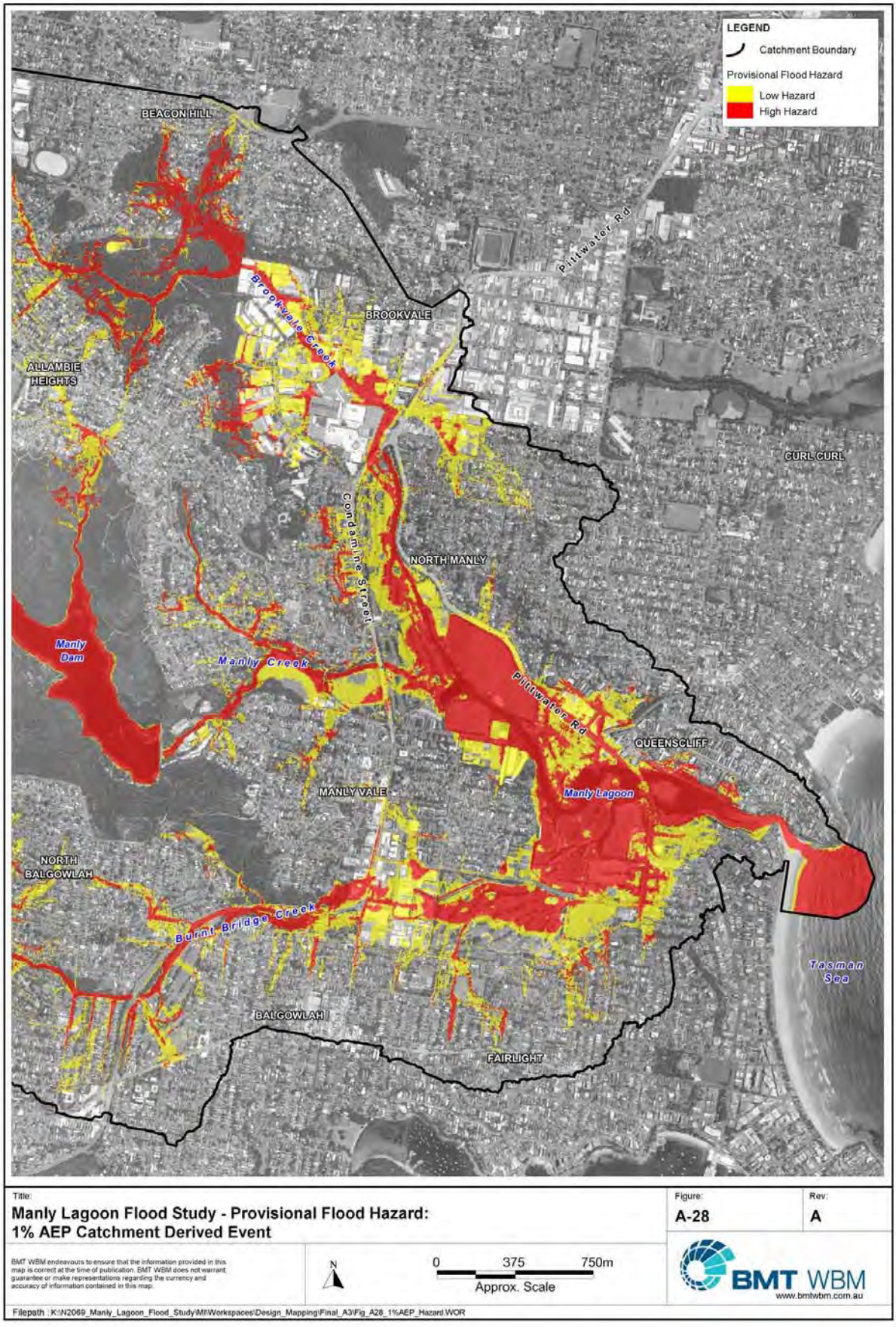
LEGEND
Catchment Boundary
Provisional Flood Hazard
Low Hazard
High Hazard
BEACON HILL
ALLAMBIE HEIGHTS
BROOKVALE
Brookvale Creek
Pittwater Rd
CURL CURL
Condamine Street
NORTH MANLY
Manly Dam
Manly Creek
Pittwater Rd
QUEENSCLIFF
MANLY VALE
Manly Lagoon
NORTH BALGOWLAH
Burnt Bridge Creek
Tasman Sea
BALGOWLAH
FAIRLIGHT
Title:
Manly Lagoon Flood Study - Provisional Flood Hazard:
1% AEP Catchment Derived Event
Figure:
A-28
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
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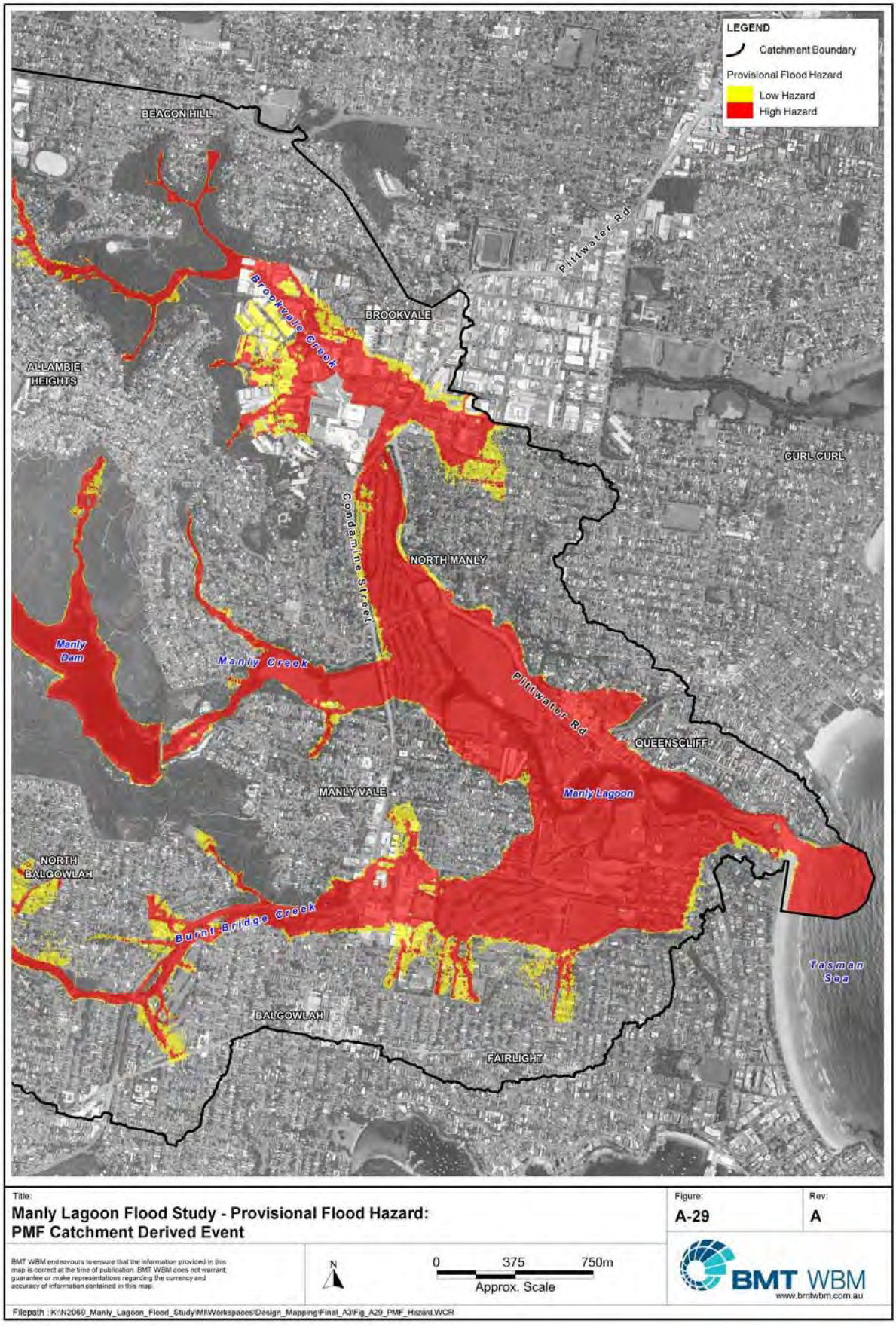
750m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
Filepath : K:\N2069_Manly_Lagoon_Flood_Study\MI\Workspaces\Design_Mapping\Final_A3\Fig_A28_1%AEP_Hazard.WOR


LEGEND
Catchment Boundary
Provisional Flood Hazard
Low Hazard
High Hazard
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
MANLY VALE
QUEENSCLIFF
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Pittwater Rd
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Provisional Flood Hazard:
PMF Catchment Derived Event
Figure:
A-29
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
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750m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
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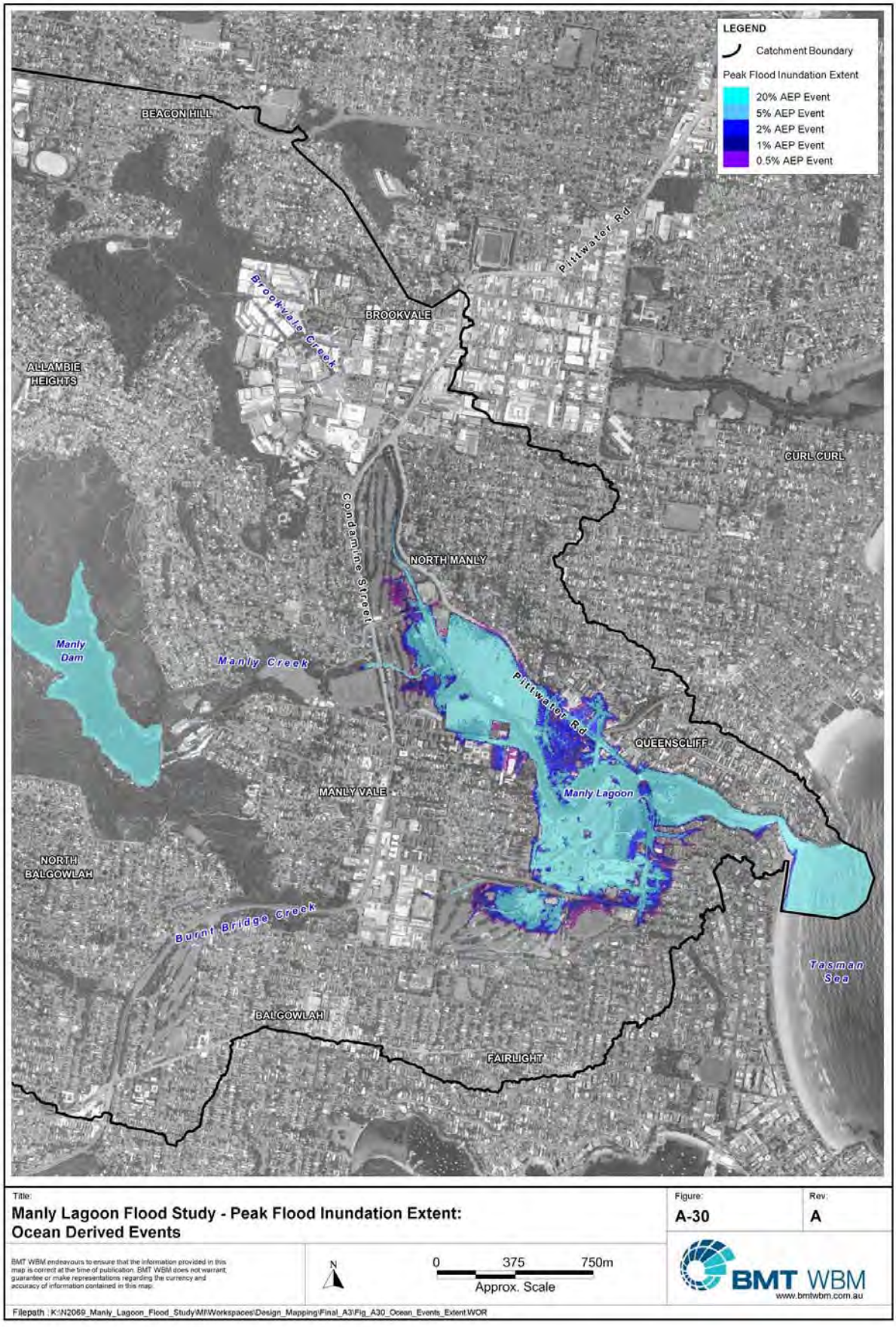
LEGEND
Catchment Boundary
Peak Flood Inundation Extent
20% AEP Event
5% AEP Event
2% AEP Event
1% AEP Event
0.5% AEP Event
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
QUEENSCLIFF
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Brookvale Creek
Condamine Street
Pittwater Rd
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Peak Flood Inundation Extent: Ocean Derived Events
Figure: A-30
Rev: A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
N
0 375 750m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
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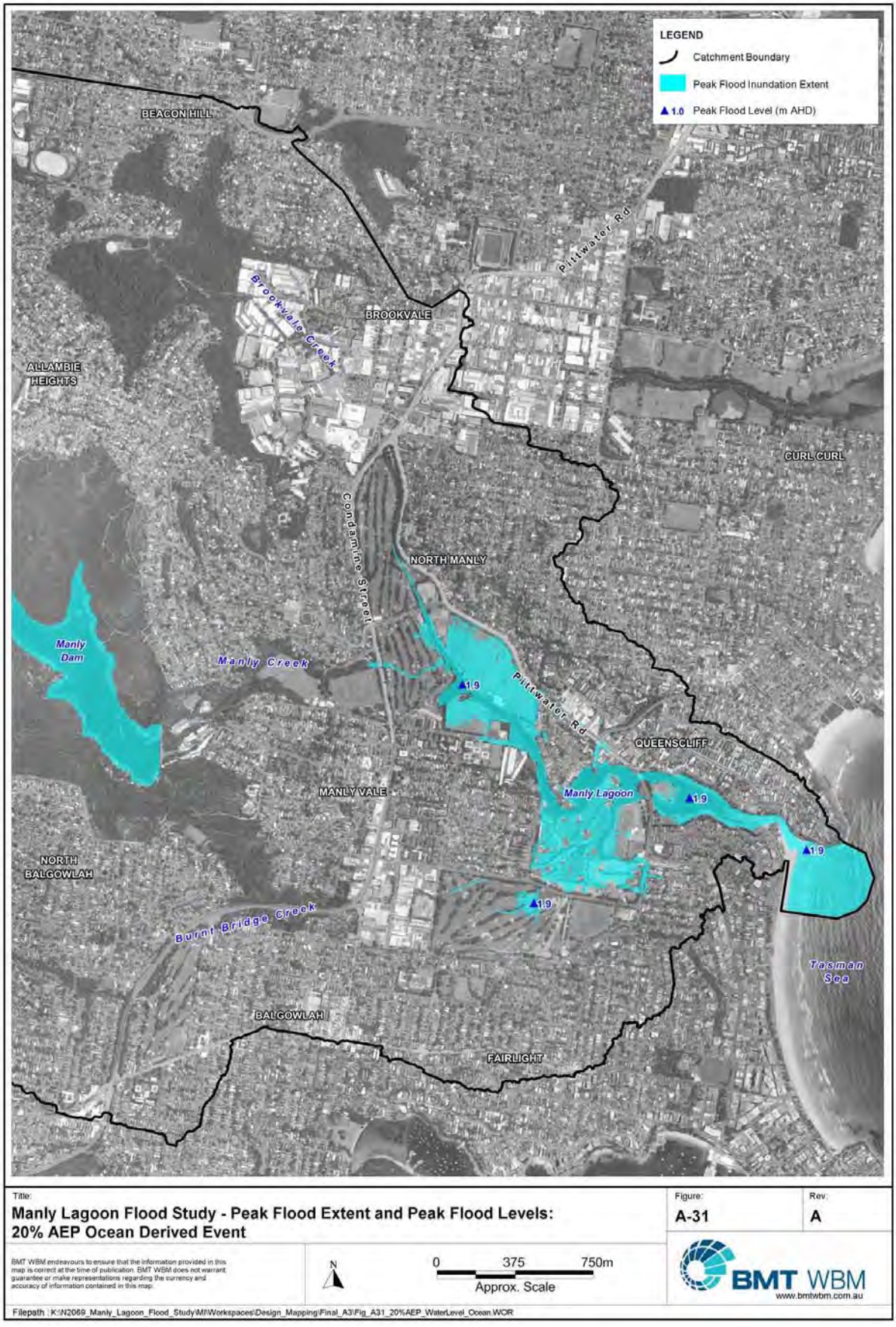
LEGEND
Catchment Boundary
Peak Flood Inundation Extent
▲1.0 Peak Flood Level (m AHD)
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
Brookvale Creek
Pittwater Rd
CURL CURL
Condamine Street
NORTH MANLY
Manly Dam
Manly Creek
▲1.9
QUEENSCLIFF
MANLY VALE
Manly Lagoon
NORTH BALGOWLAH
Burnt Bridge Creek
Tasman Sea
BALGOWLAH
FAIRLIGHT
Title:
Manly Lagoon Flood Study - Peak Flood Extent and Peak Flood Levels:
20% AEP Ocean Derived Event
Figure:
A-31
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
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750m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
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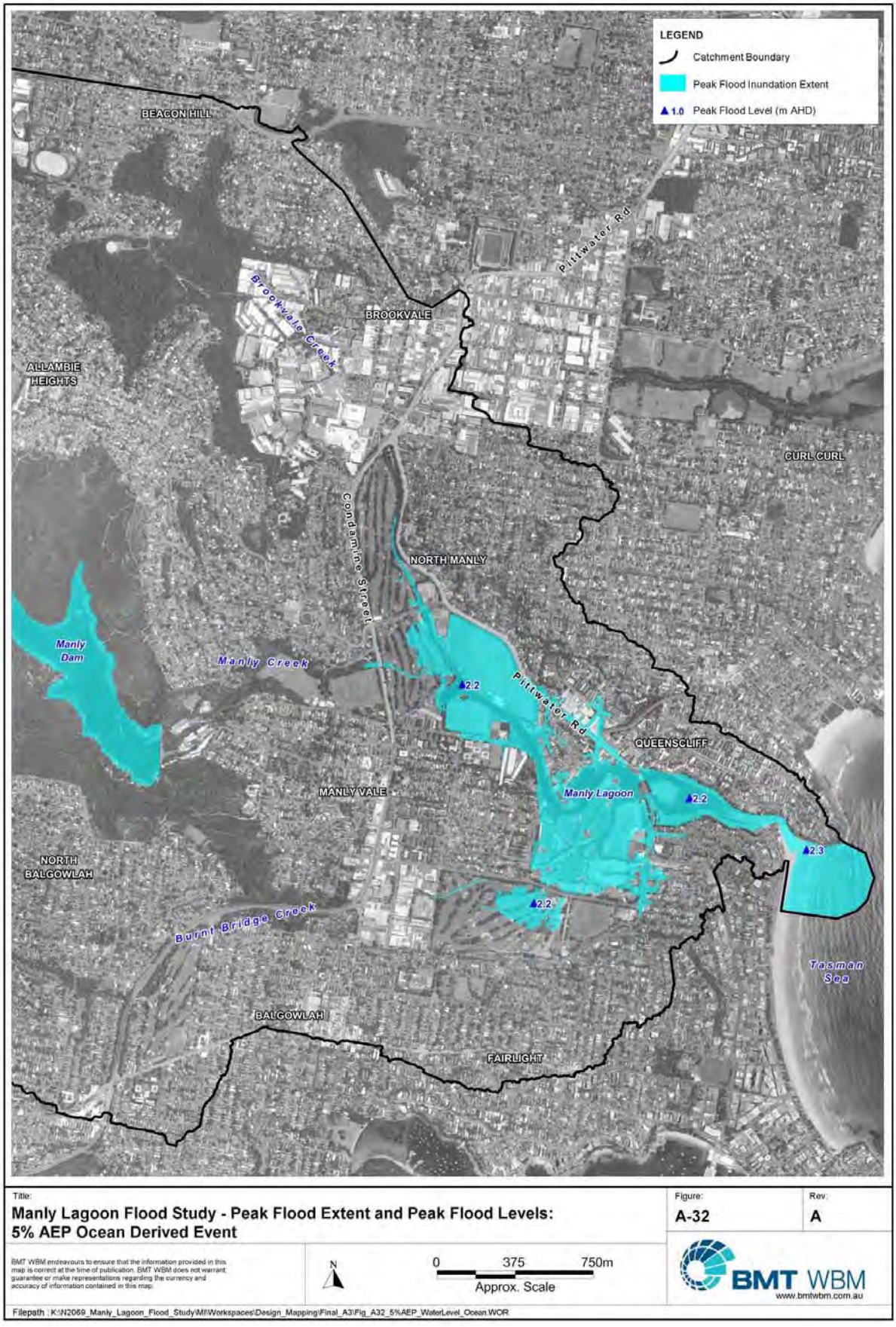
LEGEND
Catchment Boundary
Peak Flood Inundation Extent
▲1.0 Peak Flood Level (m AHD)
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
Brookvale Creek
Pittwater Rd
CURL CURL
Condamine Street
NORTH MANLY
Manly Dam
Manly Creek
▲2.2
QUEENSCLIFF
MANLY VALE
Manly Lagoon
▲2.3
NORTH BALGOWLAH
Burnt Bridge Creek
Tasman Sea
BALGOWLAH
FAIRLIGHT
Title:
Manly Lagoon Flood Study - Peak Flood Extent and Peak Flood Levels:
5% AEP Ocean Derived Event
Figure:
A-32
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
N
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375
750m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
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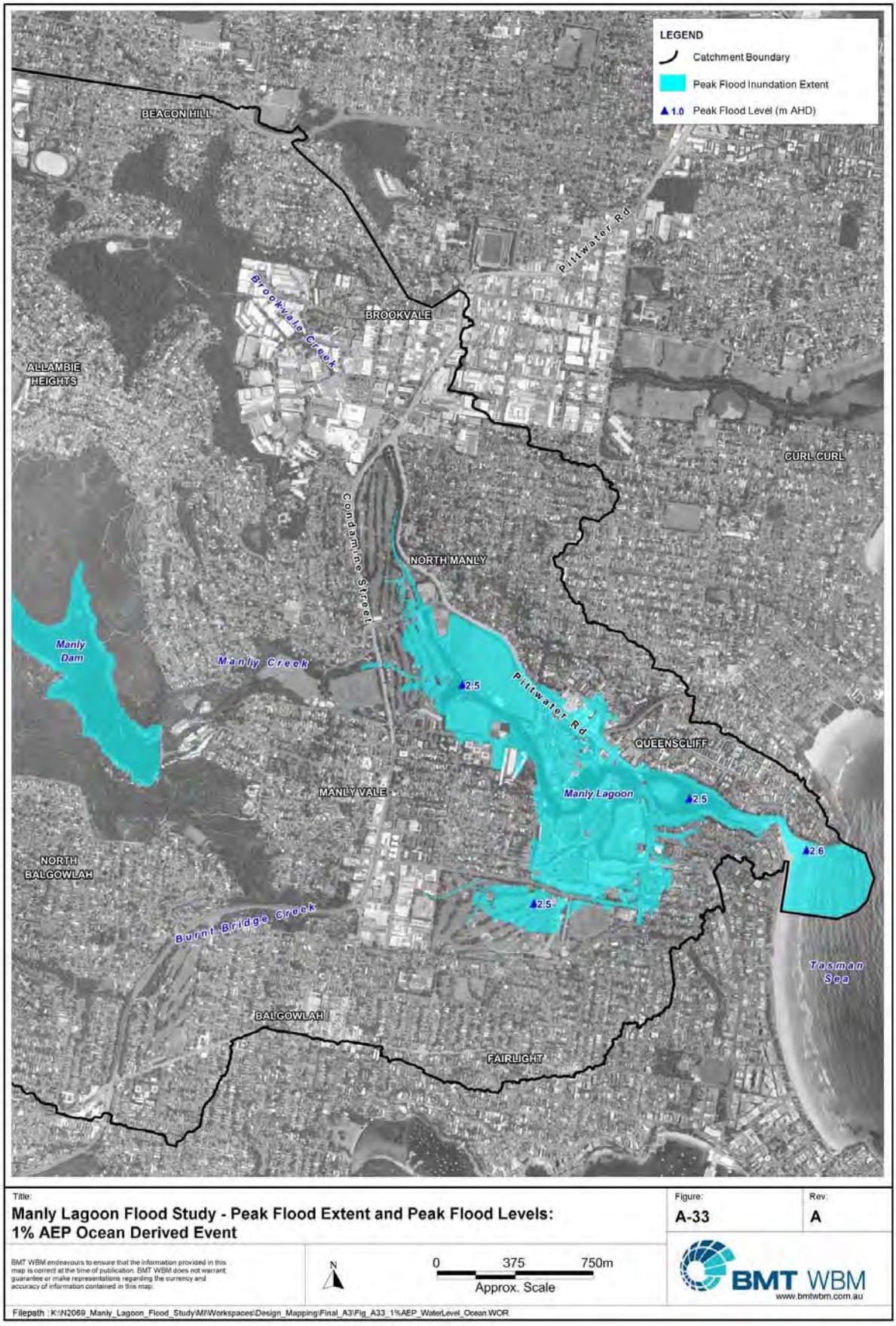
LEGEND
Catchment Boundary
Peak Flood Inundation Extent
▲1.0 Peak Flood Level (m AHD)
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
Brookvale Creek
Pittwater Rd
CURL CURL
Condamine Street
NORTH MANLY
Manly Dam
Manly Creek
▲2.5
QUEENSCLIFF
MANLY VALE
Manly Lagoon
▲2.6
NORTH BALGOWLAH
Burnt Bridge Creek
Tasman Sea
BALGOWLAH
FAIRLIGHT
Title:
Manly Lagoon Flood Study - Peak Flood Extent and Peak Flood Levels:
1% AEP Ocean Derived Event
Figure: A-33
Rev: A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
N
0 375 750m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
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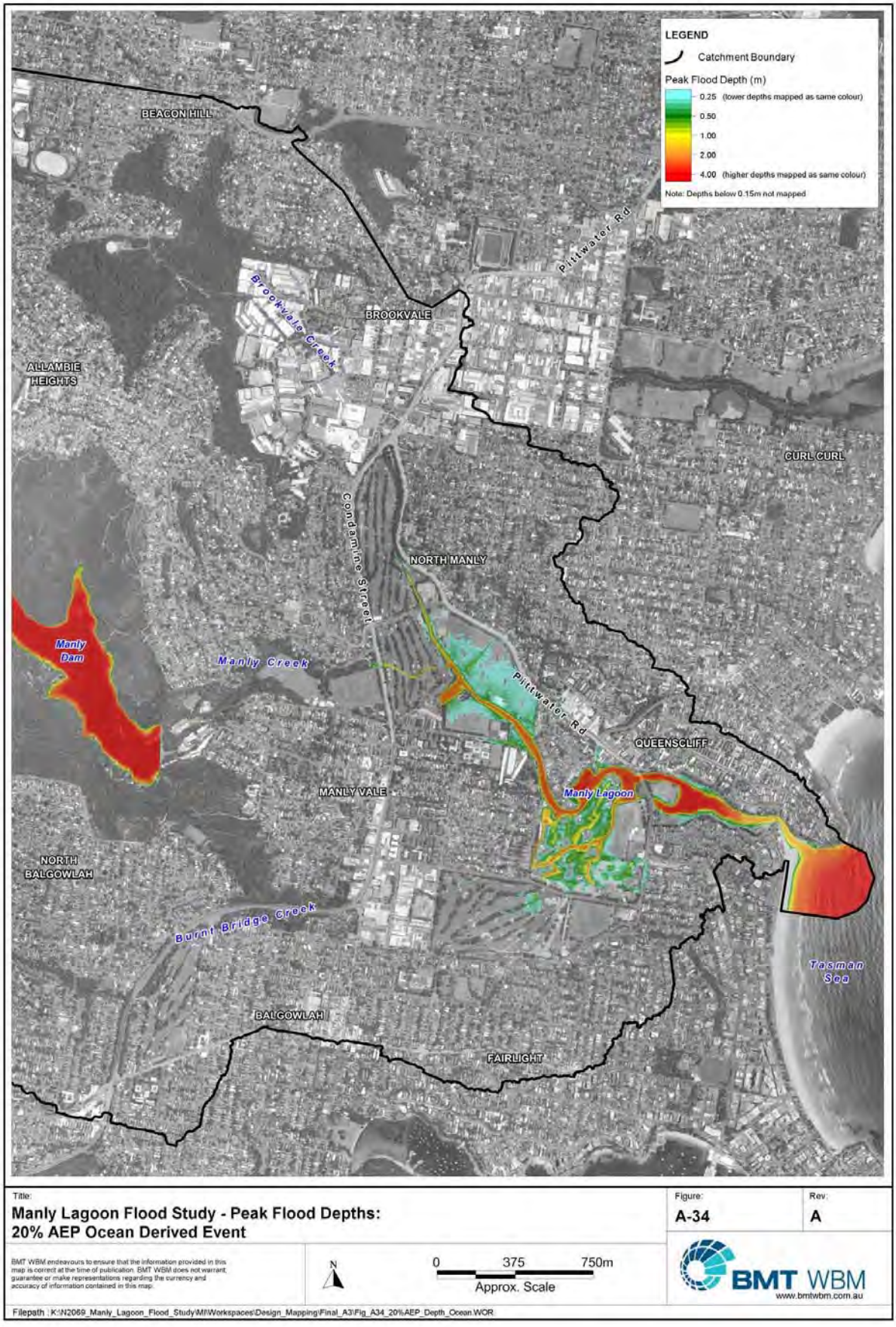
LEGEND
Catchment Boundary
Peak Flood Depth (m)
0.25 (lower depths mapped as same colour)
0.50
1.00
2.00
4.00 (higher depths mapped as same colour)
Note: Depths below 0.15m not mapped
BEACON HILL
BROOKVALE
Brookvale Creek
Pittwater Rd
ALLAMBIE HEIGHTS
CURL CURL
Condamine Street
NORTH MANLY
Manly Dam
Manly Creek
Pittwater Rd
QUEENSCLIFF
MANLY VALE
Manly Lagoon
NORTH BALGOWLAH
Burnt Bridge Creek
Tasman Sea
BALGOWLAH
FAIRLIGHT
Title:
Manly Lagoon Flood Study - Peak Flood Depths:
20% AEP Ocean Derived Event
Figure:
A-34
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
N
0
375
750m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
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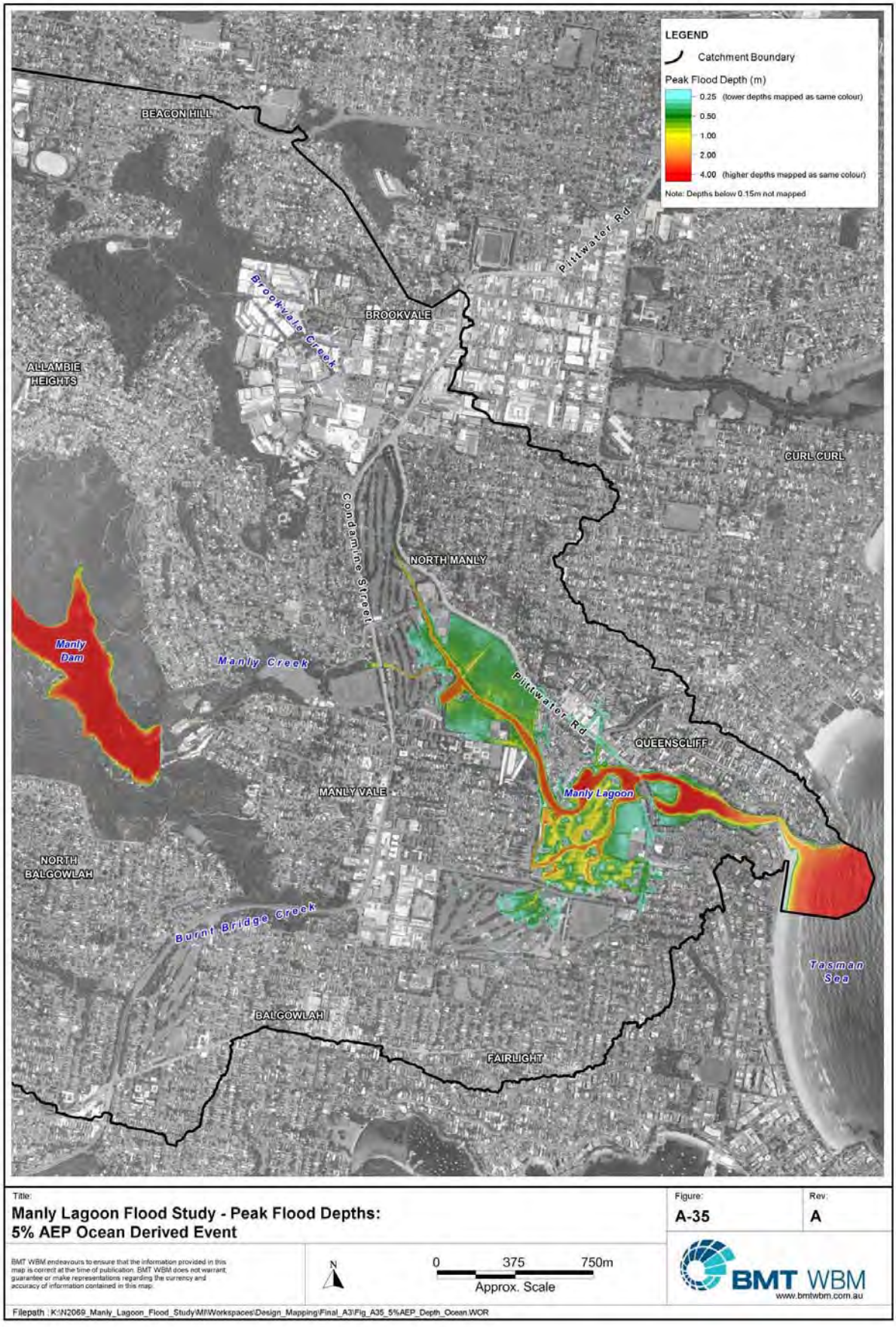
LEGEND
Catchment Boundary
Peak Flood Depth (m)
0.25 (lower depths mapped as same colour)
0.50
1.00
2.00
4.00 (higher depths mapped as same colour)
Note: Depths below 0.15m not mapped
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
QUEENSCLIFF
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Pittwater Rd
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Peak Flood Depths:
5% AEP Ocean Derived Event
Figure:
A-35
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
N
0
375
750m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
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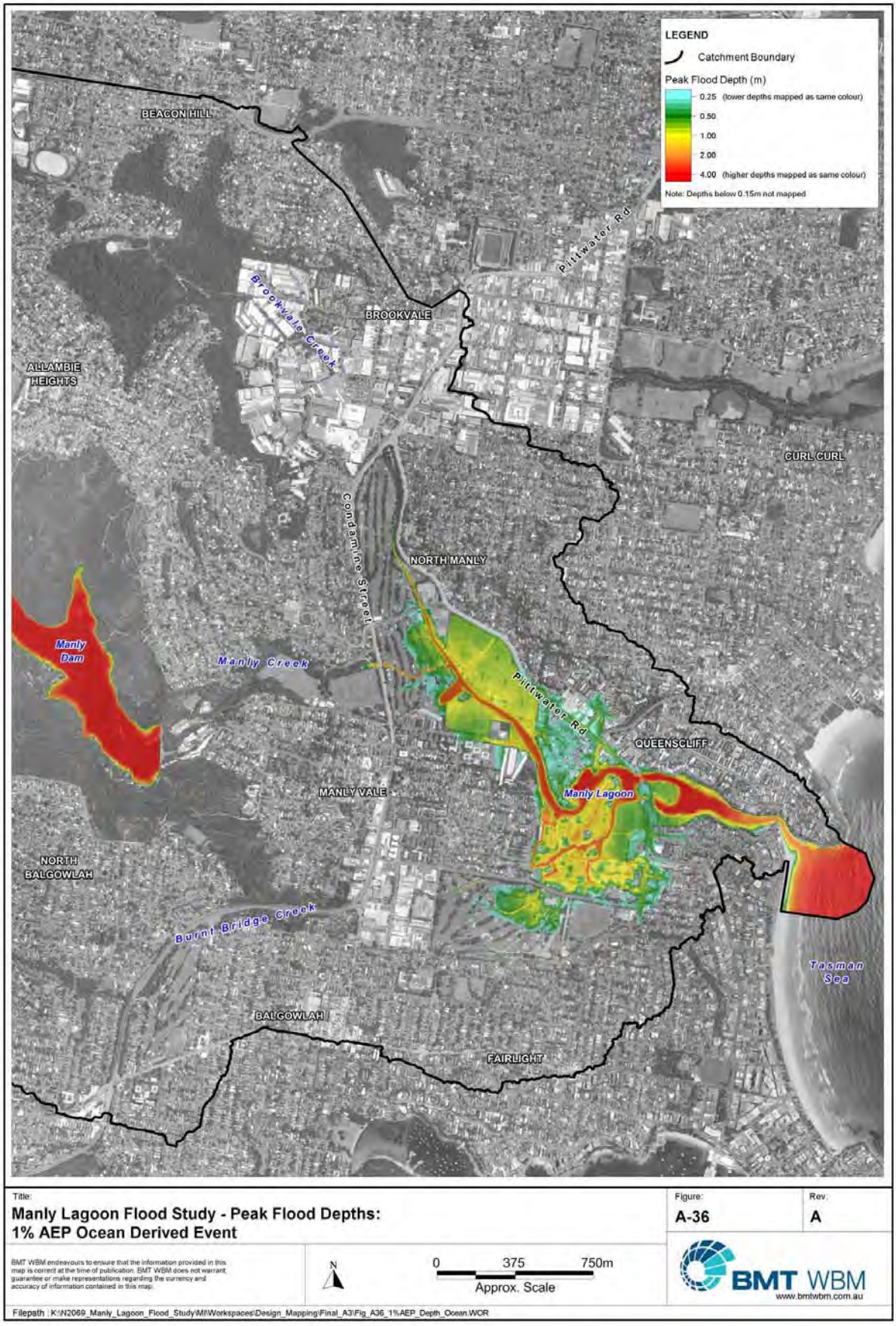
LEGEND
Catchment Boundary
Peak Flood Depth (m)
0.25 (lower depths mapped as same colour)
0.50
1.00
2.00
4.00 (higher depths mapped as same colour)
Note: Depths below 0.15m not mapped
BEACON HILL
BROOKVALE
Brookvale Creek
Pittwater Rd
ALLAMBIE HEIGHTS
CURL CURL
Condamine Street
NORTH MANLY
Manly Dam
Manly Creek
Pittwater Rd
QUEENSCLIFF
MANLY VALE
Manly Lagoon
NORTH BALGOWLAH
Burnt Bridge Creek
Tasman Sea
BALGOWLAH
FAIRLIGHT
Title:
Manly Lagoon Flood Study - Peak Flood Depths:
1% AEP Ocean Derived Event
Figure:
A-36
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
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375
750m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
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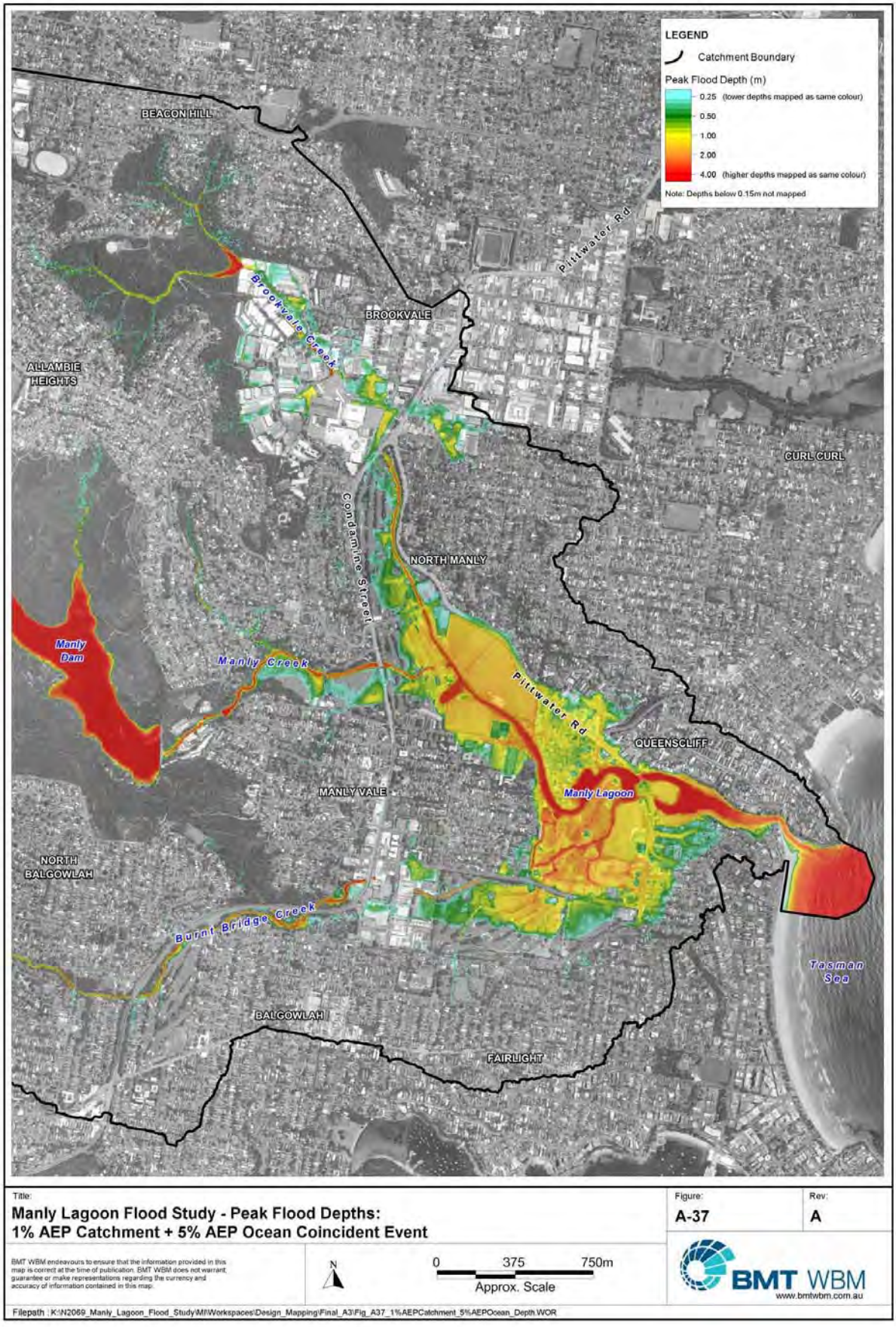
LEGEND
Catchment Boundary
Peak Flood Depth (m)
0.25 (lower depths mapped as same colour)
0.50
1.00
2.00
4.00 (higher depths mapped as same colour)
Note: Depths below 0.15m not mapped
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
QUEENSCLIFF
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Pittwater Rd
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Peak Flood Depths:
1% AEP Catchment + 5% AEP Ocean Coincident Event
Figure:
A-37
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
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375
750m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
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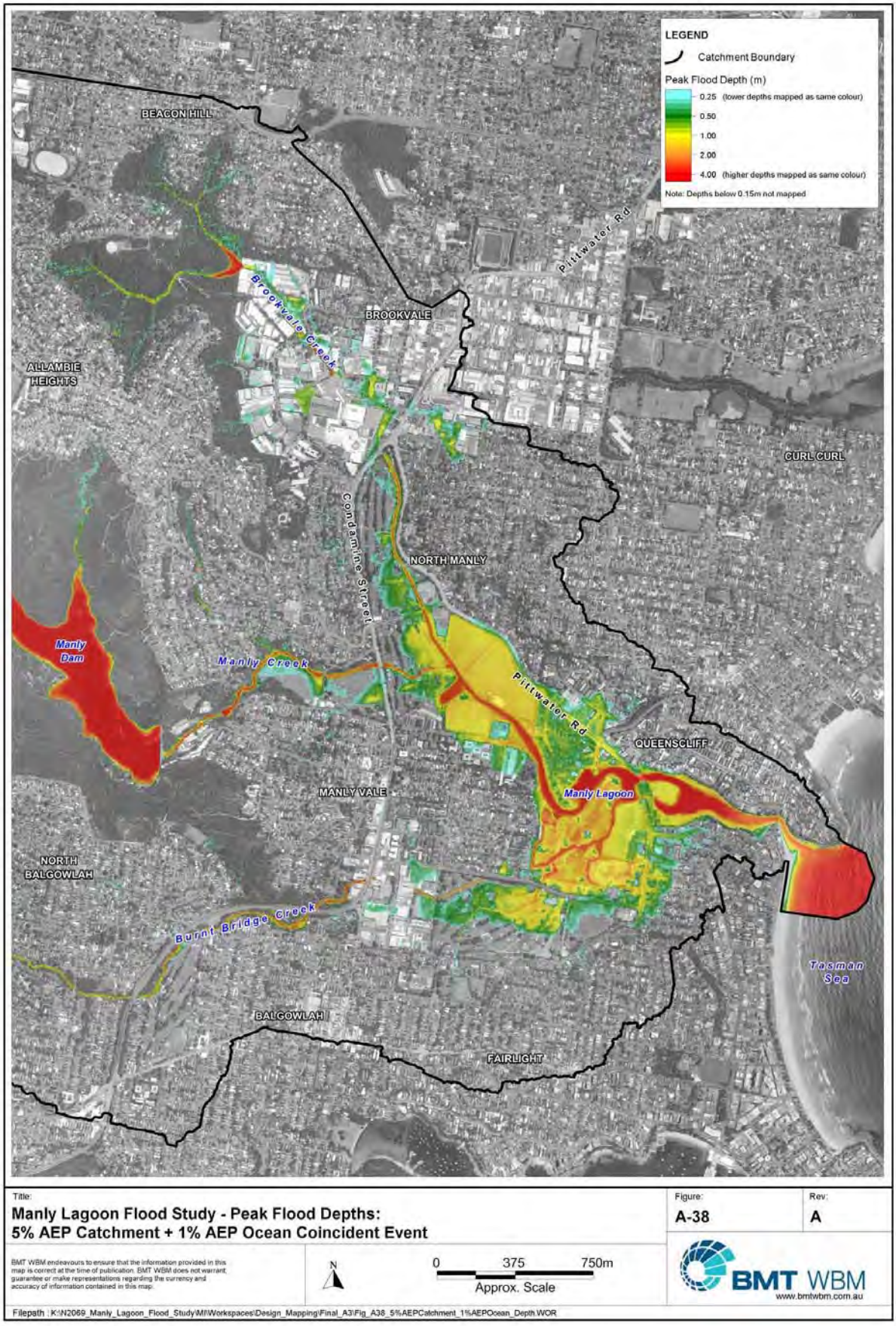
LEGEND
Catchment Boundary
Peak Flood Depth (m)
0.25 (lower depths mapped as same colour)
0.50
1.00
2.00
4.00 (higher depths mapped as same colour)
Note: Depths below 0.15m not mapped
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
QUEENSCLIFF
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Brookvale Creek
Condamine Street
Pittwater Rd
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Peak Flood Depths:
5% AEP Catchment + 1% AEP Ocean Coincident Event
Figure:
A-38
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
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750m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
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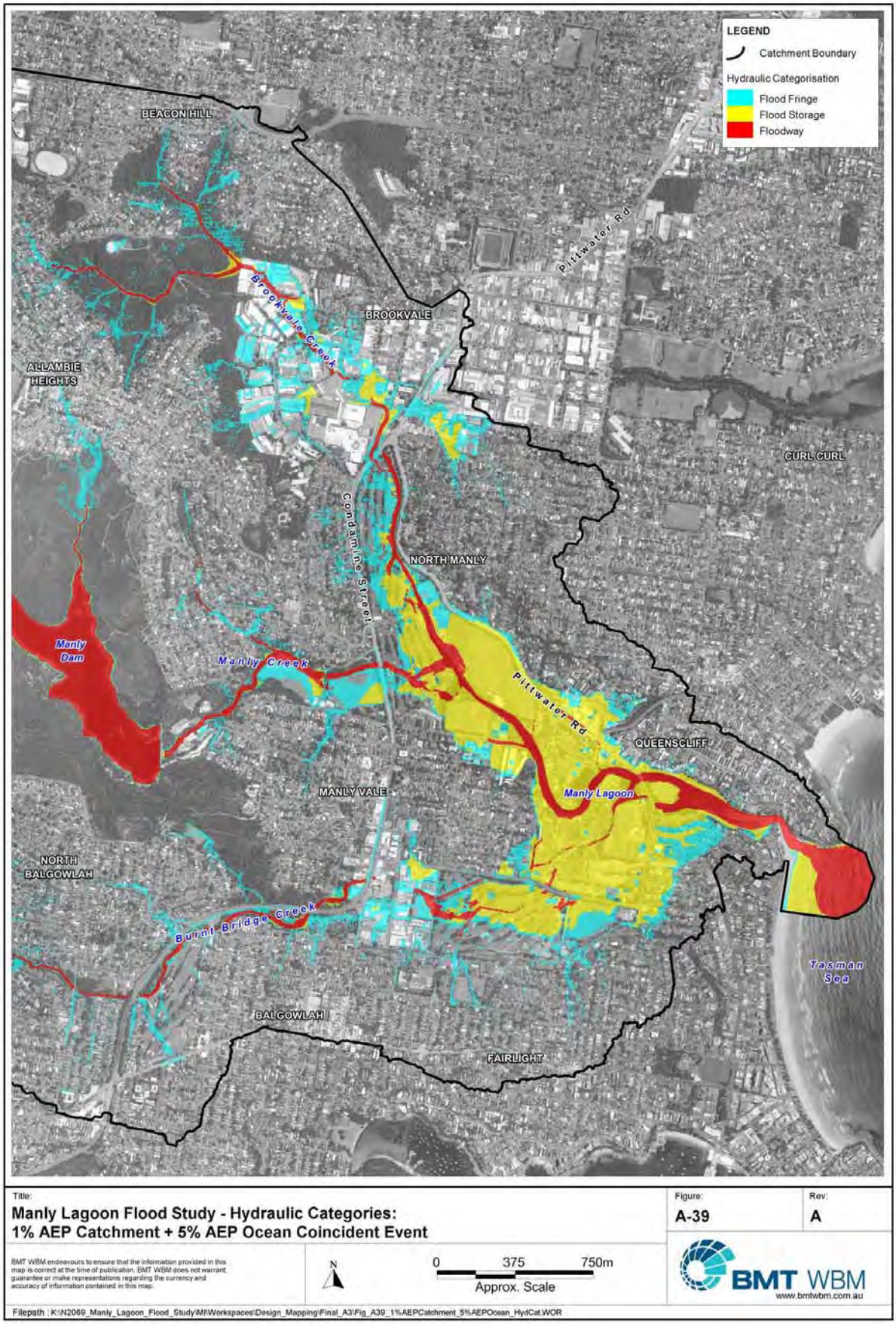
LEGEND
Catchment Boundary
Hydraulic Categorisation
Flood Fringe
Flood Storage
Floodway
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
MANLY VALE
QUEENSCLIFF
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Pittwater Rd
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Hydraulic Categories:
1% AEP Catchment + 5% AEP Ocean Coincident Event
Figure:
A-39
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
N
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750m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
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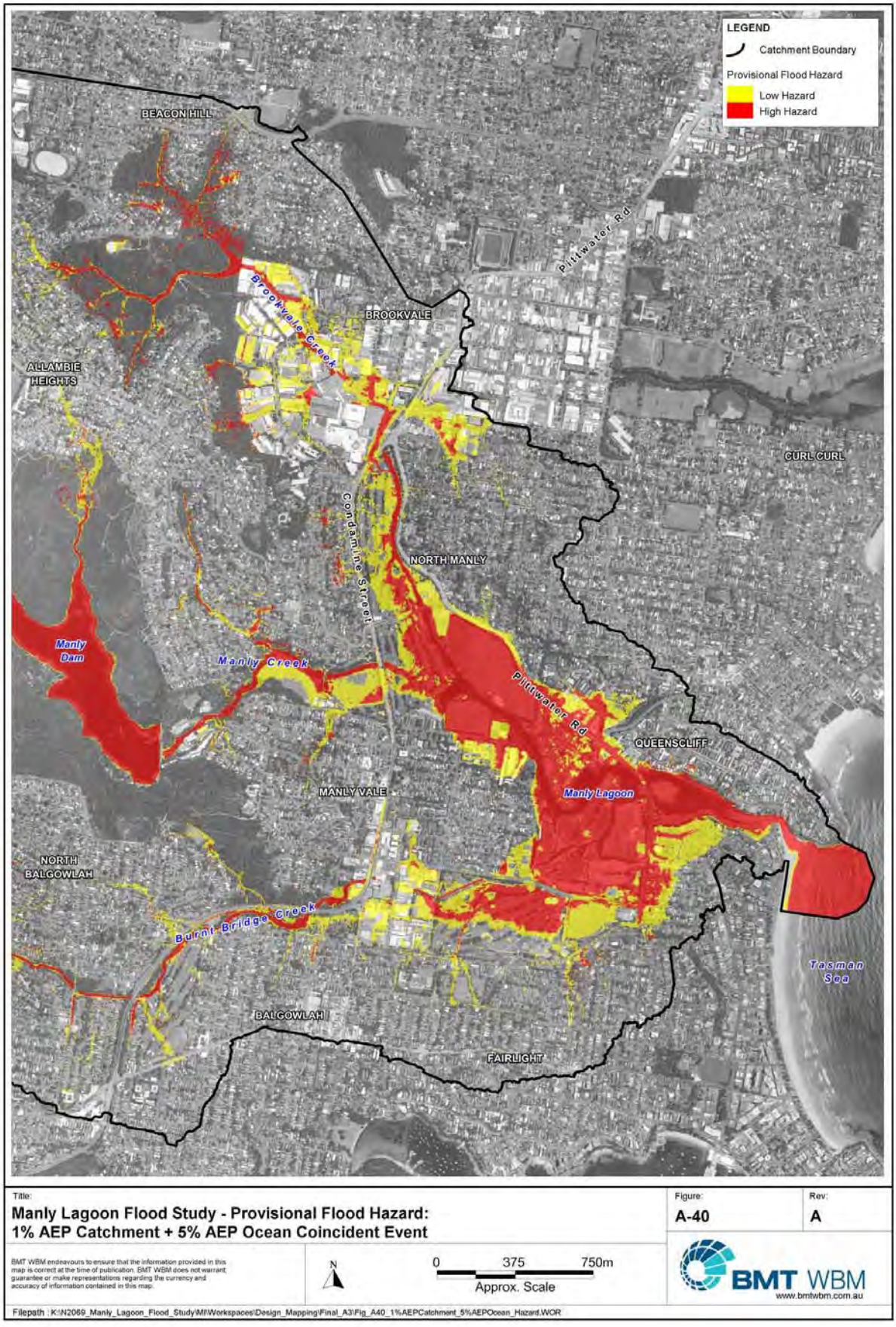
LEGEND
Catchment Boundary
Provisional Flood Hazard
Low Hazard
High Hazard
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
MANLY VALE
QUEENSCLIFF
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Pittwater Rd
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Provisional Flood Hazard:
1% AEP Catchment + 5% AEP Ocean Coincident Event
Figure:
A-40
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
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375
750m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
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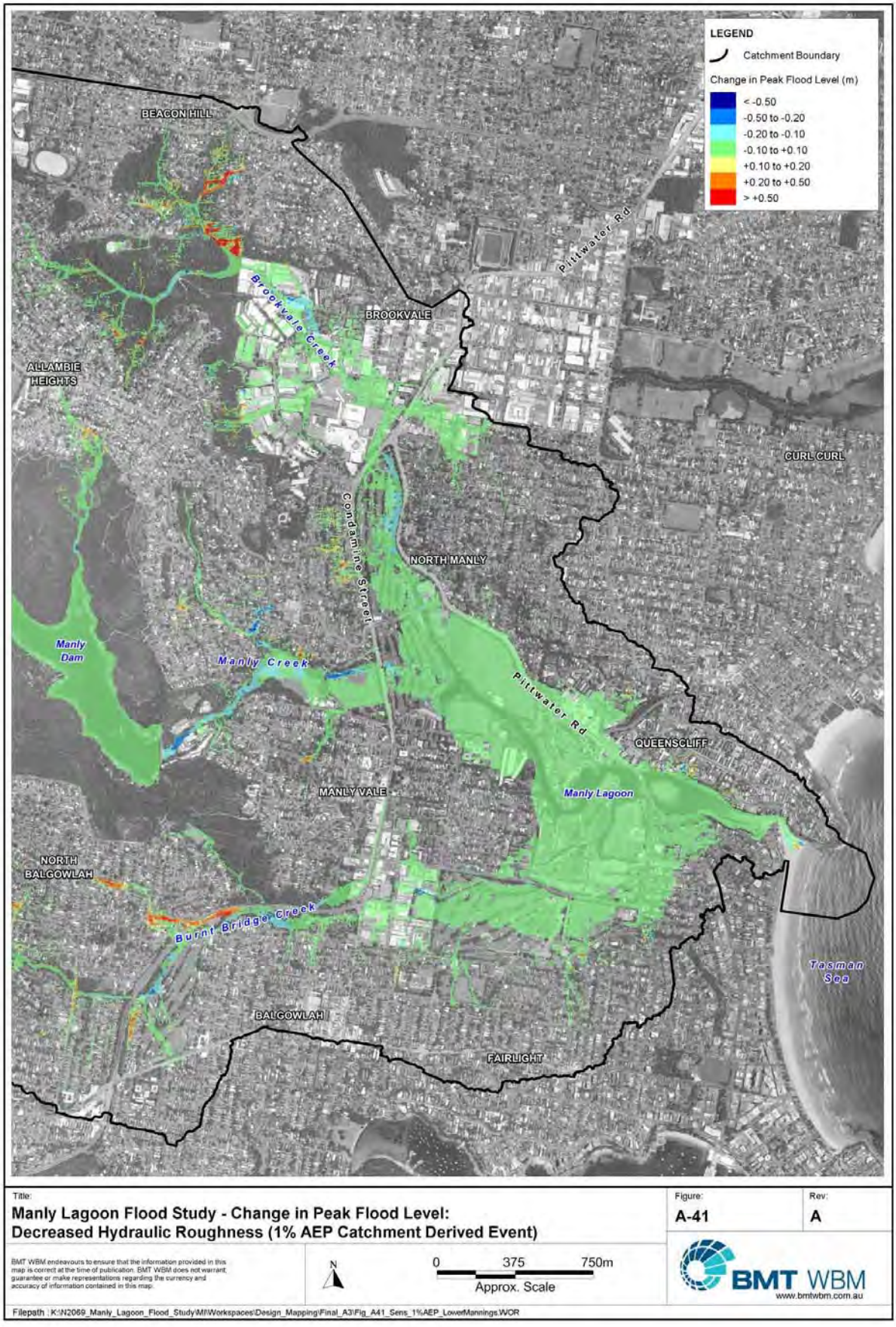
LEGEND
Catchment Boundary
Change in Peak Flood Level (m)
< -0.50
-0.50 to -0.20
-0.20 to -0.10
-0.10 to +0.10
+0.10 to +0.20
+0.20 to +0.50
> +0.50
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
QUEENSCLIFF
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Pittwater Rd
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Change in Peak Flood Level:
Decreased Hydraulic Roughness (1% AEP Catchment Derived Event)
Figure:
A-41
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
N
0
375
750m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
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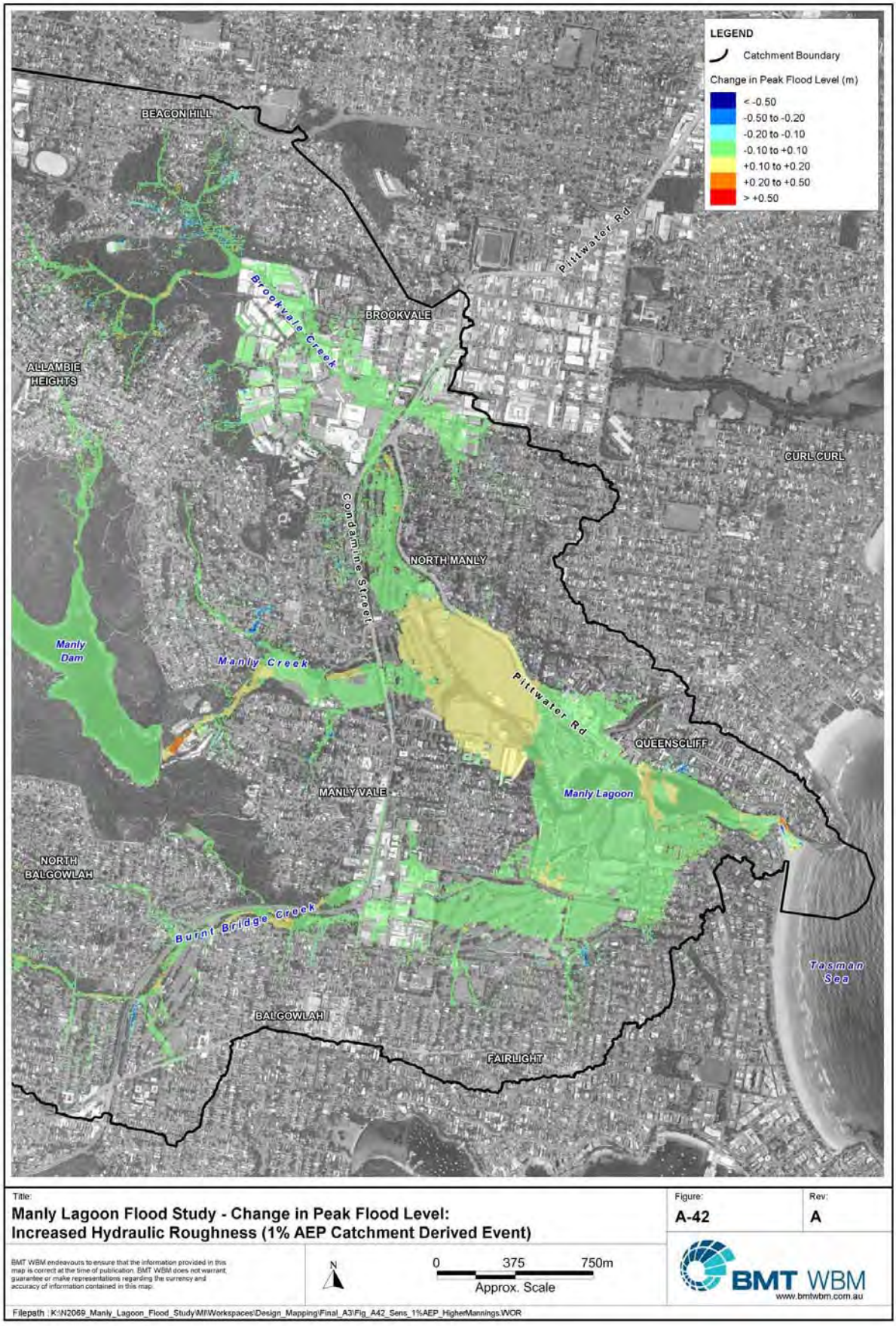
LEGEND
Catchment Boundary
Change in Peak Flood Level (m)
< -0.50
-0.50 to -0.20
-0.20 to -0.10
-0.10 to +0.10
+0.10 to +0.20
+0.20 to +0.50
> +0.50
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
MANLY VALE
QUEENSCLIFF
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Pittwater Rd
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Change in Peak Flood Level:
Increased Hydraulic Roughness (1% AEP Catchment Derived Event)
Figure:
A-42
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
N
0
375
750m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
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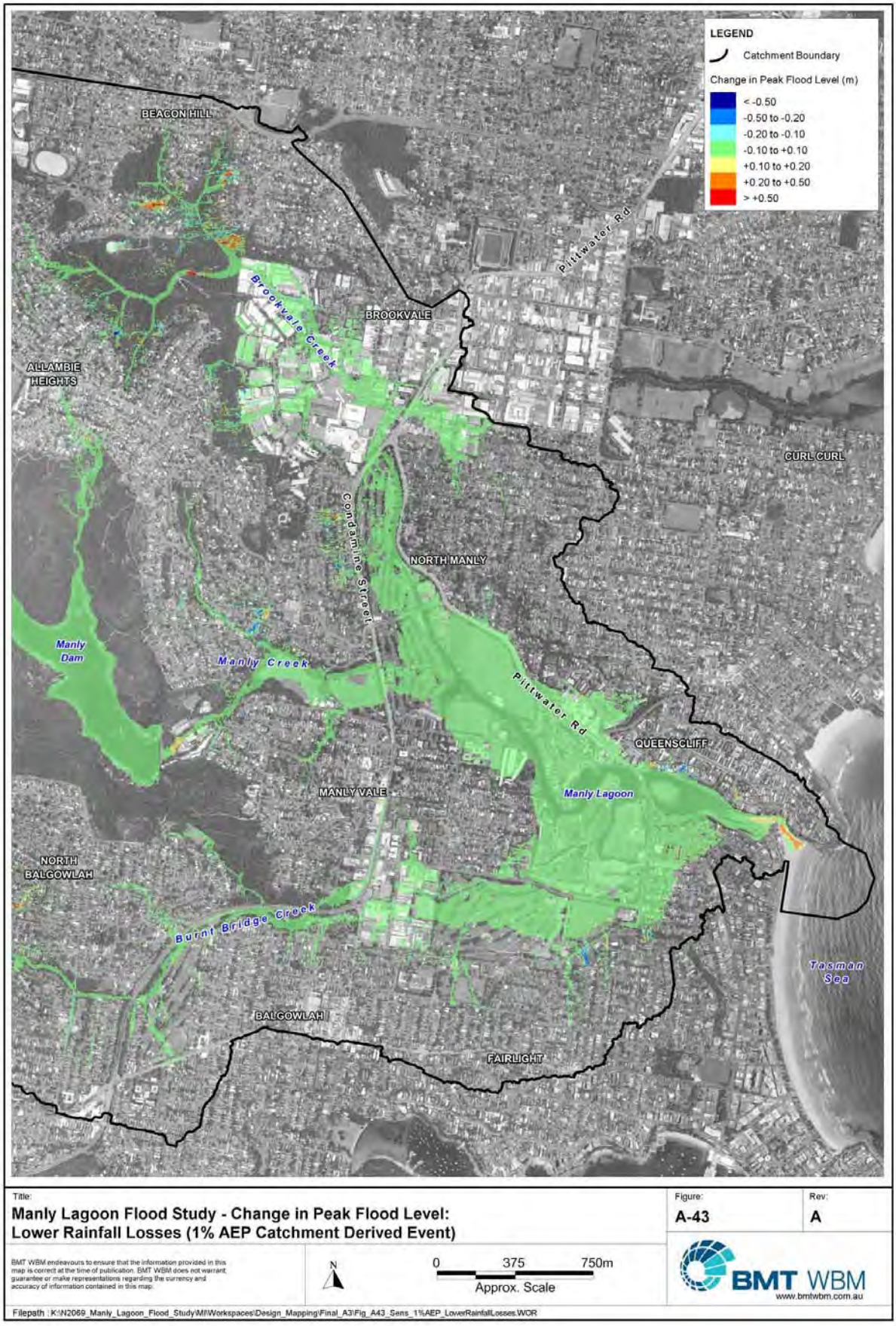
LEGEND
Catchment Boundary
Change in Peak Flood Level (m)
< -0.50
-0.50 to -0.20
-0.20 to -0.10
-0.10 to +0.10
+0.10 to +0.20
+0.20 to +0.50
> +0.50
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
QUEENSCLIFF
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Pittwater Rd
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Change in Peak Flood Level:
Lower Rainfall Losses (1% AEP Catchment Derived Event)
Figure:
A-43
Rev:
A
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Approx. Scale
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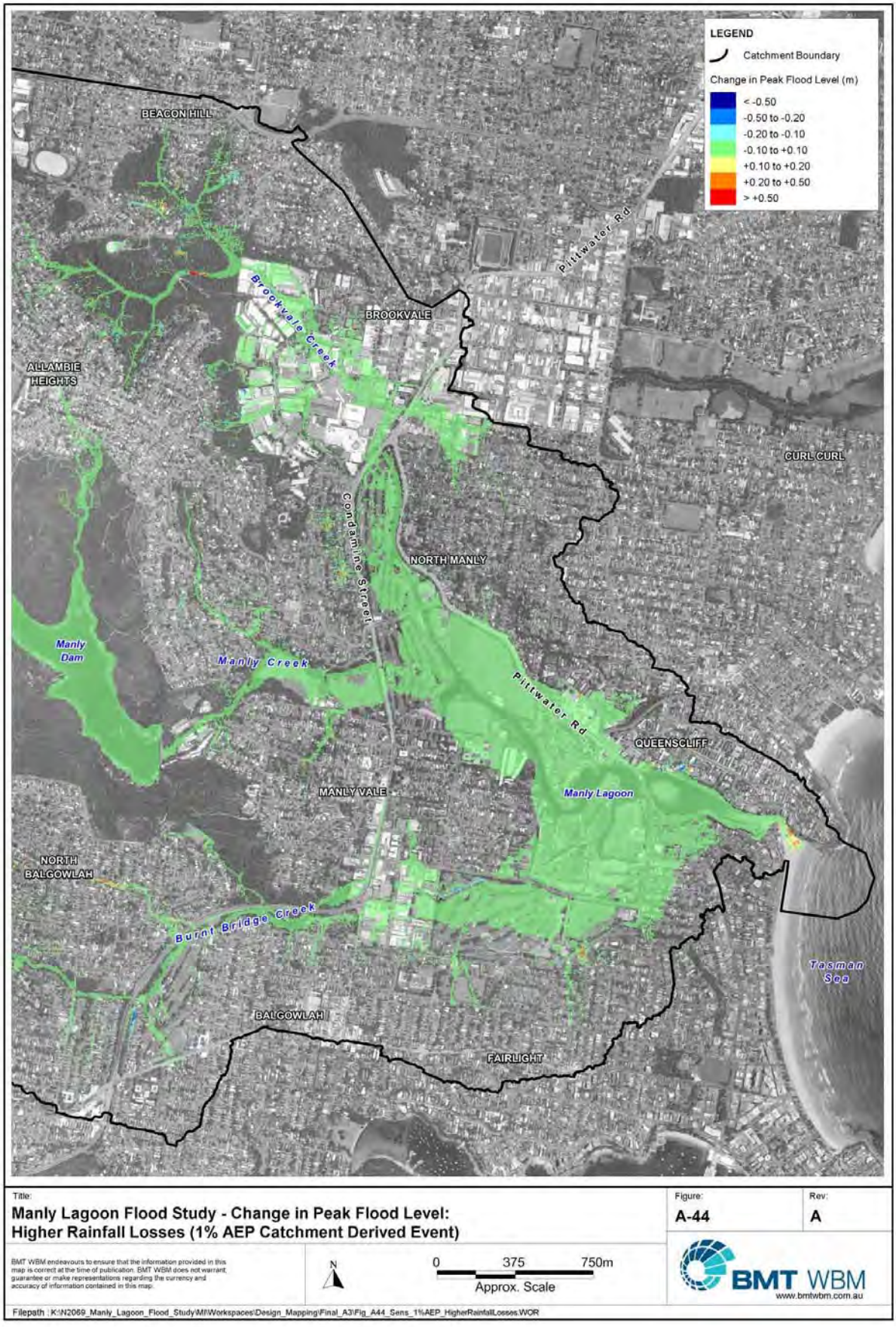
LEGEND
Catchment Boundary
Change in Peak Flood Level (m)
< -0.50
-0.50 to -0.20
-0.20 to -0.10
-0.10 to +0.10
+0.10 to +0.20
+0.20 to +0.50
> +0.50
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
QUEENSCLIFF
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Pittwater Rd
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Change in Peak Flood Level:
Higher Rainfall Losses (1% AEP Catchment Derived Event)
Figure:
A-44
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
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750m
Approx. Scale
BMT WBM
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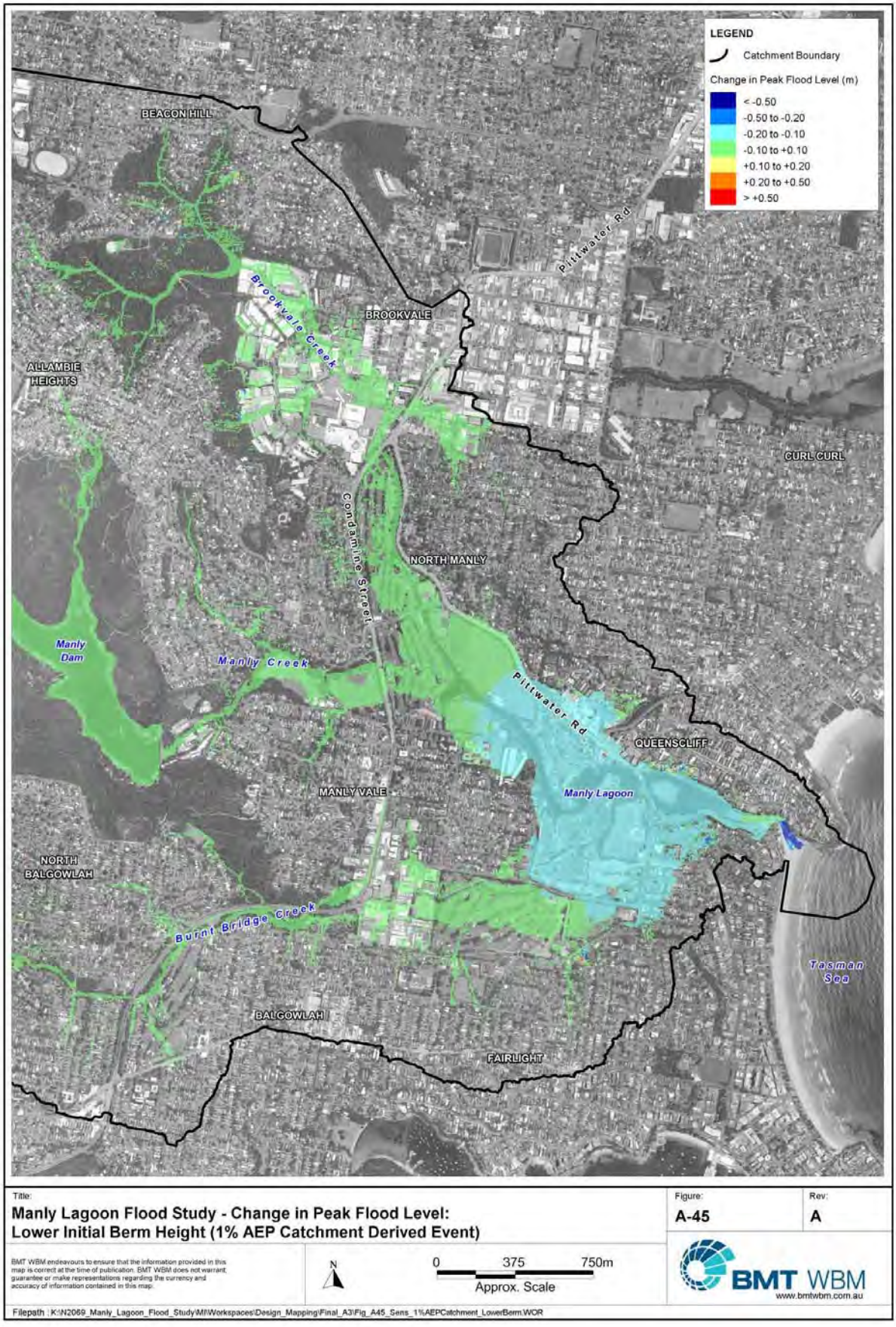
LEGEND
Catchment Boundary
Change in Peak Flood Level (m)
< -0.50
-0.50 to -0.20
-0.20 to -0.10
-0.10 to +0.10
+0.10 to +0.20
+0.20 to +0.50
> +0.50
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
MANLY VALE
QUEENSCLIFF
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Pittwater Rd
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Change in Peak Flood Level:
Lower Initial Berm Height (1% AEP Catchment Derived Event)
Figure:
A-45
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
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Approx. Scale
BMT WBM
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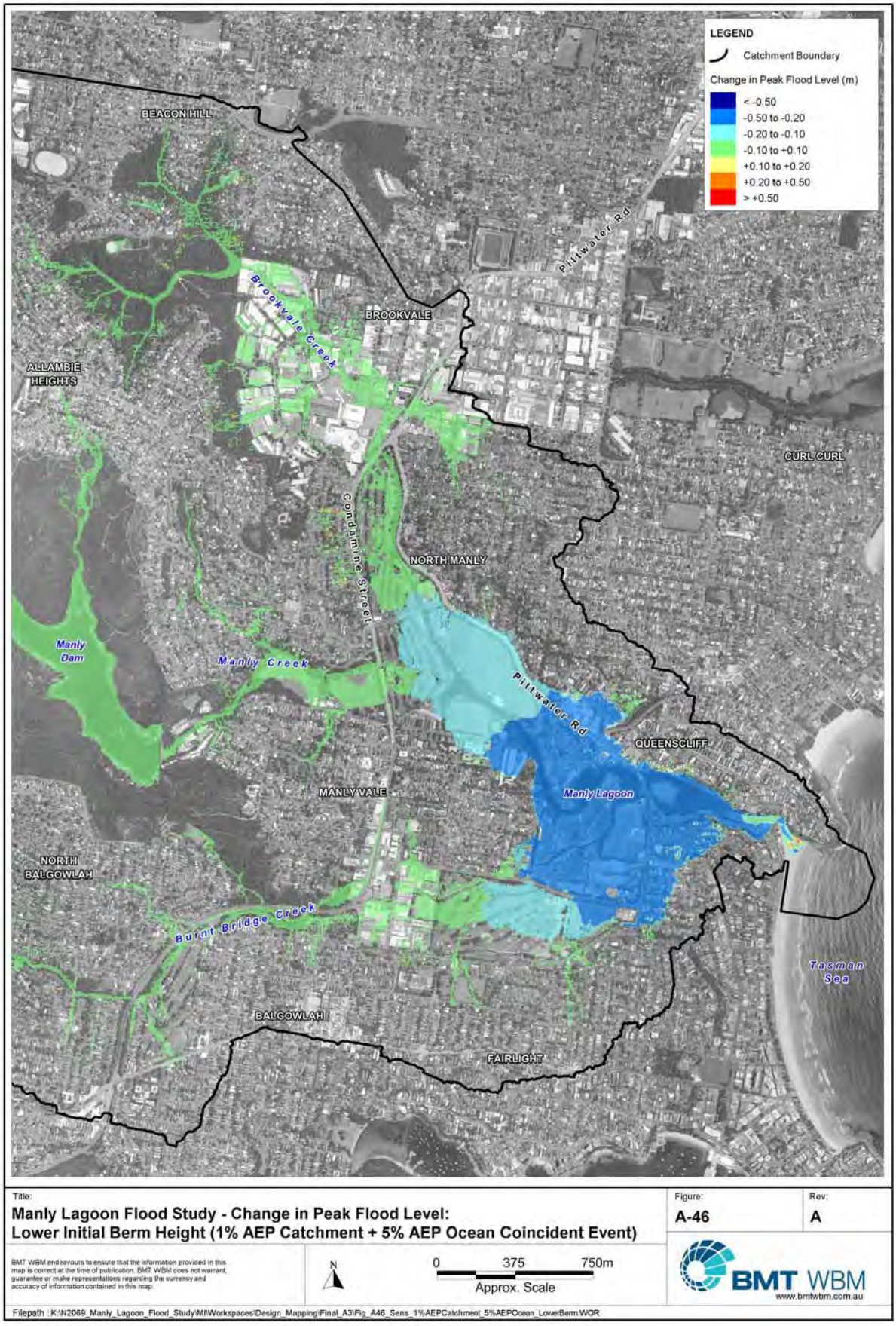
LEGEND
Catchment Boundary
Change in Peak Flood Level (m)
< -0.50
-0.50 to -0.20
-0.20 to -0.10
-0.10 to +0.10
+0.10 to +0.20
+0.20 to +0.50
> +0.50
BEACON HILL
Pittwater Rd
Brookvale Creek
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
Condamine Street
NORTH MANLY
Manly Dam
Manly Creek
Pittwater Rd
QUEENSCLIFF
Manly Lagoon
MANLY VALE
NORTH BALGOWLAH
Burnt Bridge Creek
Tasman Sea
BALGOWLAH
FAIRLIGHT
Title:
Manly Lagoon Flood Study - Change in Peak Flood Level:
Lower Initial Berm Height (1% AEP Catchment + 5% AEP Ocean Coincident Event)
Figure:
A-46
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
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Approx. Scale
BMT WBM
www.bmtwbm.com.au
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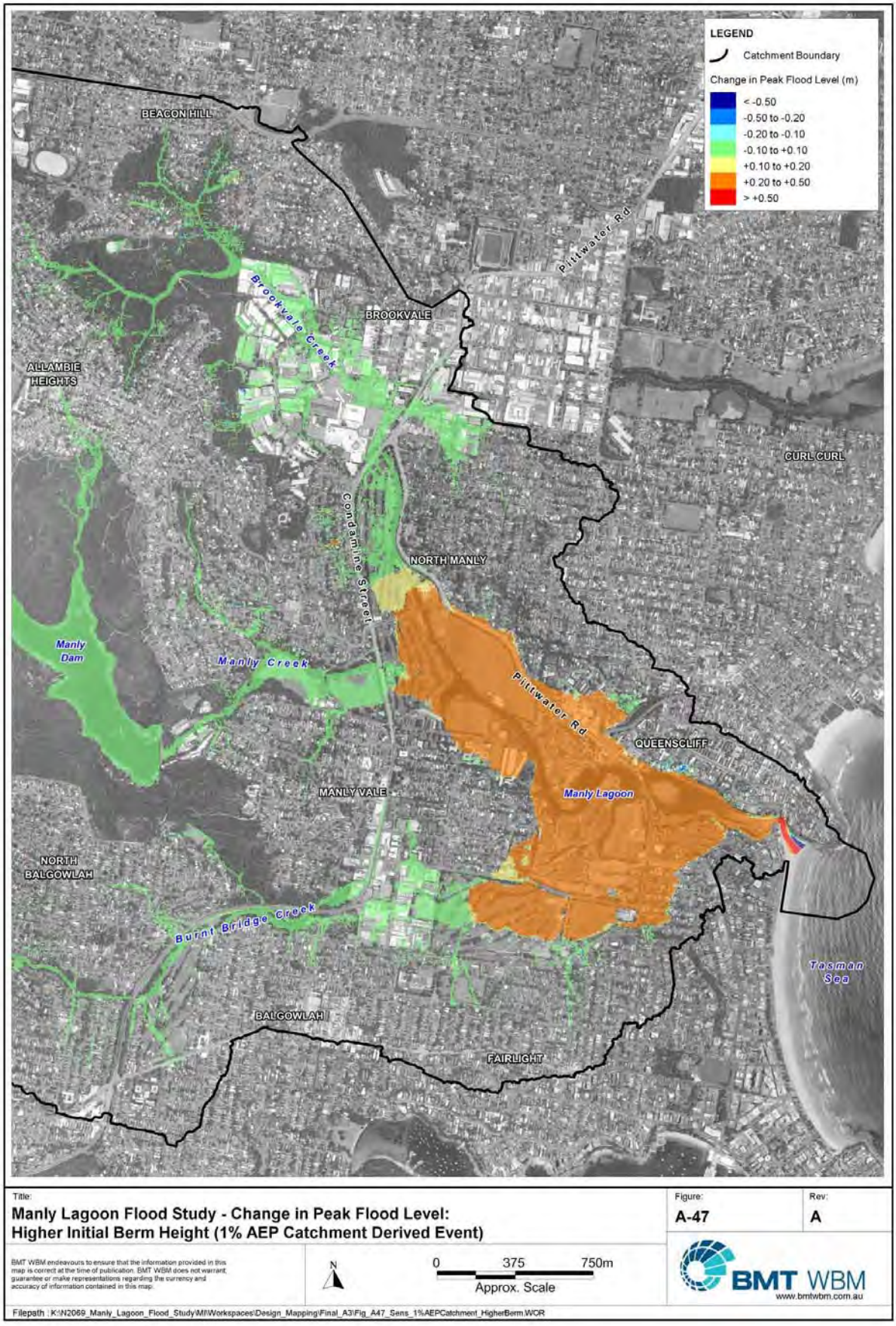
LEGEND
Catchment Boundary
Change in Peak Flood Level (m)
< -0.50
-0.50 to -0.20
-0.20 to -0.10
-0.10 to +0.10
+0.10 to +0.20
+0.20 to +0.50
> +0.50
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
QUEENSCLIFF
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Pittwater Rd
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Change in Peak Flood Level:
Higher Initial Berm Height (1% AEP Catchment Derived Event)
Figure:
A-47
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
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750m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
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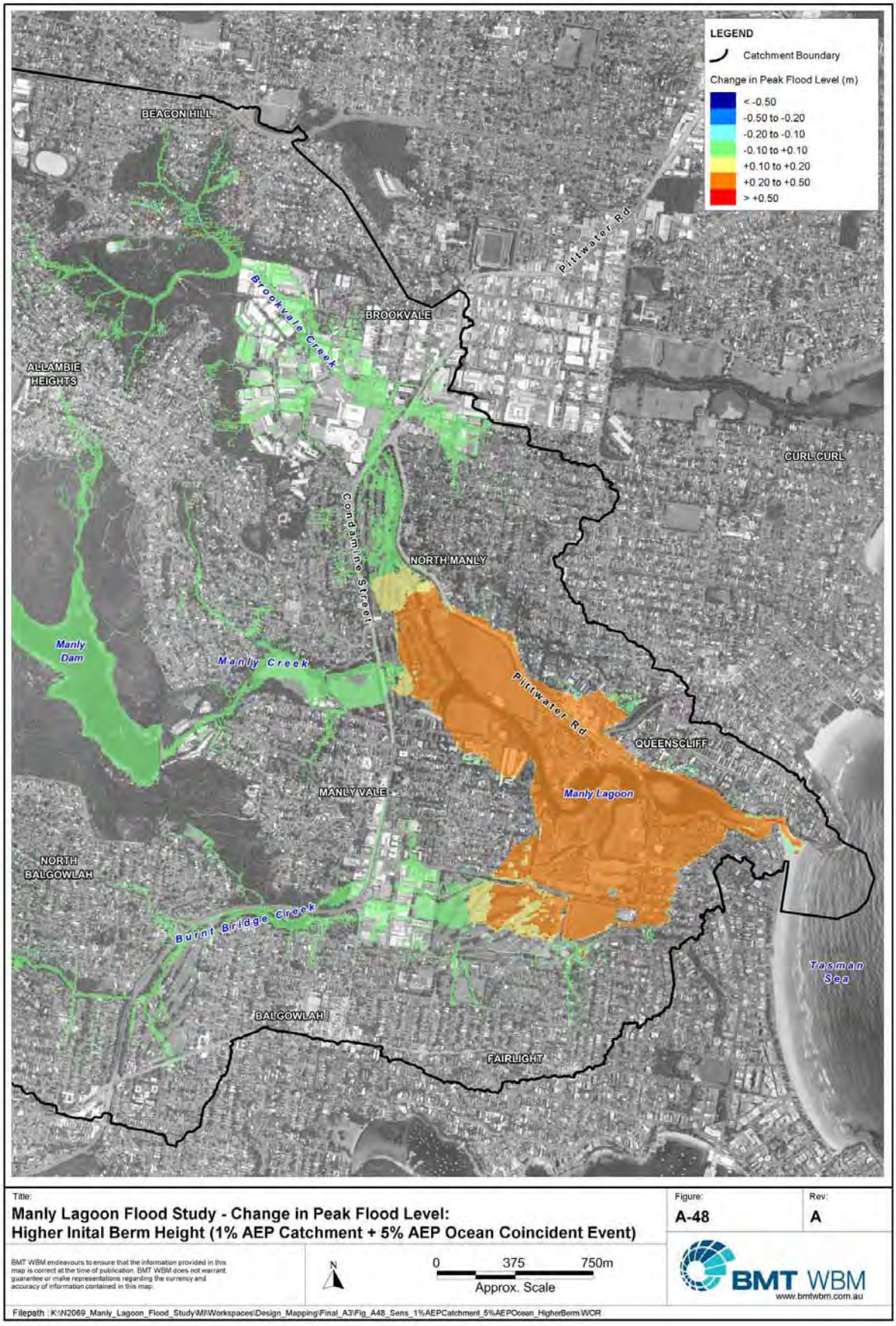
LEGEND
Catchment Boundary
Change in Peak Flood Level (m)
< -0.50
-0.50 to -0.20
-0.20 to -0.10
-0.10 to +0.10
+0.10 to +0.20
+0.20 to +0.50
> +0.50
BEACON HILL
Pittwater Rd
Brookvale Creek
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
Condamine Street
NORTH MANLY
Manly Dam
Manly Creek
Pittwater Rd
QUEENSCLIFF
MANLY VALE
Manly Lagoon
NORTH BALGOWLAH
Burnt Bridge Creek
Tasman Sea
BALGOWLAH
FAIRLIGHT
Title:
Manly Lagoon Flood Study - Change in Peak Flood Level:
Higher Inital Berm Height (1% AEP Catchment + 5% AEP Ocean Coincident Event)
Figure:
A-48
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
N
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750m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
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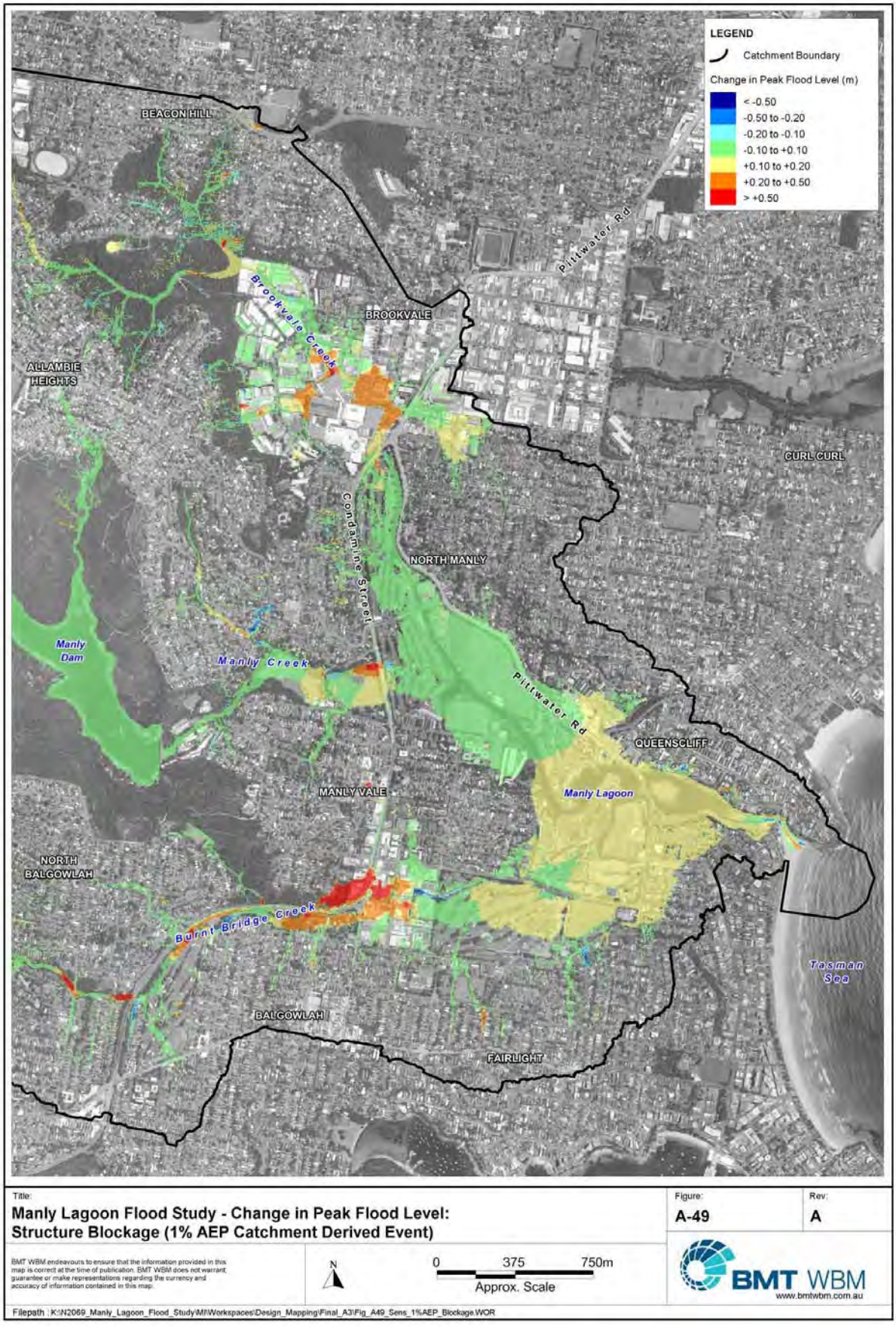
LEGEND
Catchment Boundary
Change in Peak Flood Level (m)
< -0.50
-0.50 to -0.20
-0.20 to -0.10
-0.10 to +0.10
+0.10 to +0.20
+0.20 to +0.50
> +0.50
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
QUEENSCLIFF
Brookvale Creek
Condamine Street
Pittwater Rd
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Change in Peak Flood Level:
Structure Blockage (1% AEP Catchment Derived Event)
Figure:
A-49
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
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Approx. Scale
BMT WBM
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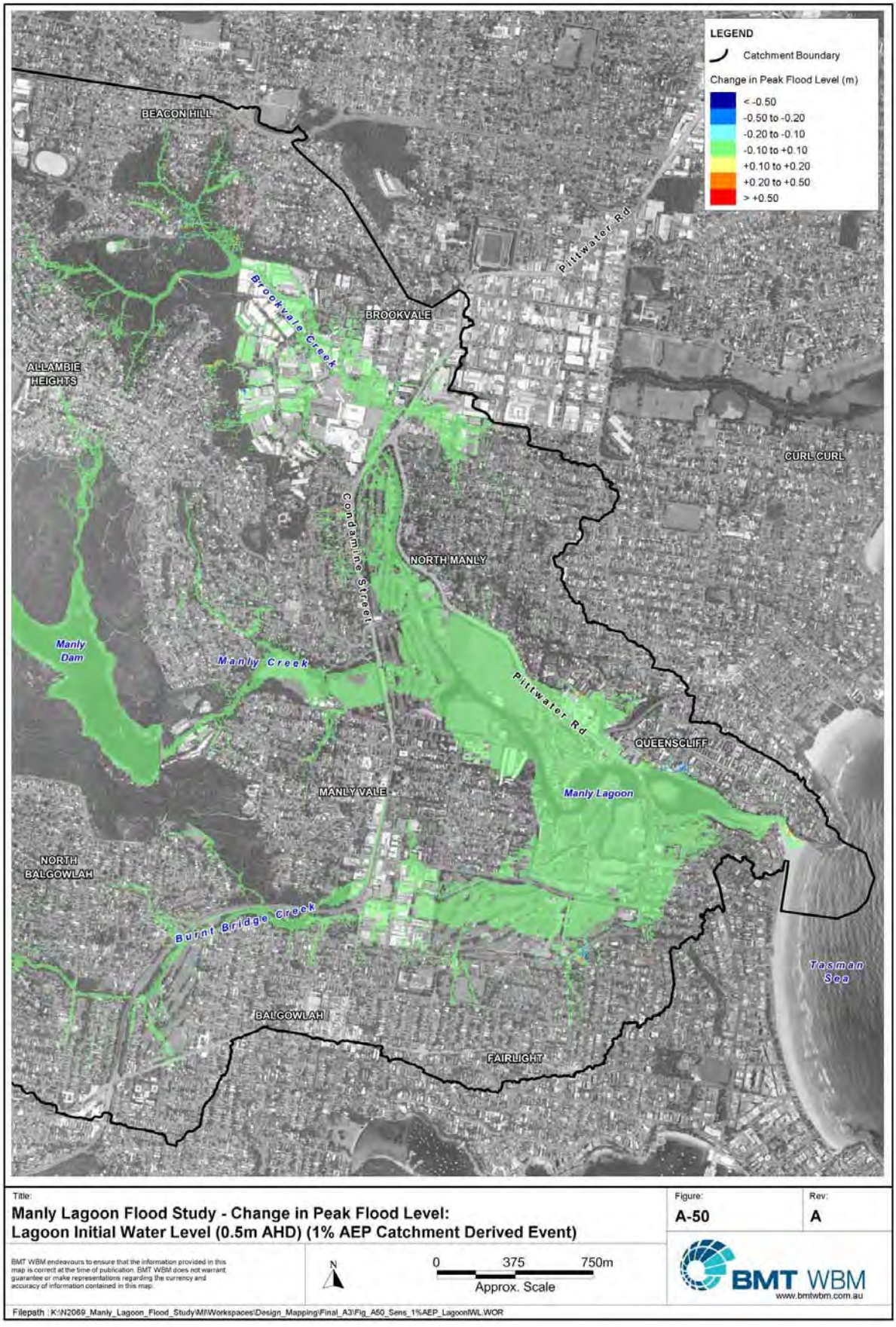
LEGEND
Catchment Boundary
Change in Peak Flood Level (m)
< -0.50
-0.50 to -0.20
-0.20 to -0.10
-0.10 to +0.10
+0.10 to +0.20
+0.20 to +0.50
> +0.50
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
MANLY VALE
QUEENSCLIFF
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Pittwater Rd
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Change in Peak Flood Level:
Lagoon Initial Water Level (0.5m AHD) (1% AEP Catchment Derived Event)
Figure:
A-50
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
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750m
Approx. Scale
BMT WBM
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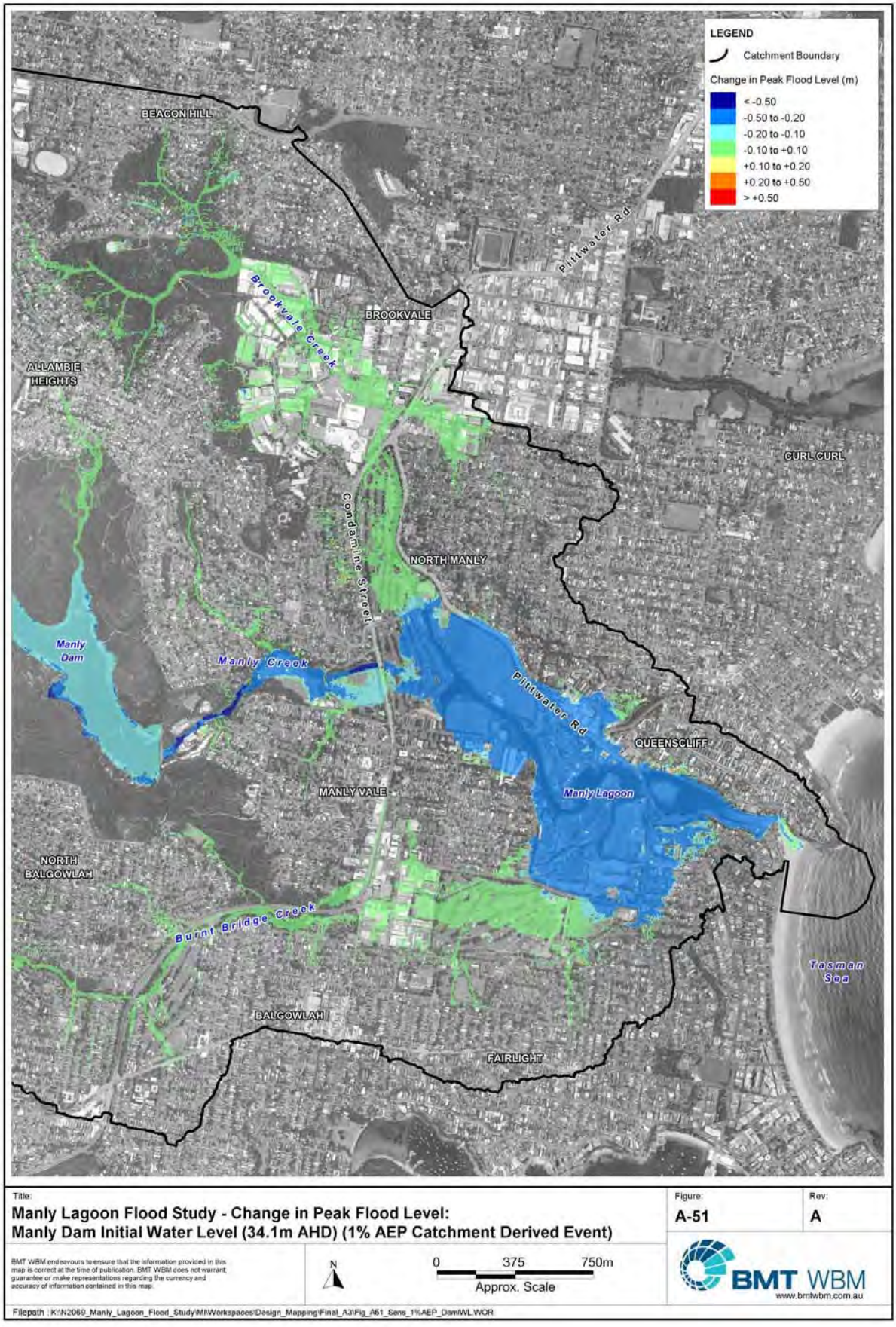
LEGEND
Catchment Boundary
Change in Peak Flood Level (m)
< -0.50
-0.50 to -0.20
-0.20 to -0.10
-0.10 to +0.10
+0.10 to +0.20
+0.20 to +0.50
> +0.50
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
MANLY VALE
QUEENSCLIFF
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Pittwater Rd
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Change in Peak Flood Level:
Manly Dam Initial Water Level (34.1m AHD) (1% AEP Catchment Derived Event)
Figure:
A-51
Rev:
A
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750m
Approx. Scale
BMT WBM
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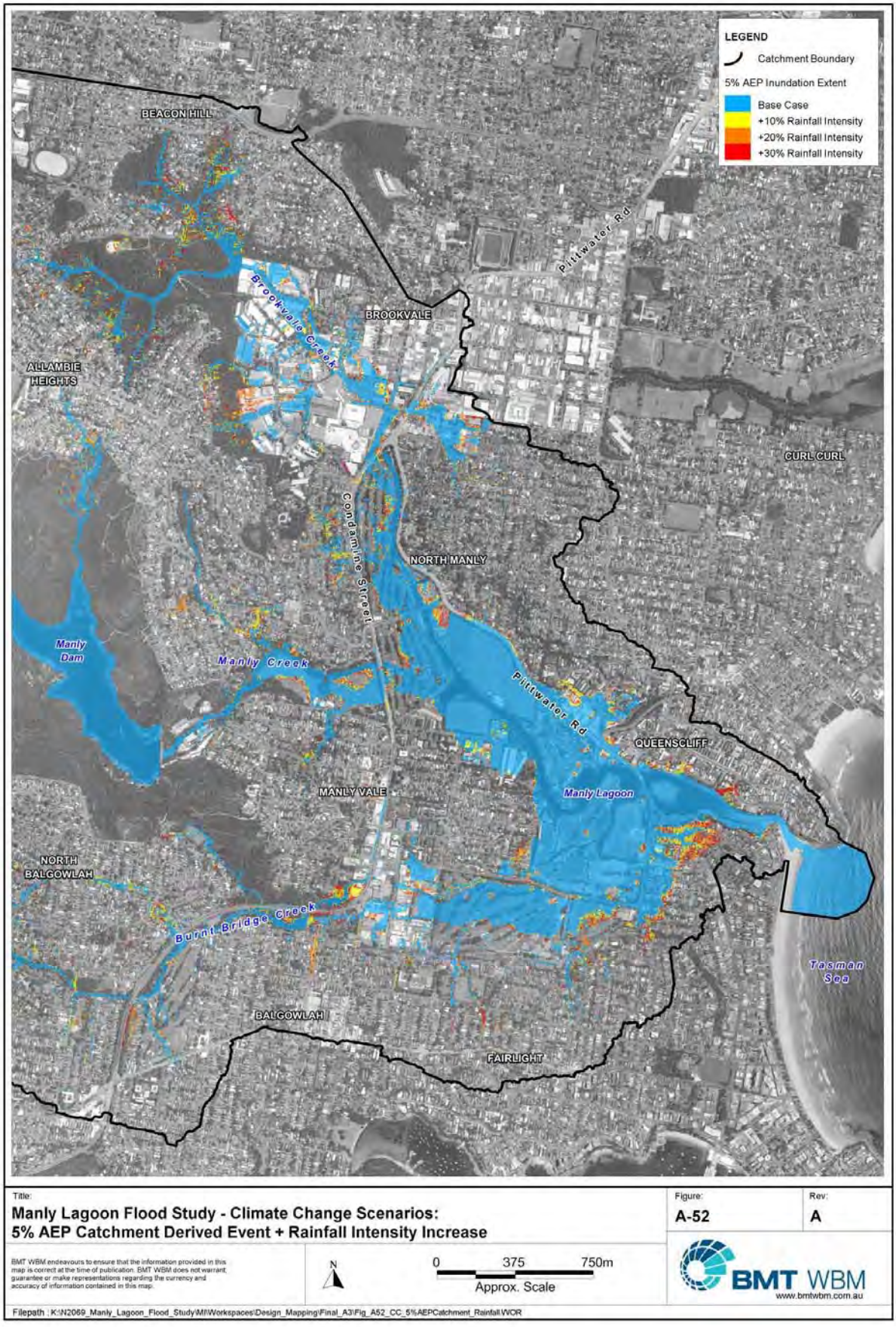
LEGEND
Catchment Boundary
5% AEP Inundation Extent
Base Case
+10% Rainfall Intensity
+20% Rainfall Intensity
+30% Rainfall Intensity
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
QUEENSCLIFF
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Brookvale Creek
Condamine Street
Pittwater Rd
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Climate Change Scenarios:
5% AEP Catchment Derived Event + Rainfall Intensity Increase
Figure: A-52
Rev: A
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Approx. Scale
BMT WBM
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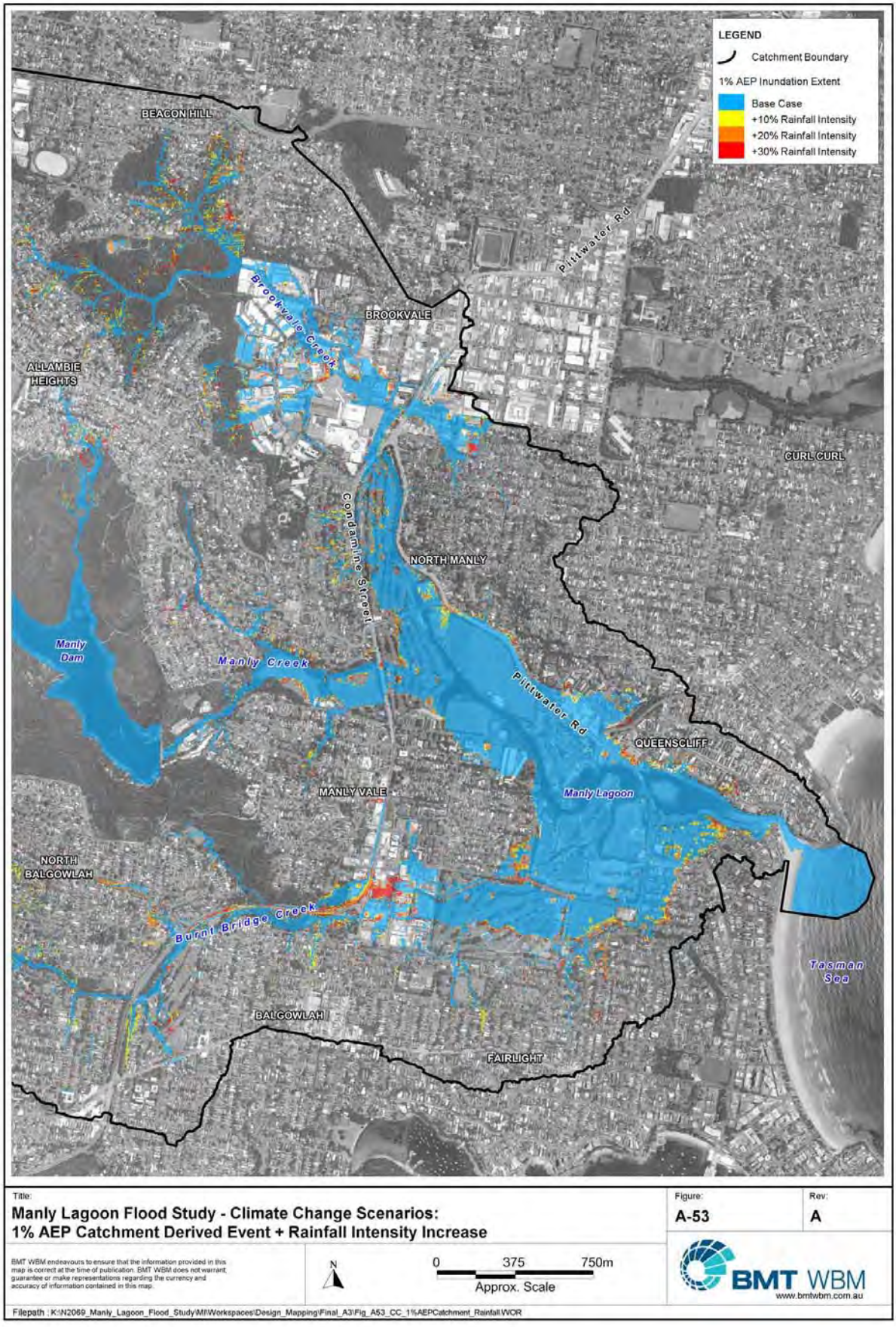
LEGEND
Catchment Boundary
1% AEP Inundation Extent
Base Case
+10% Rainfall Intensity
+20% Rainfall Intensity
+30% Rainfall Intensity
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
QUEENSCLIFF
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Brookvale Creek
Condamine Street
Pittwater Rd
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Climate Change Scenarios:
1% AEP Catchment Derived Event + Rainfall Intensity Increase
Figure: A-53
Rev: A
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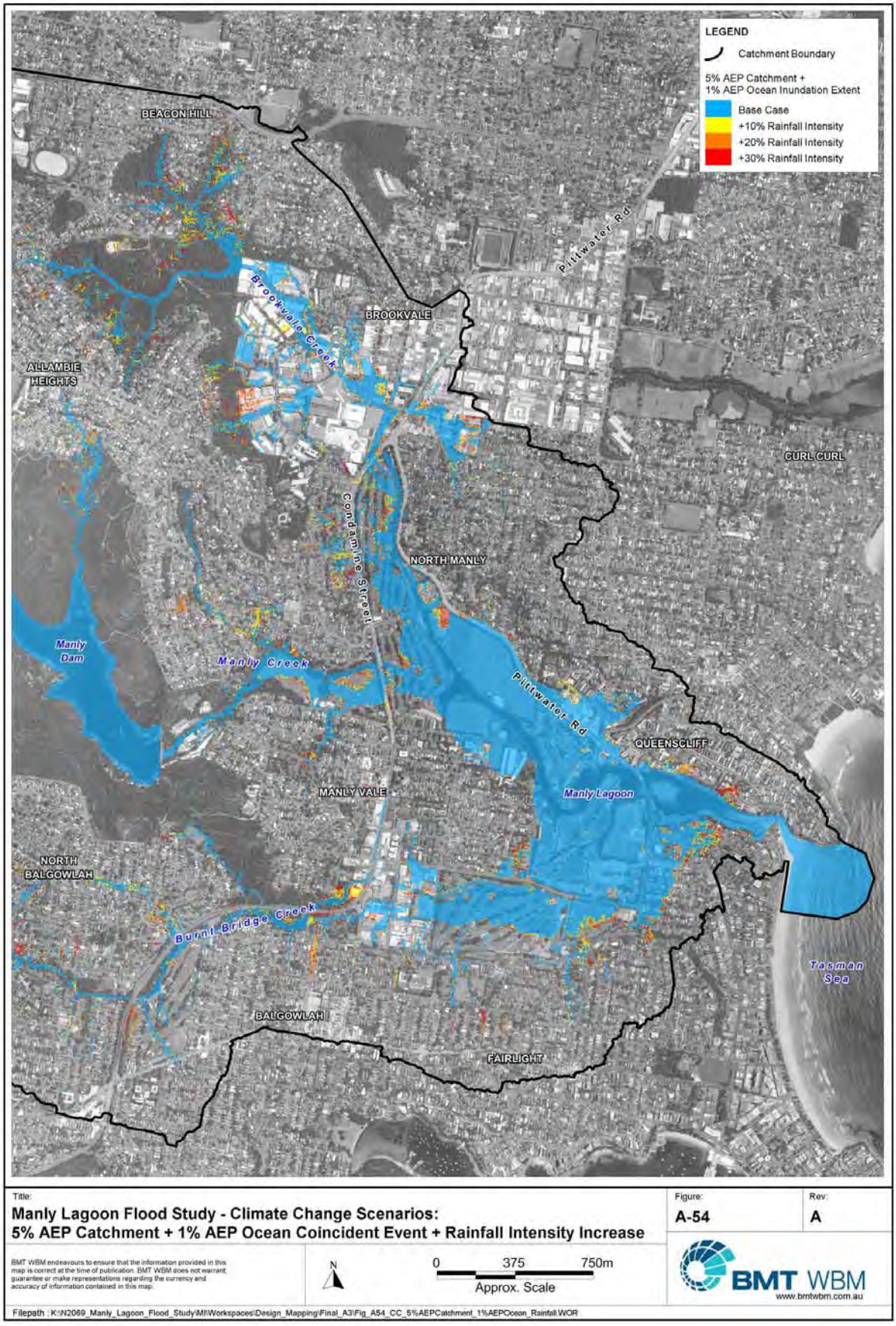
LEGEND
Catchment Boundary
5% AEP Catchment +
1% AEP Ocean Inundation Extent
Base Case
+10% Rainfall Intensity
+20% Rainfall Intensity
+30% Rainfall Intensity
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
QUEENSCLIFF
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Brookvale Creek
Condamine Street
Pittwater Rd
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Climate Change Scenarios:
5% AEP Catchment + 1% AEP Ocean Coincident Event + Rainfall Intensity Increase
Figure: A-54
Rev: A
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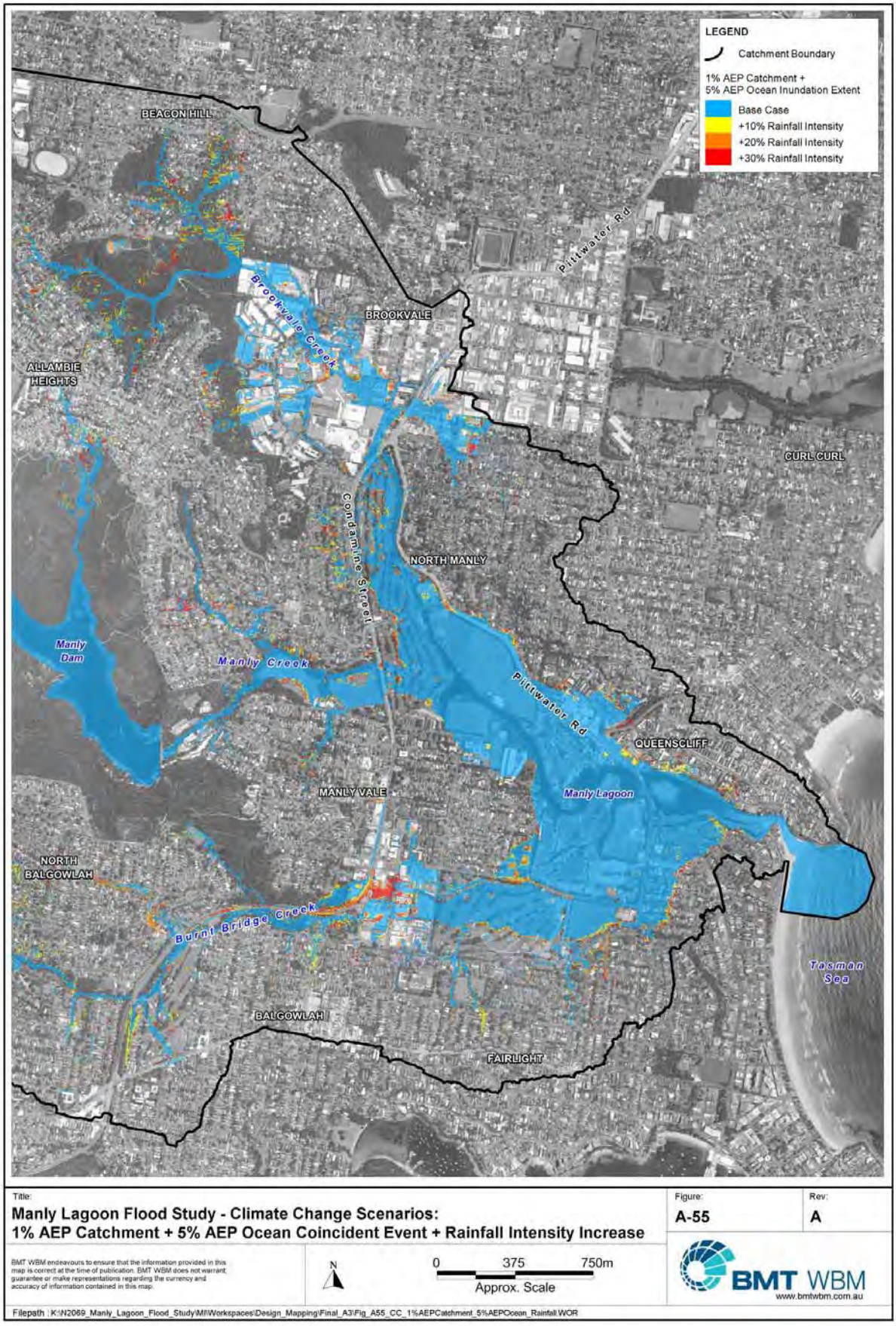
LEGEND
Catchment Boundary
1% AEP Catchment +
5% AEP Ocean Inundation Extent
Base Case
+10% Rainfall Intensity
+20% Rainfall Intensity
+30% Rainfall Intensity
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
QUEENSCLIFF
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Pittwater Rd
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Climate Change Scenarios:
1% AEP Catchment + 5% AEP Ocean Coincident Event + Rainfall Intensity Increase
Figure: A-55
Rev: A
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Approx. Scale
BMT WBM
www.bmtwbm.com.au
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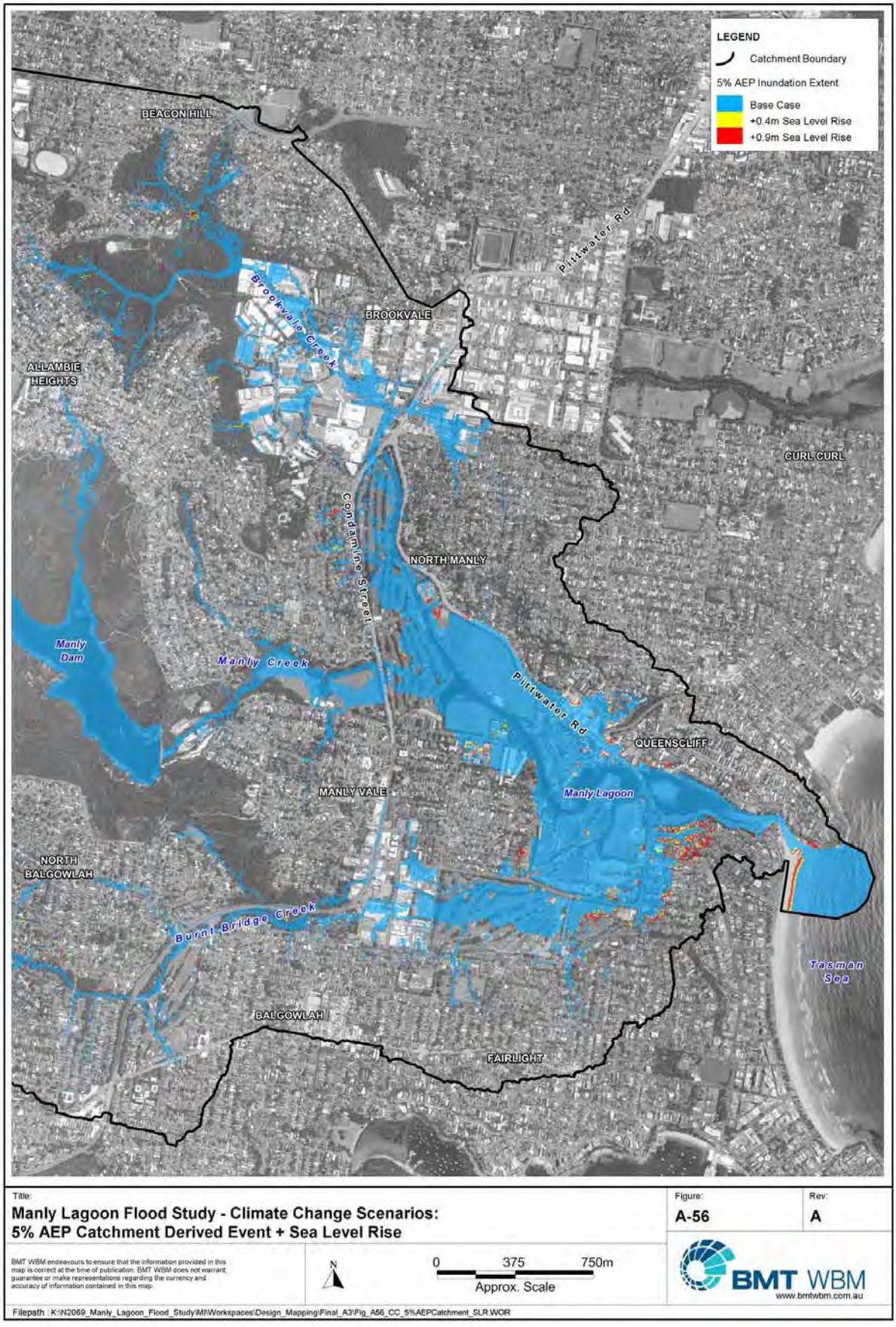
LEGEND
Catchment Boundary
5% AEP Inundation Extent
Base Case
+0.4m Sea Level Rise
+0.9m Sea Level Rise
BEACON HILL
Pittwater Rd
Brookvale Creek
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
Condamine Street
NORTH MANLY
Manly Dam
Manly Creek
Pittwater Rd
QUEENSCLIFF
MANLY VALE
Manly Lagoon
NORTH BALGOWLAH
Burnt Bridge Creek
Tasman Sea
BALGOWLAH
FAIRLIGHT
Title:
Manly Lagoon Flood Study - Climate Change Scenarios:
5% AEP Catchment Derived Event + Sea Level Rise
Figure:
A-56
Rev:
A
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Approx. Scale
BMT WBM
www.bmtwbm.com.au
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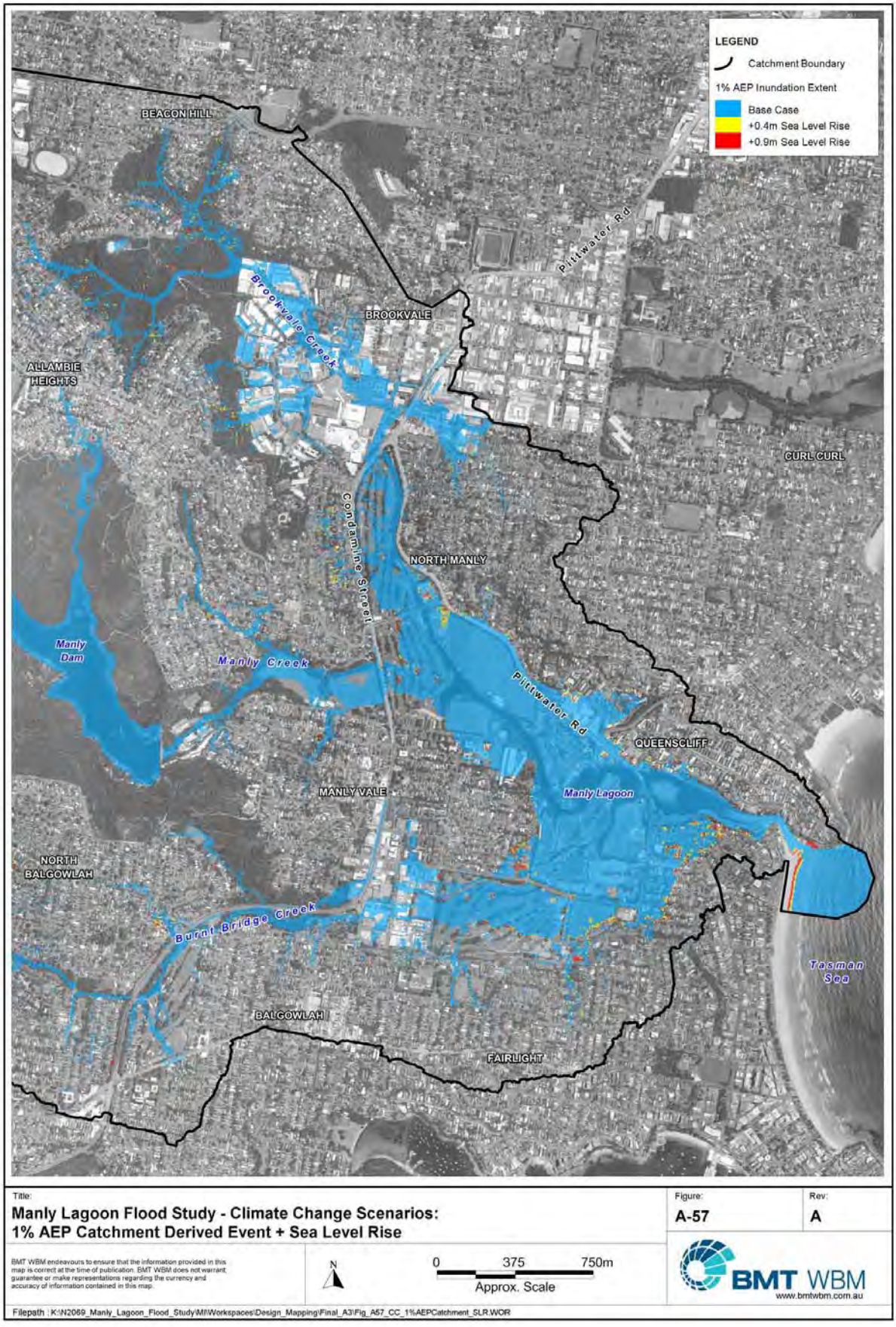
LEGEND
Catchment Boundary
1% AEP Inundation Extent
Base Case
+0.4m Sea Level Rise
+0.9m Sea Level Rise
BEACON HILL
Pittwater Rd
Brookvale Creek
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
Condamine Street
NORTH MANLY
Manly Dam
Manly Creek
Pittwater Rd
QUEENSCLIFF
MANLY VALE
Manly Lagoon
NORTH BALGOWLAH
Burnt Bridge Creek
Tasman Sea
BALGOWLAH
FAIRLIGHT
Title:
Manly Lagoon Flood Study - Climate Change Scenarios:
1% AEP Catchment Derived Event + Sea Level Rise
Figure:
A-57
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
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750m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
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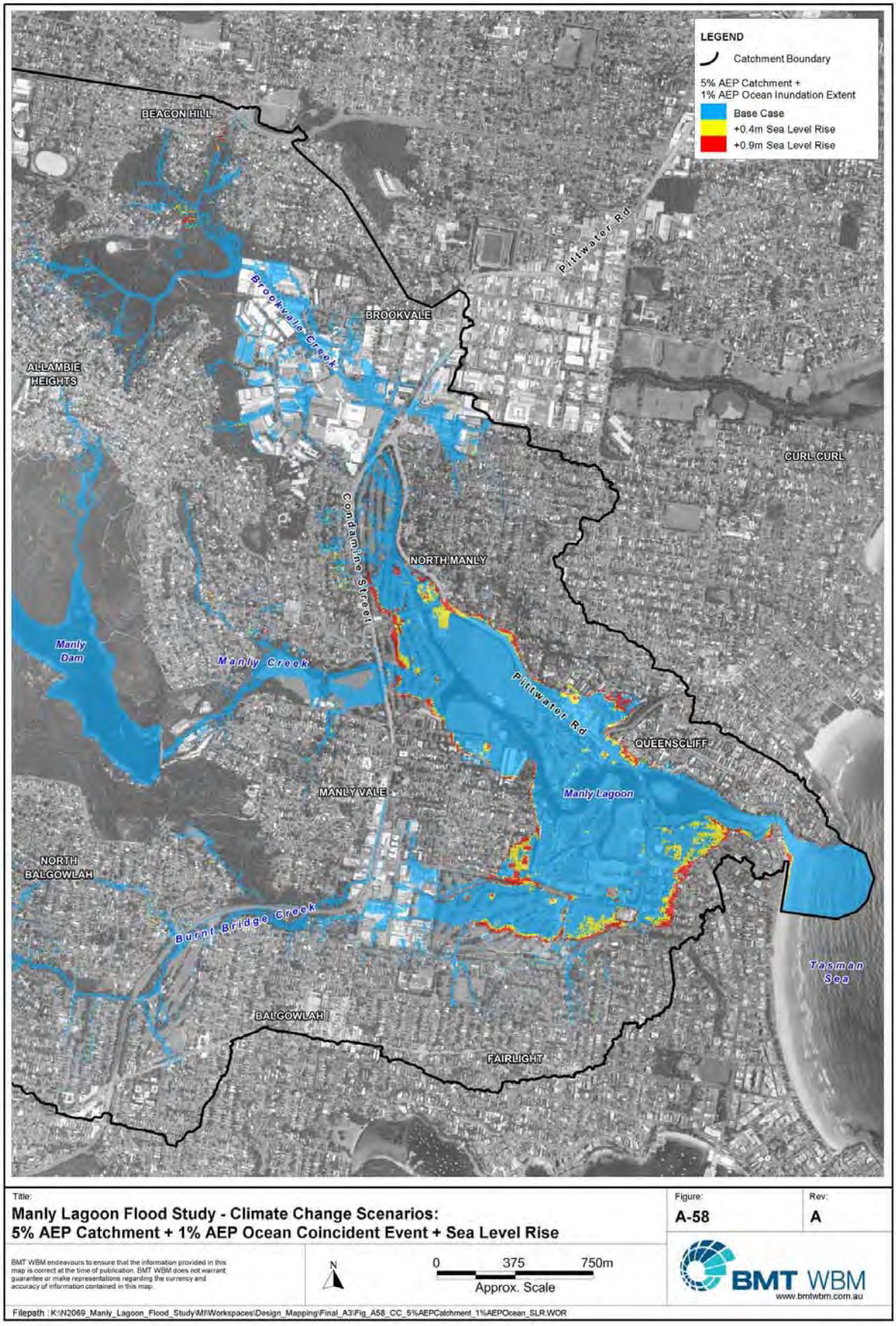
LEGEND
Catchment Boundary
5% AEP Catchment +
1% AEP Ocean Inundation Extent
Base Case
+0.4m Sea Level Rise
+0.9m Sea Level Rise
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
QUEENSCLIFF
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Brookvale Creek
Pittwater Rd
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Climate Change Scenarios:
5% AEP Catchment + 1% AEP Ocean Coincident Event + Sea Level Rise
Figure:
A-58
Rev:
A
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.
N
0
375
750m
Approx. Scale
BMT WBM
www.bmtwbm.com.au
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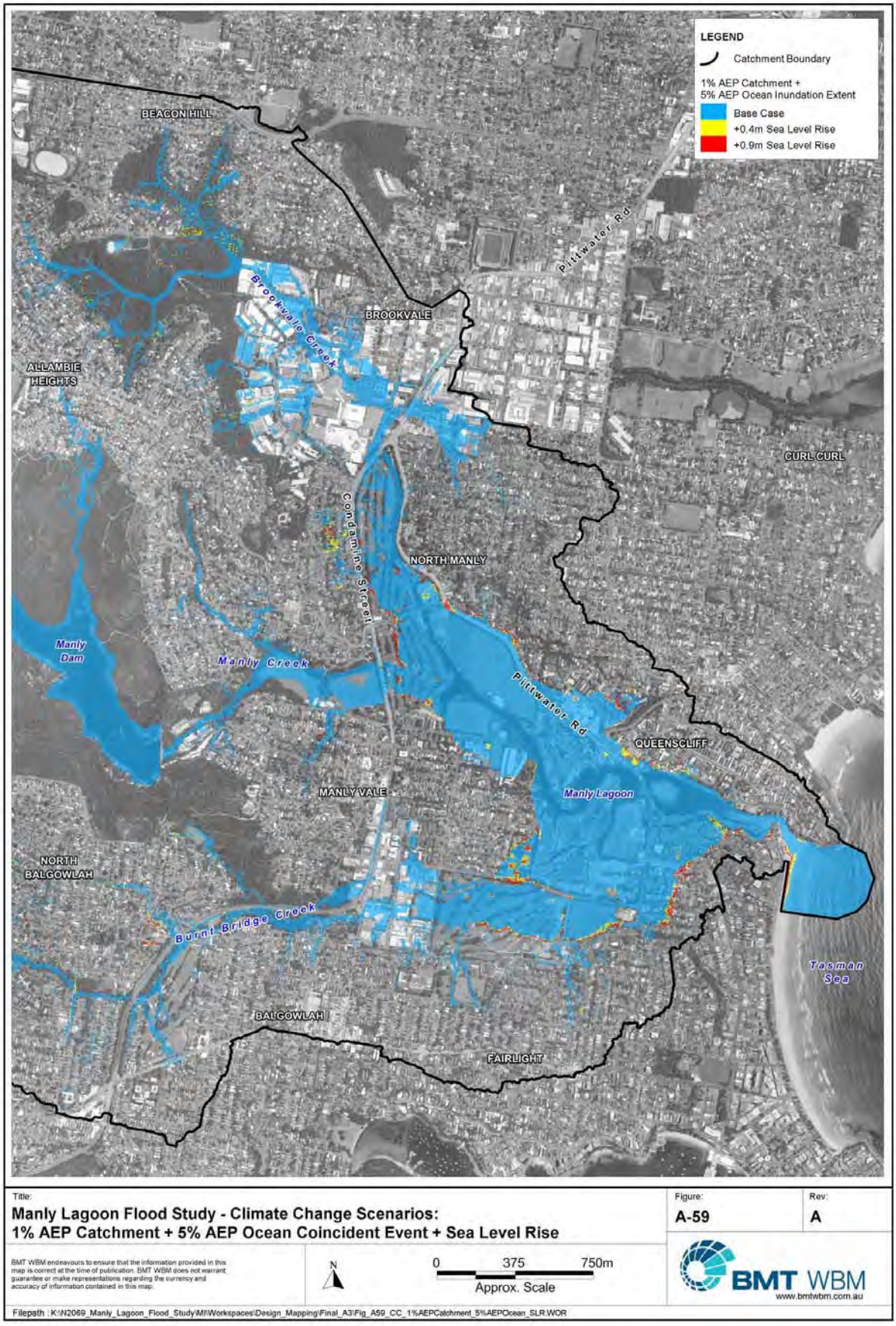
LEGEND
Catchment Boundary
1% AEP Catchment +
5% AEP Ocean Inundation Extent
Base Case
+0.4m Sea Level Rise
+0.9m Sea Level Rise
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
QUEENSCLIFF
MANLY VALE
NORTH BALGOWLAH
BALGOWLAH
FAIRLIGHT
Pittwater Rd
Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Climate Change Scenarios:
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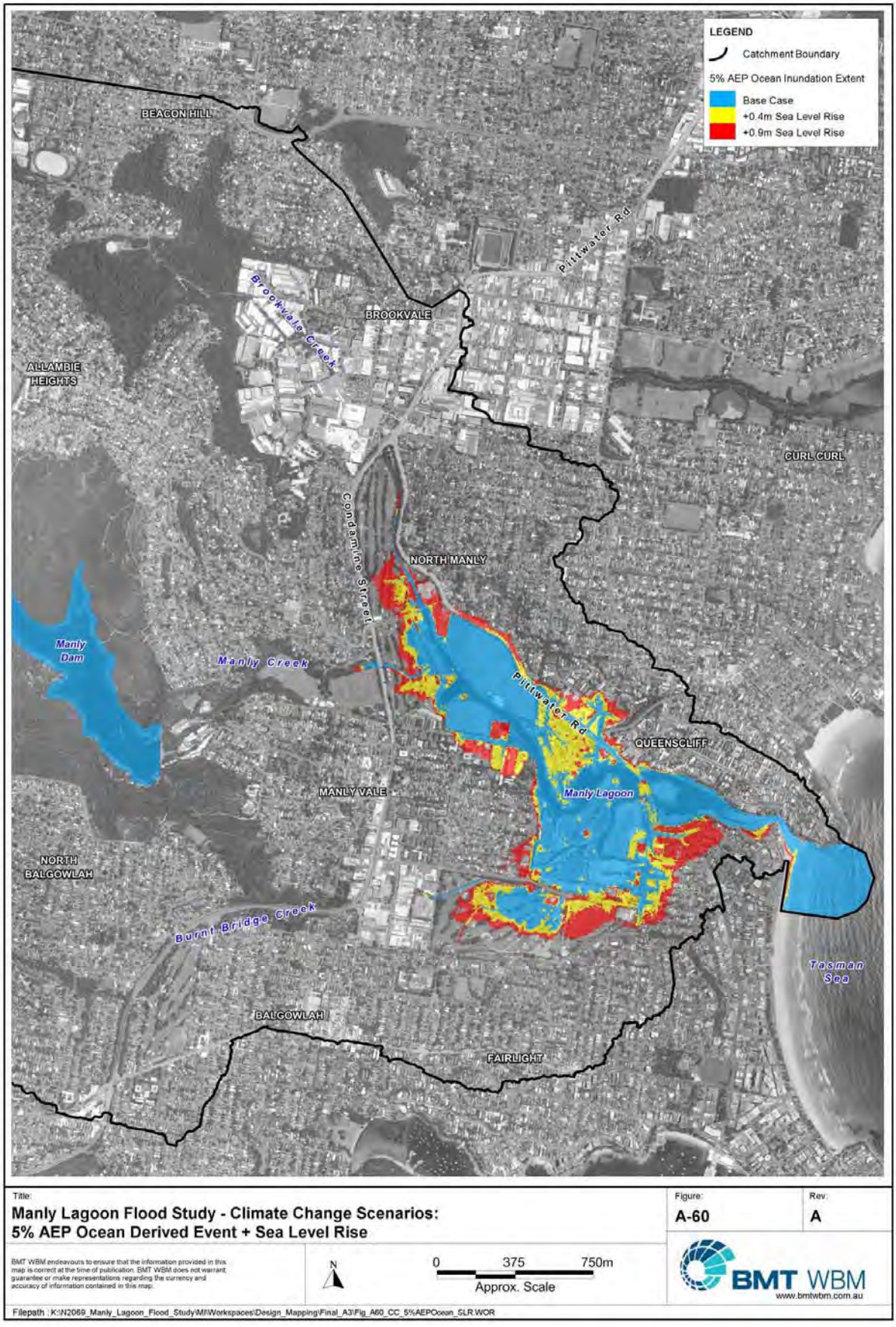
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Pittwater Rd
ALLAMBIE HEIGHTS
CURL CURL
Condamine Street
NORTH MANLY
Manly Dam
Manly Creek
QUEENSCLIFF
MANLY VALE
Manly Lagoon
NORTH BALGOWLAH
Burnt Bridge Creek
Tasman Sea
BALGOWLAH
FAIRLIGHT
Title:
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5% AEP Ocean Derived Event + Sea Level Rise
Figure:
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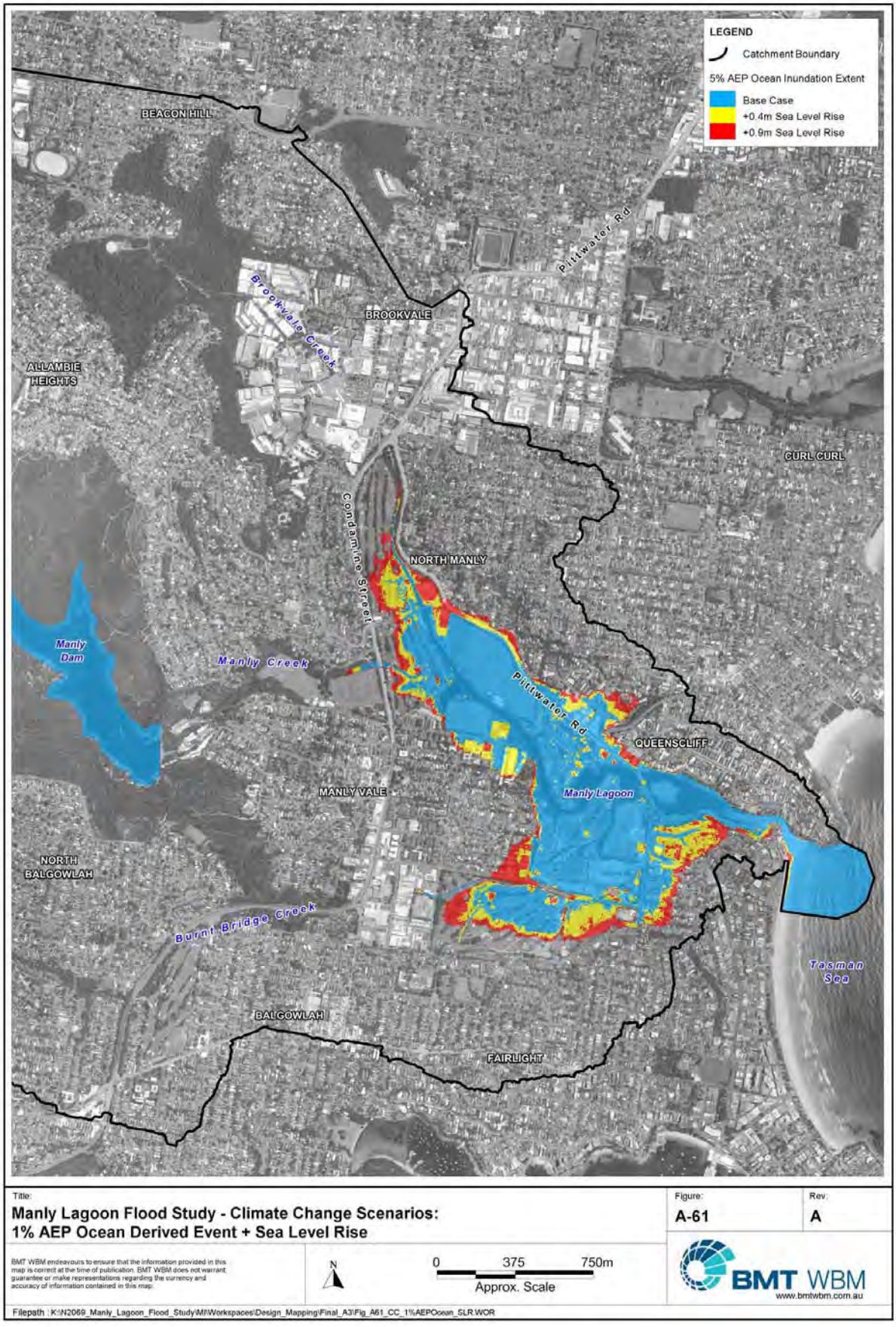
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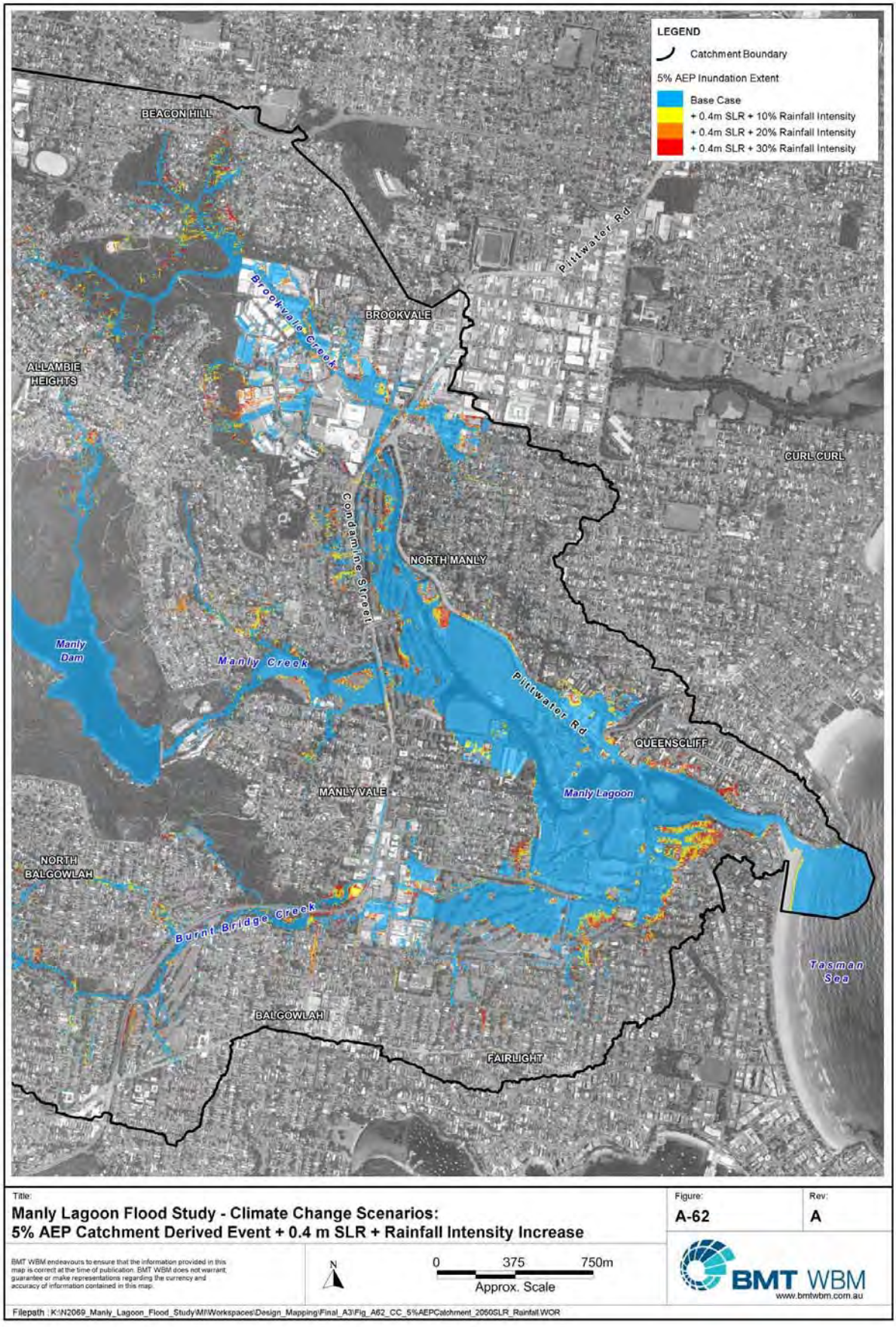
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NORTH MANLY
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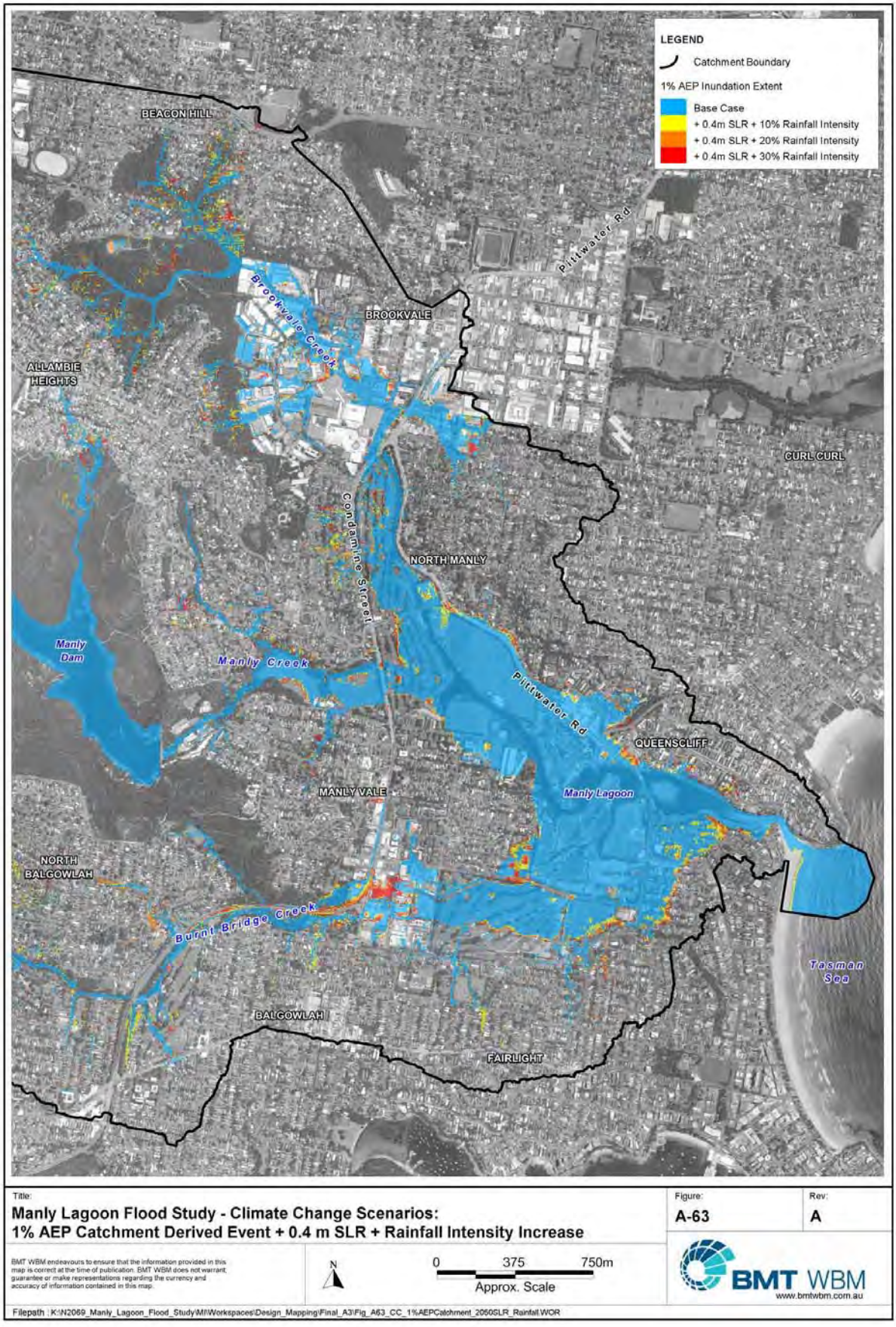
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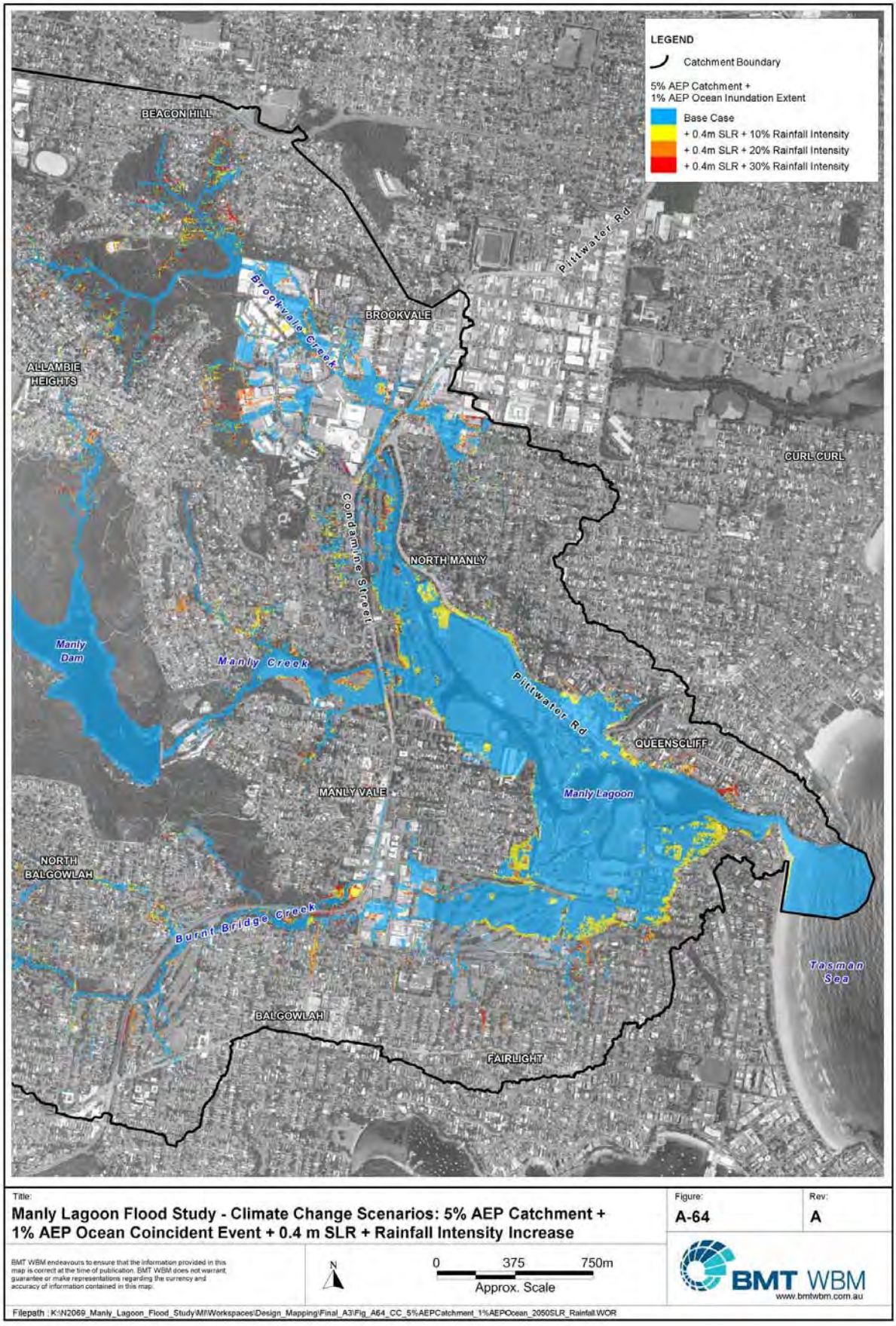
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Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Pittwater Rd
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
Manly Lagoon Flood Study - Climate Change Scenarios: 5% AEP Catchment + 1% AEP Ocean Coincident Event + 0.4 m SLR + Rainfall Intensity Increase
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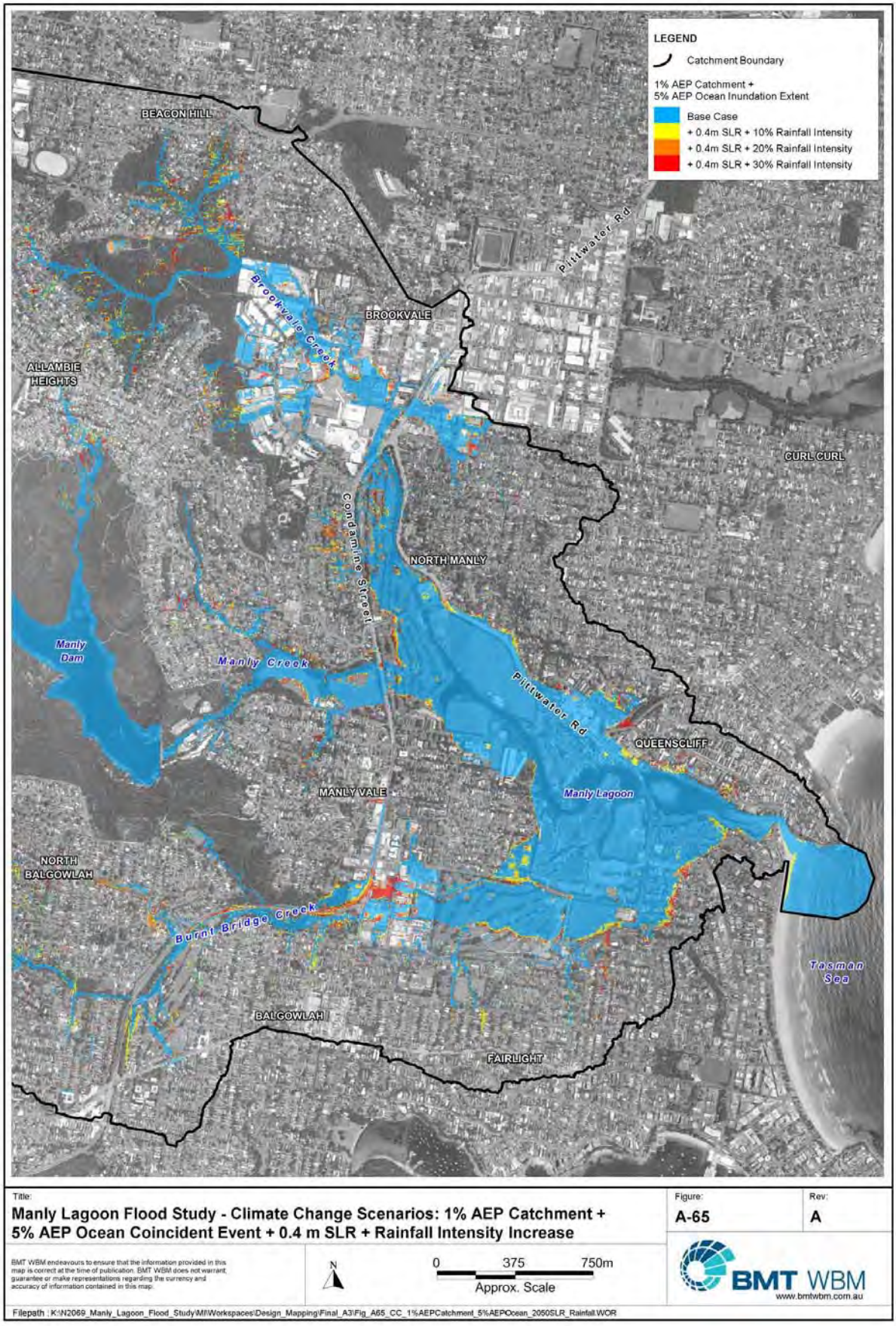
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Manly Lagoon
NORTH BALGOWLAH
Burnt Bridge Creek
Tasman Sea
BALGOWLAH
FAIRLIGHT
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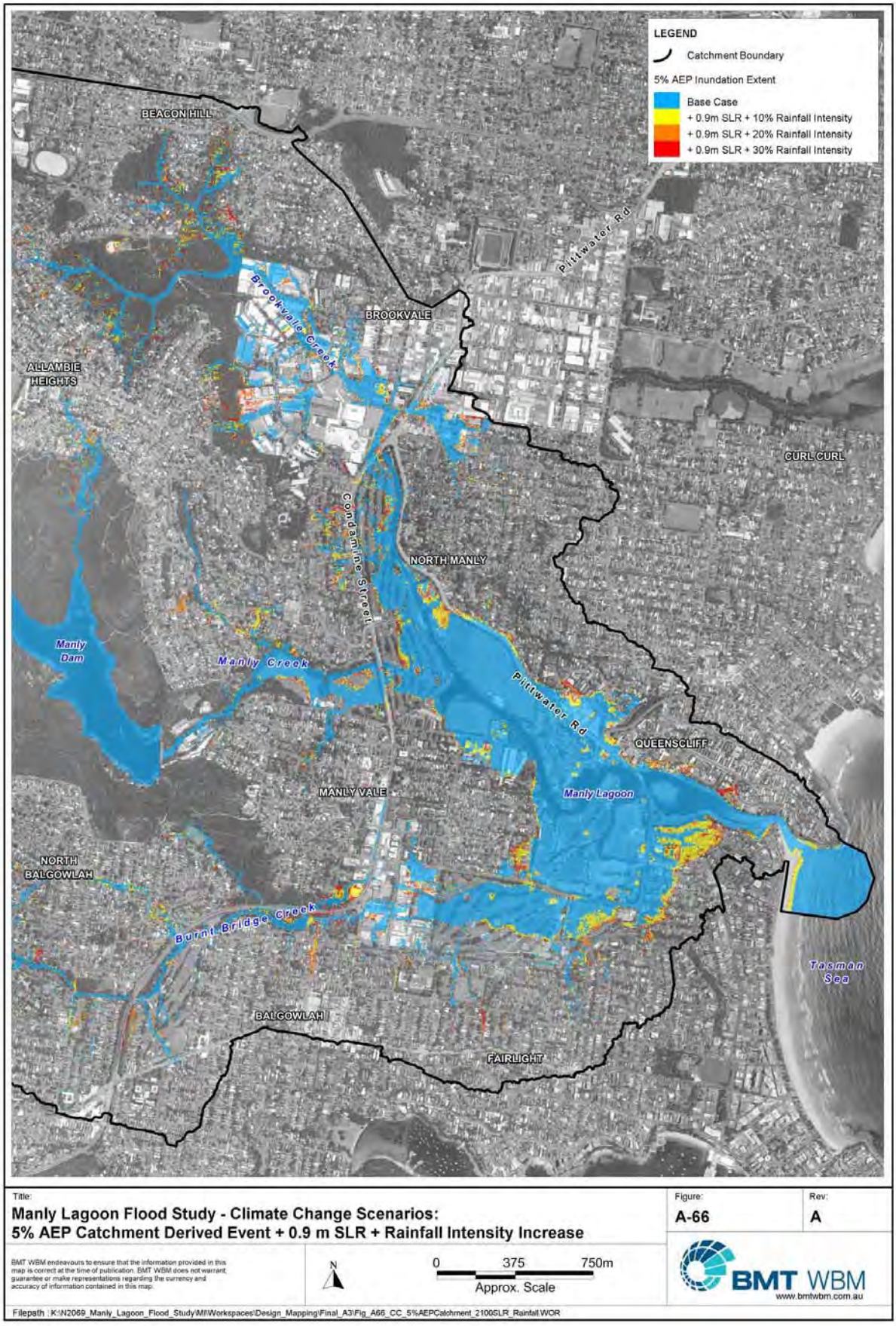
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+ 0.9m SLR + 30% Rainfall Intensity
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ALLAMBIE HEIGHTS
CURL CURL
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Brookvale Creek
Condamine Street
Manly Dam
Manly Creek
Pittwater Rd
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
Title:
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Figure:
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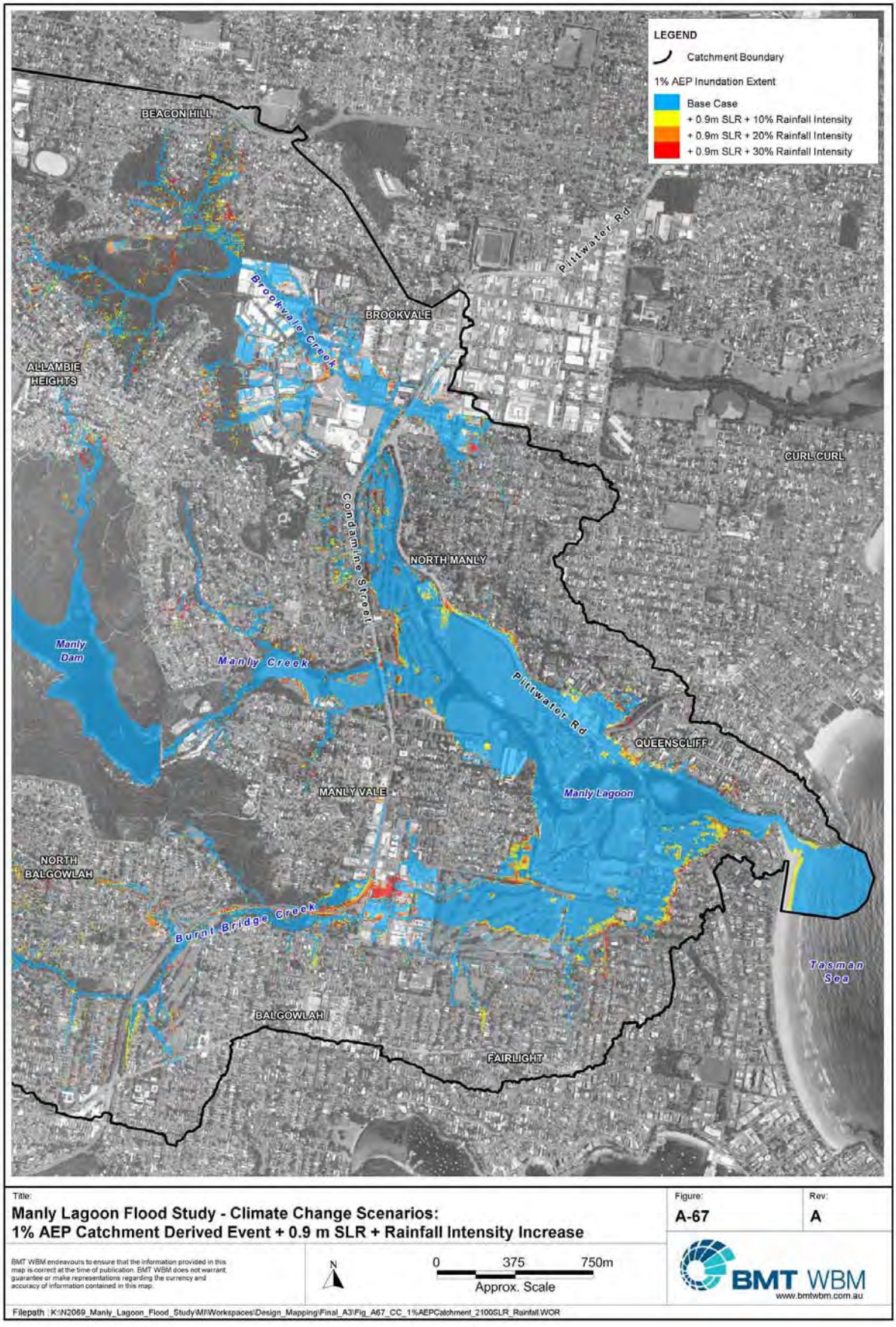
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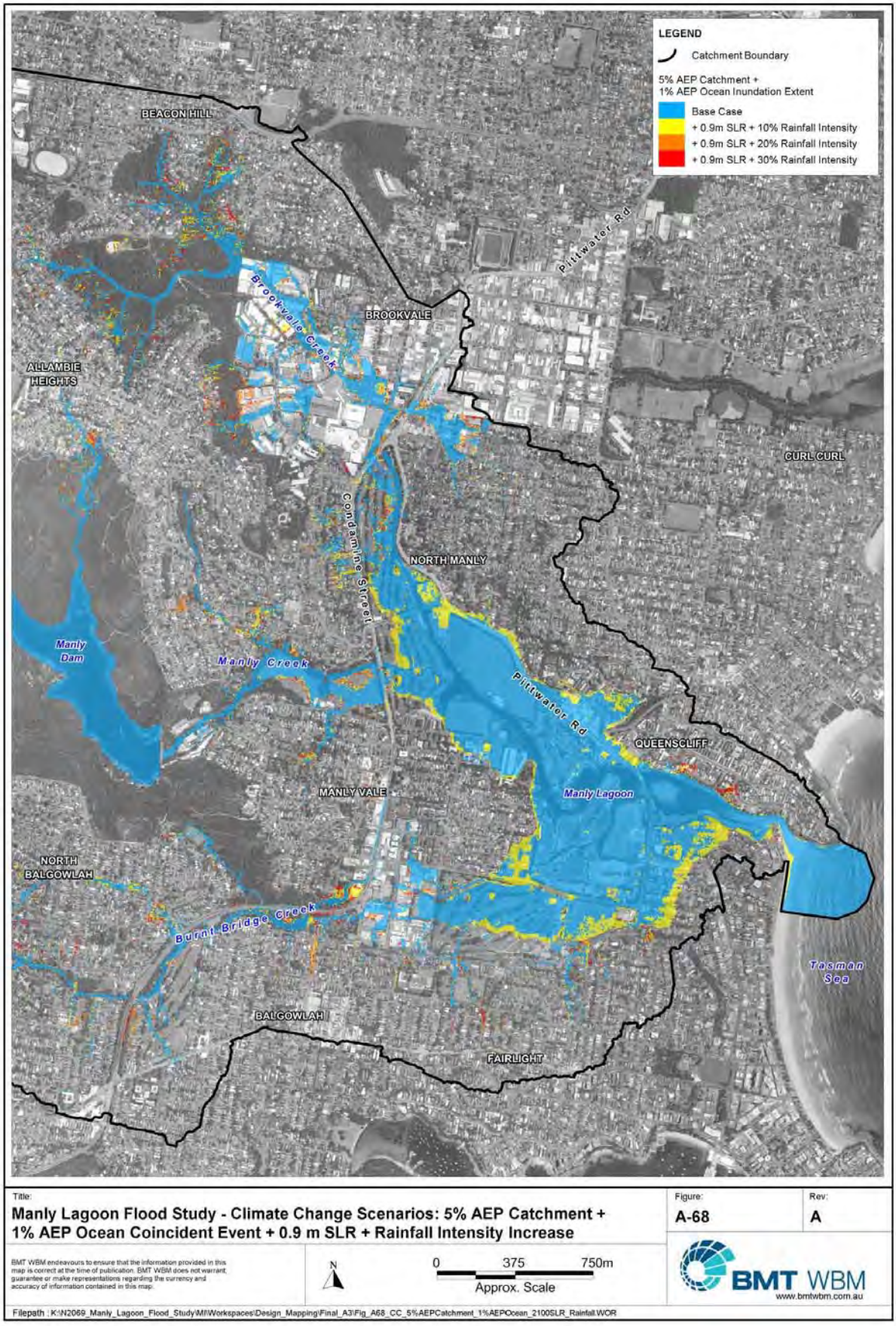
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BEACON HILL
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FAIRLIGHT
QUEENSCLIFF
Brookvale Creek
Condamine Street
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Manly Dam
Manly Creek
Manly Lagoon
Burnt Bridge Creek
Tasman Sea
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Figure: A-68
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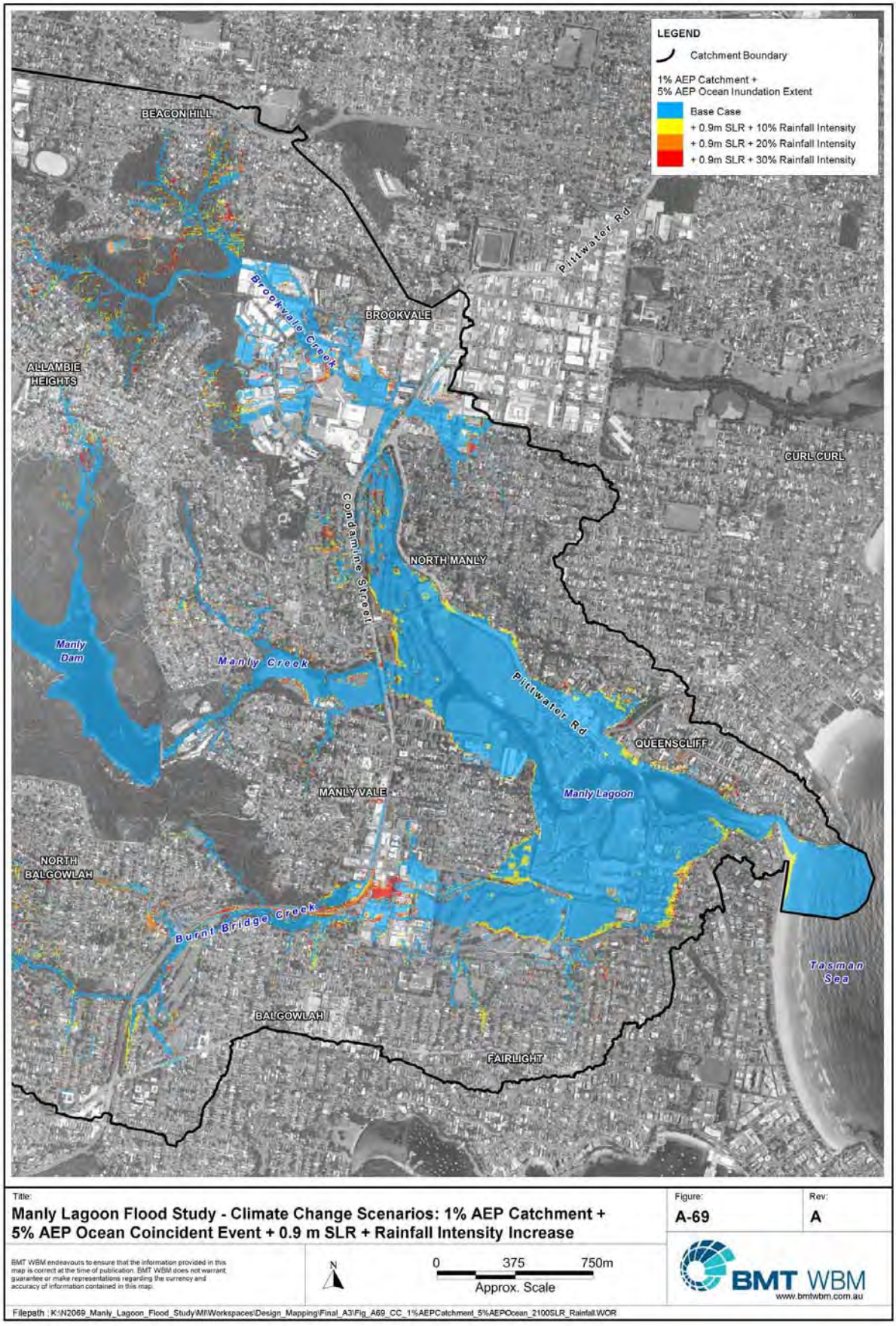
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+ 0.9m SLR + 20% Rainfall Intensity
+ 0.9m SLR + 30% Rainfall Intensity
BEACON HILL
BROOKVALE
ALLAMBIE HEIGHTS
CURL CURL
NORTH MANLY
MANLY VALE
QUEENSCLIFF
NORTH BALGOWLAH
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Condamine Street
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BMT WBM Perth	Suite 3, 1161 Hay Street West Perth 6005 Tel +61 8 9328 2029 Fax +61 8 9484 7588 Email perth@bmtwbm.com.au Web www.bmtwbm.com.au
BMT WBM Sydney	Level 1, 256-258 Norton Street Leichhardt 2040 PO Box 194 Leichhardt NSW 2040 Tel +61 2 9713 4836 Fax +61 2 9713 4890 Email sydney@bmtwbm.com.au Web www.bmtwbm.com.au
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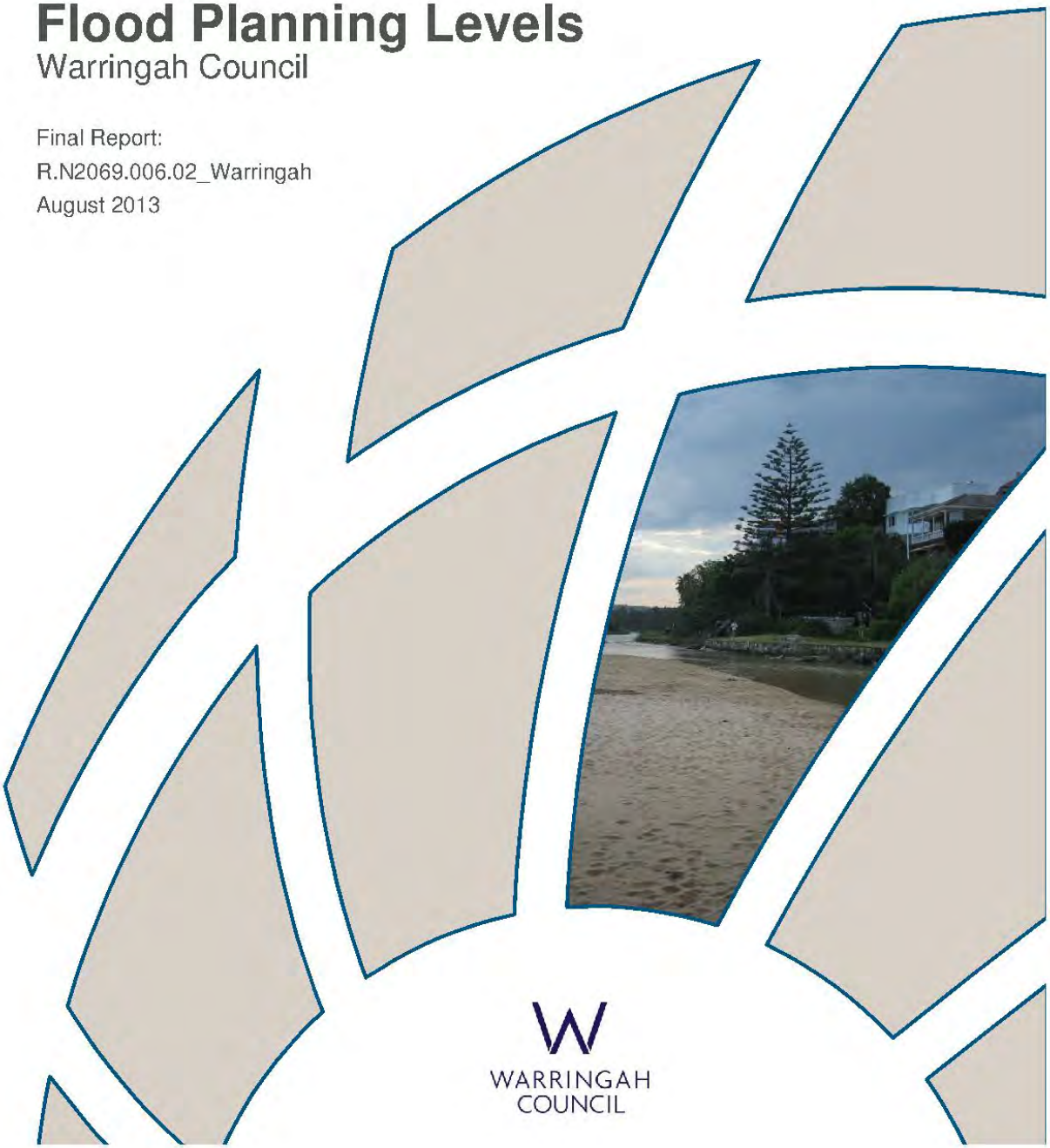
Manly Lagoon Flood Study - Flood Planning Levels

Warringah Council

Final Report:
R.N2069.006.02_Warringah
August 2013



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Client :	Warringah Council
Client Contact:	Valerie Tulk
Client Reference	

Title :	Manly Lagoon Flood Study – Flood Planning Levels Report
Author :	Darren Lyons
Synopsis :	Report for the Manly Lagoon Flood Study covering the establishment of flood planning levels.

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1 INTRODUCTION

The Manly Lagoon Flood Study (BMT WBM, 2013) has been prepared for Warringah and Manly Councils to define the existing flood behaviour in the Manly Lagoon catchment and establish the basis for subsequent floodplain management activities.

This study updates the previous studies on the Lagoon including the Manly Lagoon Flood Study (MHL, 1992) and smaller localised flood studies, providing a holistic assessment of flooding within the catchment. The current flood study considers land use changes subsequent to previous modelling investigations, the influence of the Manly Lagoon entrance on flood behaviour and the influence of potential climate change.

1.1 Flood Planning Levels

Land use planning and development controls are key mechanisms by which Warringah Council (Council) can manage flood-affected areas within the Manly Lagoon catchment. Such mechanisms will influence future development (and redevelopment) and therefore the benefits will accrue gradually over time. Without comprehensive floodplain planning, existing problems may be exacerbated and opportunities to reduce flood risks may be lost.

Flood Planning Levels (FPLs) are used for planning purposes, and directly determine the extent of the Flood Planning Area (FPA), which is the area of land subject to flood-related development controls, as described below.

Council's Development Control Plan (DCP) has been developed with the aim to reduce the likelihood that dwellings are inundated by flooding and to reduce the likelihood of people being exposed to dangerous flood situations. The DCP specifies how the FPL is applied to new development. For instance, floor levels of new development within the FPA are typically required to be at or above Council's adopted FPL.

The FPL is defined by an established design flood level of selected magnitude combined with a specified freeboard considered appropriate for the land use in question. The purpose of the freeboard is to account for the risk associated with various uncertainties in the predicted flood level. These risks may include variation between flood modelling results and actual flood events, the effect of localised factors on flood levels and potential wave action.

Council's adopted FPL is based on the 1% Annual Exceedance Probability (AEP) flood level + 0.5m freeboard. This is as per the guidelines from the NSW Government's Floodplain Development Manual (2005). For the Manly Lagoon catchment, the design 1% AEP event conditions are based on the coincident occurrence of both catchment and ocean derived flooding. This scenario incorporates a 1% AEP catchment rainfall condition with a 5% AEP ocean water level condition (storm surge scenario).

The FPL can be based on different flood magnitudes and different freeboards, if there is sufficient justification. It is also possible to have a graded set of FPLs in place, dependent on the nature of the development and the relevant flood risk classification. Council's FPLs will be reviewed during the subsequent Floodplain Risk Management Study.

1.2 Flood Planning Area

The design flood levels and inundation extents determined through the detailed modelling undertaken in the Manly Lagoon Flood Study (BMT WBM, 2013) provides the basis for establishing the Flood Planning Level (FPL) and associated Flood Planning Area (FPA).

The FPA is the area of land below the FPL and thus subject to flood-related development controls. The FPA for the Manly Lagoon catchment is shown in Figure 1-1.

In deriving the FPA from the flood study results, consideration has been given to the flood severity and risks both on a catchment wide and property basis, as well as the resolution of the computer modelling. The following provides a summary of the various filters used to refine the mapping of the FPA:

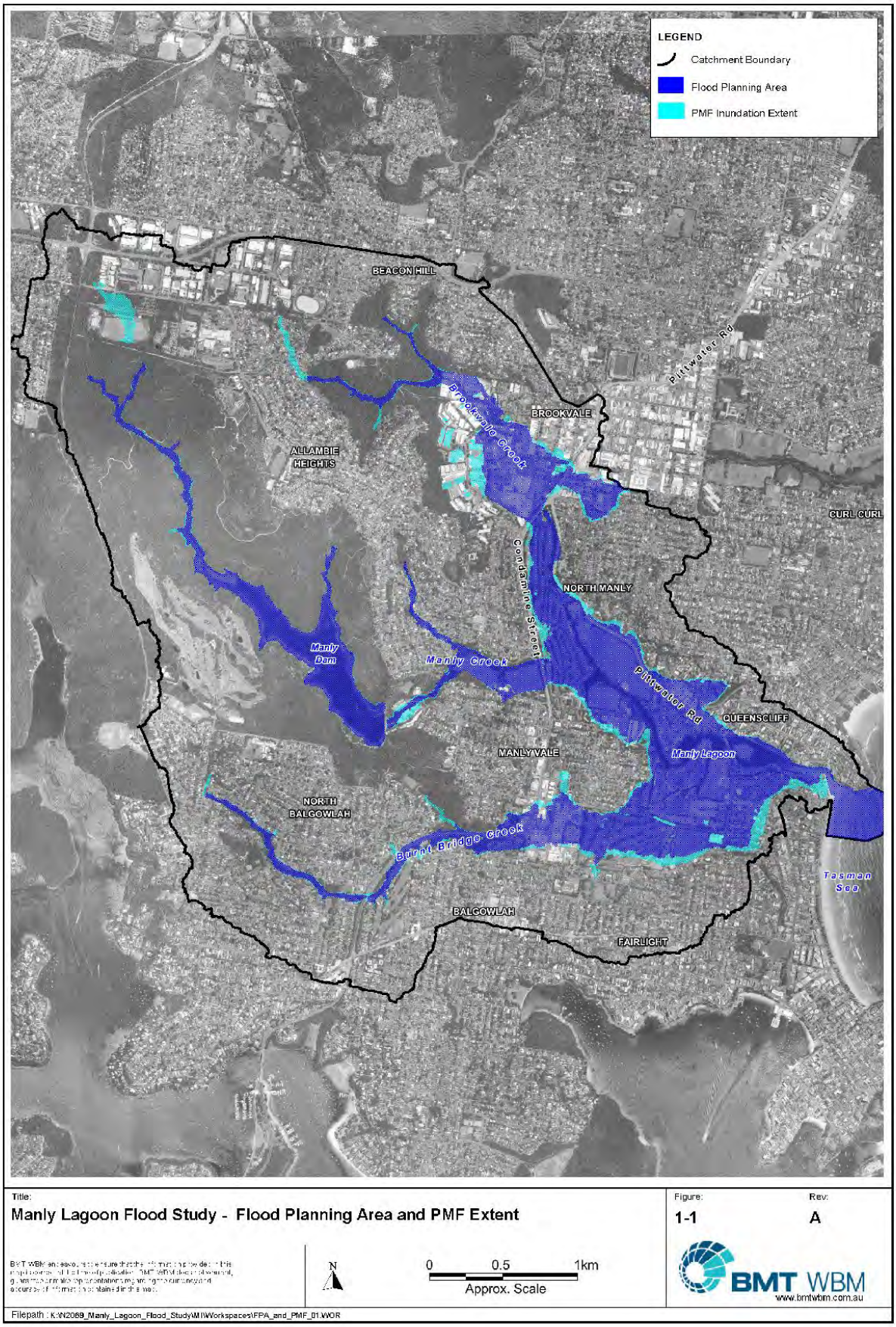
- Areas with depth of flooding at the 1% AEP magnitude less than 0.15m are not included;
- Overland flowpaths with minor flows (velocity x depth product < 0.2 m^2/s) are not included;
- Overland flow path defined using above filters are required to be contiguous; and
- Properties with less than 2% of the cadastral lot area within the FPA are not included.

1.3 The Probable Maximum Flood

The Probable Maximum Flood (PMF) is the largest flood that could conceivably occur at a particular location, incorporating the worst flood producing catchment conditions. The PMF defines the extent of flood prone land, that is, the floodplain (NSW Floodplain Development Manual, 2005).

Whilst flood-related development controls for residential development are only applied to new development on land below the FPL, consideration is also given to rarer floods up to and including the PMF event in certain other circumstances. Typical examples of where floods of this magnitude are used to inform floodplain risk management actions include emergency management and response activities, and siting of critical infrastructure (e.g. hospitals).

The PMF extent is shown in Figure 1-1. As with the FPA, consideration has been given to the magnitude and severity of local flow conditions in mapping the PMF extent. A similar filtering process has been adopted as for the FPA, albeit with a higher threshold of 0.3m for inundation depth.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QUEENSCLIFF
MANLY VALE
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2 REFERENCES

BMT WBM (2013). *Manly Lagoon Flood Study*. Prepared for Warringah Council and Manly Council, NSW.

Manly Hydraulics Laboratory (1992). *Manly Lagoon Flood Study Report MHL603*. Public Works Department NSW. Prepared for Warringah Council and Manly Council. NSW.

NSW Department of Infrastructure, Planning and Natural Resources (DIPNR) (2005) *Floodplain Development Manual*.

WARRINGAH COUNCIL

NOTES from

Manly Lagoon Catchment Coordinating Committee

The Manly Lagoon Catchment Coordinating Committee was held in the

Guringai Room, Warringah Council, Civic Centre, Dee Why on

25 July 2013

Todd Dickinson
Group Manager Natural Environment

Manly Lagoon Catchment Coordinating Committee

KEY CONSTITUTIONAL REQUIREMENTS	
Quorum	A quorum of the Committee shall comprise one Councillor from Warringah Council and one Councillor from Manly Council, or their nominees as well as four other members of the Committee.
Meetings	(i) Meetings of the Committee shall be held at the Manly Council Chambers or in the Committee rooms at the Warringah Council Civic Centre, on such dates and times as determined by the Committee. (ii) The Chairperson of the Committee may call a Special Meeting if in the Chairperson's opinion there are matters of urgency that require consideration. (iii) Notice of all meetings of the Committee shall be given by the issue of Notice of Meeting and Agenda, in accordance with Clause (x) hereof. (iv) Subject to Clause (ix) below, all members shall vote on each matter on the business paper, and if any member neglects or refuses to vote, such shall be recorded as a negative vote. (v) The Minutes of the Committee meeting shall be presented to both Warringah and Manly Councils for the consideration as soon as practicable after the meeting of the Committee. Any recommendations of the Committee shall not be deemed to be a decision of both Councils until such decision is adopted by the respective Councils. (vi) Any report of the Committee or any portion thereof, may be amended by the Councils in any manner they think fit, or may be referred back to the Committee for the further consideration. (vii) The decision of the Councils on the recommendations of the Committee shall be forwarded to Committee representatives. (viii) A member of the Committee shall not at meetings of the Committee vote on, or take part in the discussion of, any matter in which that person or any relation of that person, has, personally or by their partner, any pecuniary interest, **without declaring that interest.** (ix) The Committee shall not have power to incur expenditure or to bind the Councils, provided that if the councils have delegated to the Committee functions of inspection and supervision, any order which the Committee may find it necessary to give in pursuant of any such delegation shall be give to or through the General Manager.
Amendments to the Constitution	Amendments to the constitution shall only be made by a resolution of both Councils subsequent upon recommendation of the Committee and subsequent the agreement of the majority of organisations entitled to voting membership on the Committee.
Dissolution	Notwithstanding the Clause relating to Decision making hereof, the Committee may at anytime be dissolved and disbanded by a resolution of the Councils.

2013/222086

Notes

Manly Lagoon Catchment Coordinating Committee

Members of the Committee, namely:

Citizen members:

Cr Sue Heins	Warringah Council (Chairperson)
Cr Michael Regan	Warringah Council
Dr Helen Wilkins	Warringah Community Representative
Dr Frank Gleason	Warringah Community Representative
Mr Brian Murphy	Warringah Mall Management
Cr Candy Bingham	Manly Council
Cr Hugh Burns	Manly Council
Dr Judy Lambert	Manly Community Representative
Mr Terrence Murphy	Manly Community Representative
Mr Mike Baird MP	State Member for Manly
Mr Mark Roberts	Manly Lagoon Committee
Mr Chris Barry	Save Manly Dam Catchment Committee
Mr Michael Bradbery	Manly, Balgowlah, Wakehurst and Warringah Golf Clubs

State Government Representatives:

Mr Stan Rees	NSW Department of Primary Industries (Crown Lands)
Mr Gus Pelosi	NSW Office of Environment and Heritage
Mr Marcel Green	NSW Department of Primary Industries (Fisheries NSW)
Mr Norm Nikolich	Sydney Water
Mr Mark Simpson / Mr Tony Pinelli/ Mr Wayne Lyne	NSW State Emergency Services

Warringah Council Staff Representatives:

Mr Todd Dickinson	Group Manager Natural Environment
Mr Adrian Turnbull	Environmental Strategy Manager
Ms Jodie Crawford	Senior Environment Officer – Catchment
Mr Jason Ruszczyk	Environment Officer – Catchment

Manly Council Staff Representatives:

Mr Michael Galloway	Team Leader, Water Cycle Management Team
Mr Ed McPeake	Natural Resources and Community & Environmental Partner
Mr Patrick Stuart	Catchments Project Officer

All other Councillors are free to attend as Observers and are invited to do so and to engage in discussion, but not in voting in any matter before the committee.

Notes

Present:

Warringah Council Members

Cr Sue Heins (Chairperson)

Manly Council Members

Community & Stakeholder Representatives

Dr Judy Lambert – Manly Community Representative
Mr Terrence Murphy – Manly Community Representative
Dr Frank Gleason – Warringah Community Representative
Dr Helen Wilkins – Warringah Community Representative

Mr Mark Roberts – Manly Lagoon Committee
Mr Michael Bradbery – Manly, Balgowlah, Wakehurst and Warringah Golf Clubs
Mr David Parsons – Save Manly Dam Catchment Committee
Mr Richard Cox – Warringah Chamber of Commerce and Industry Inc.

State Government Representatives

Mr Gus Pelosi – OEH
Mr Stan Rees – DPI - Crown Lands
Mr Marcel Green – DPI - Fisheries
Mr David Buchtmann - SES

Council Advisors

Warringah:
Mr Todd Dickinson
Mr Adrian Turnbull
Mr Duncan Howley
Mr Jason Ruszczyk

Manly:
Mr Michael Galloway
Mr Patrick Stuart

In attendance:

Denise Regan – Minute Taker (Warringah Council)

Manly Lagoon Catchment Coordinating Committee

ACKNOWLEDGEMENT OF COUNTRY

1. APOLOGIES
Norm Nikolich, Cr Candy Bingham.

In accordance with the Terms of Reference of this Committee a quorum could not be reached in the absence of a Councillor from Manly Council or their nominated representative. The meeting could take place but no actions could be voted on or moved and only Notes could be produced.

2. CONFIRMATION OF MINUTES
The minutes from the meeting held on 21 March, 2013 could not be confirmed as there was not a quorum.

3. MATTERS ARISING FROM PREVIOUS MINUTES

6.2 Manly Dam water releases
Submitted by Mr Bradbery

UPDATE: Mr Turnbull, Warringah Council, gave an update advising that improvements have been made to the processes related to water releases from Manly Dam. These processes are working well and Council is confident that incidents of releasing water from the dam while blockages occur have been overcome.

A further update would be given under item 4.2 following.

6.4 Grant Investigations for Restoration of Manly Creek
Raised by Mark Roberts

UPDATE: Link had been forwarded as promised and Committee members confirmed that they had received the email however Mr Roberts requested that the link be resent see - http://www.sydneycoastalcouncils.com.au/Funding_Guide. A further update would be given under item 5.2 following.

4. GENERAL BUSINESS

4.1 Manly Lagoon Flood Study
Submitted by Warringah Council

The Chair welcomed Duncan Howley from Warringah Council who gave a presentation update on the Manly Lagoon Flood Study (Attachment 3). Mr Howley advised there had been a significant number of public submissions and these were being addressed as appropriate. He advised that the draft Flood Study would be sent out to this Committee prior to being submitted to Council for adoption.

Mr Bradbery questioned the correlation between opening Manly Lagoon and the release of water from Manly Dam in this Study. Mr Turnbull advised that these matters had been considered in the Study.

Dr Gleason suggested that climate change needed to be incorporated as this will affect sea level which can also influence floodwater levels due to potential changes in entrance conditions. He also congratulated both Councils on a job well done.

4.2 Draft Memorandum of Understanding for the Joint Management of Manly Lagoon and its Catchment (MoU)
Submitted by Warringah Council

Update given by Mr Ruszczyk who informed the committee that the updated MoU had been signed off by both Councils, as had a Project Agreement between both Councils for routine maintenance contracts related to Manly Lagoon. These two documents enabled Warringah Council to secure a five year permit from Fisheries for emergency clearance works should the low flow pipes become blocked with kelp. Warringah Council thanked Manly Council for the collaboration and Marcel Green for working with both Councils throughout and issuing the permit.

Mr Galloway agreed that having a good guiding principle in place would help towards successful projects taking place.

The Chair congratulated both Councils on achieving this success.

5. GENERAL BUSINESS

5.1 Dredging/Clearing the Mouth of Manly Lagoon at Somerville Bridge
Submitted by Mark Roberts

Mr Roberts raised his concerns regarding the amount of sand under and to the west of Stuart Somerville Bridge. He suggested that the accumulated sand was impeding tidal movement within the lagoon and that this was leading to a decline in water quality. He mentioned that dredging this area used to happen annually but had not been done for a number of years, and suggested that it is currently the ideal seasonal conditions for the removal of this sand.

In response, Mr Galloway spoke to a presentation (see Attachment 4) which illustrated the steady persistence and location of the sediment tongue at the lagoon entrance through a comparison of historic aerial photos (1930 to present) and a permanent datum as a reference point (red arrow and 1st casuarina). The aerial photographs indicate that the sand tongue has been present to the same extent since at least 1930. These images also suggested that the 2001,03 and 06 dredging operations had little long term effect as the extent of the sand appears to have returned to the same location within a year and similar to what has been displayed over the last 70 years.

Mr Galloway discussed the three dredging operations which took place in 2001, 03 and 06, and tabled two research papers investigating entrance clearance efficacy of these in Manly Lagoon:

- "Monitoring: The Last Step in the Estuary Management Planning Process" written by Danny Wiecek (Natural Resource Project Officer, Coasts and Estuaries, Department of Natural Resources), John Floyd (Senior Natural Resource Officer, Estuaries, Department of Natural Resources) and Paul Smith (Water Cycle Management Team Leader Manly Council) and,
- "Does Dredging in ICOLL Entrances Improve Tidal Flushing?" written by D, Wiecek and J. Flood from Department of Environment and Climate Change, Sydney NSW. (see Attachments 5 and 6).

In both these reports the results appear to suggest that entrance clearance works on all three occasions did not lead to any increase in tidal response/flushing and thus did not provide the stated environmental outcomes/benefits.

Mr Galloway also tabled the Minutes of the Manly Lagoon Catchment Coordinating Committee meeting held 14 December 2006 where the Committee noted that removal of small amounts of marine sand appeared to have little effect on improving tidal flushing (see Attachment 7).

Mr Turnbull provided a view of the current tidal movement within Manly Lagoon through the Northern Beaches Lagoon Watch website (please see http://new.mhl.nsw.gov.au/users/NorthernBeachesLagoonWatch/) which showed a high correlation between the Queenscliff and Riverview Parade water level gauges. This suggests that that there is currently no impediment to regular tidal patterns.

Both Mr Galloway and the Committee Chairperson noted that the Committee and both Councils should be clear on the objectives, benefits and costs of any proposed sediment removal, before undertaking such works. It is noted that if the objective can only be related to aesthetic benefit rather than environmental outcomes, then the ability to seek additional grant funding from the Office of Environment and Heritage is severely constrained.

5.2 Sediment Build up in Brookvale and Manly Creeks
Submitted by The Hon. Mike Baird MP

Minister Baird requested the issue of sediment build-up in Brookvale and Manly Creeks be raised at the next Manly Lagoon Catchment Coordinating Committee meeting on 25 July.

Both these creeks exhibit the same degradation that was identified for Burnt Bridge Creeks which has since had rectification work carried out. These include:

- *Poor water quality*
- *Extensive weed infestation. Ludwigea peruviana, Acestosa, Taro, Cape Ivey, Morning Glory Vine, Madiera Vine, Castor Oil Plant, Palm Grass and an aquatic weed Brazilian Milfoil that infests the weir adjacent to the Condamine Street Bridge*
- *Erosion of creek banks*
- *Massive build-up of sediment*
- *Reduced biodiversity.*

Both these creeks run through and adjacent to Warringah Golf Club and they have contacted Minister Baird in relation to the impact the above issues are having on the course and eventually upon Manly Lagoon itself. Minister Baird has approached the Environment Minister on behalf of the Club seeking funding to address the sediment build up. Minister Parker has advised that given the terms of reference of the Committee already cover the catchment, you have interests in the above and could provide further information on the following:

- *Have any funds been allocated for rectification work on either Manly or Brookvale creeks?*
- *Has a review of either creek taken place?*
- *Is any work scheduled for either Brookvale or Manly Creeks?*
- *Are there any funds still available to the committee or have they been fully expended?*

The agenda submission from The Hon. Mike Baird was reviewed and address by Mr Turnbull.

Mr Turnbull noted the comparison of Brookvale and Manly Creeks with respect to recent works undertaken in Burnt Bridge Creek, and discussed the geographical location of Burnt Bridge Creek and Manly Lagoon as adjoining two Local Government Areas. This situation makes them eligible for significant State Government grant contributions that enabled recent restoration works.

Neither Manly nor Brookvale Creek are in this position, however Council is willing to undertake further creek restoration works should State Government funding become available.

- *Have any funds been allocated for rectification work on either Manly or Brookvale creeks?*

  WC applied for grant funding in March 2013 from the Sustainable Environment stream of the Caring for our Country program to undertake works, Council is expecting to be notified soon as to whether this application has been successful.

  Components of the proposed grant funded project include bank stabilisation works on Brookvale Creek (adjacent to the 6th Hole site of Warringah Golf Course), and general weed control contracts for both creeks.

  The question of Warringah Mall's redevelopment was raised, Mr Dickinson advised that he was aware that a Development Application had been submitted, that the stormwater asset and GPT at Condamine/Pittwater Rd junction will be upgraded, but did not know any other details.

- *Has a review of either creek taken place?*

  Yes, both Manly and Brookvale Creeks were reviewed within the comprehensive Warringah Creek Management Study (2004), which included an evaluation of the state of the creeks and their catchment values. Significantly, it ranked catchments as being in 'Group A' of high ecological condition, 'Group B' of moderate condition and high sensitivity to change, and 'Group C' being the most significantly impacted.

  High priority for Council is protect and manage those creeks which are of high value (Groups A & B), as even modest increases in development are likely to lead to substantial declines in creek values. It is noted that both Manly and Brookvale Creeks are within Group C catchments, and while recognised as being in degraded condition, are in a relatively stable state and as such are a lower priority for Council funding when LGA wide catchment management is considered.

  In addition, Council monitors creek condition and prioritises works as appropriate. This prioritisation has resulted in the Caring for our Country grant application noted earlier to undertake bank stabilisation works on Brookvale Creek (adjacent to the 6th Hole site of Warringah Golf Course), and general weed control contracts for both creeks.

- *Is any work scheduled for either Brookvale or Manly Creeks?*

  Yes, current scheduled works include:

  1. Brookvale Creek riparian bush regeneration contract - targeted weed control. Ludwigea peruviana, Acestosa, Taro, Cape Ivey, Morning Glory Vine, Madiera Vine, Castor Oil Plant, Palm Grass

  2. Continuation of Gross Pollutant Trap cleaning contracts

3. Passmore Reserve (Brookvale Creek) bush regeneration contract
4. David Thomas Reserve (Manly Creek) bush regeneration contract – the vegetation regrowth has been slow following a hazard reduction burn in May last year perhaps due to high levels of disturbance. Please see additional discussion below.

In addition, if Council is successful in its Caring for Our Country grant application – those works described earlier (Q1) will also be undertaken.

- *Are there any funds still available to the committee or have they been fully expended?*

The Manly Lagoon Catchment Coordinating Committee is an advisory body to both Councils, and as such does not have delegated financial control.

- *Additional discussion*

The issue of Crown land parcels in Manly Creek adjacent to Manly Dam was raised and Warringah Council staff responded, advising:

A Notice of Motion was raised by Cr Harris to go to 24 April 2012 Council meeting. It was resolved that a short report be prepared for 24 July 2012 meeting outlining future management options for 4 parcels of Crown land along Manly Creek.

This report recommended that the 2 parcels in good condition should continue to be managed by Council on behalf of the Crown, and that a letter requesting landowners consent be sent. To date Council has not received a response to this request. These 2 parcels contain both Public Recreation and Low Density Residential zonings. This was a result of a direct translation of WLEP2000.

There are no requirements for "transfer of management" of the 2 parcels in order for Council to manage them. Council will continue to manage the 2 parcels to the best of its ability within available resources. The remaining 2 parcels were considered to be degraded and therefore it was not appropriate for Council funds to be expended on land of lower conservation value that it does not currently manage.

5.3 Burnt Bridge Creek Update and WSUD Development Controls
Submitted by Manly Council

Mr Galloway discussed the successful works completed at Manly West Park sediment basin (354.9 tonnes) from lower Burnt Bridge Creek, and the proposed removal of accumulated sediment (300 tonnes) from upper Burnt Bridge Creek. He also discussed water sensitive urban design development controls in the Manly LEP/DCP 2013.
Note - PowerPoint presentation was unable to be viewed therefore it was agreed that it would be included in notes for information, see Attachment 8.

5.4 Sydney Water Update
Submitted by Norm Nikolich

Sydney Water Community Update for June was noted see Attachment 2.

5.5 New Business

The Chair thanked Dr Frank Gleason for his published study on *Ecological roles of zoosporic parasites in blue carbon systems* which was forwarded to Committee members prior to the meeting. Committee members congratulated Dr Gleason on his efforts.

6. NEXT MEETING
Meeting schedule to be confirmed as follows:

Thursday, 5pm on:

21 November, 2013
6 March, 2014

There being no further business the meeting closed at 6:40 pm.

Attachment 1

Indicative Map showing the extent of Manly Lagoon Catchment.

The catchment draining to Manly Lagoon is approximately 18 square kilometres, and includes the suburbs of Balgowlah, North Balgowlah, Allambie Heights, Manly Vale, North Manly, Queenscliff, or parts thereof, as well as Manly Dam, four Golf Courses, and Warringah Mall.

Attachment 2

Sydney WATER

Northern Beaches Storage Project

Community update – June 2013

The Northern Beaches Storage Project (NBSP) team is completing construction work to connect the tank to the Narrabeen Submain

About the project

Sydney Water is building a wet weather wastewater overflow storage tank at 27 Sydenham Road, Brookvale.

Belowground pipes running down Chard and Sydenham Roads will connect the tank to the Narrabeen Submain under Winbourne Estate.

This is called the Northern Beaches Storage Project (NBSP).

Construction started in September 2011 and should be finished by mid 2013.

Work hours

Our normal work hours are between 7 am and 6 pm, Monday to Friday and 8 am to 1 pm on Saturdays, if required.

However, we will need to extend our hours and work longer days at certain times to meet engineering and construction needs such as concrete pours, deliveries and removal of heavy plant.

On site construction update

The construction of the storage tank is now complete and the testing of the tank is continuing.

We have:

- built an electrical control building
- almost finished the belowground pipework around the tank
- continued the mechanical and electrical work in the pumping station and tank
- finished the external brickwork

Work in June and July 2013

We will:

- finish the mechanical and electrical work in the pumping station and tank
- install a roof membrane
- start to restore the area around the tank including landscaping and fencing.

Testing the tank

In April, we filled the tank with clean water to check the external walls.

You may have noticed some damp spots or water on the walls. This is normal for concrete tanks and indicates where additional sealing is needed. We are currently carrying out some sealing work.

We are also testing the underground pipes and the pumping station. The testing will continue until July and then we will empty the tank and prepare for service.

Chard Road update

Work on the off-take chamber in Winbourne Estate's driveway in Chard Road is still progressing.

We have:

- excavated around the Narrabeen Submain
- continued to build the large chamber that will connect the pipes to the storage tank and the Narrabeen Submain
- continued to carry out noisy work at night to reduce the disruption to neighbours.

SW353 6/13

Sydney WATER

Work in June and July 2013

We will

- finish building the large off-take chamber that will connect the pipes to the storage tank and the Narrabeen Submain
- complete the restoration work at the end of Chard Road and in Winbourne Estate.

During the work, about five car parking spaces have been temporarily removed at the end of Chard Road so that traffic control can manage pedestrians and vehicle movements around the site.

Work to connect the electricity to site

On **Saturday 15 June and Sunday 16 June 2013**, Ausgrid will be connecting the site to the electricity grid.

We will

- dig a trench in front of our site on Chard Road to lay a cable
- connect the overhead supply into the site
- remove five parking spaces outside our site.

The work will take two days to complete, weather permitting. We will work between 8 am and 5 pm.

While we do not expect there to be any disruption to the service, Ausgrid will notify any affected customers.

Sydenham Road update

The work on Sydenham Road is now almost complete.

Work to install an electrical cable along Sydenham Road

On **Saturday 29 June 2013**, we will be installing an electrical cable into the existing conduit that runs along the southern side of Sydenham Road.

This will involve:

- opening the cable pits in the road to feed an electrical cable from our site to Winbourne Estate
- removing parking along the southern side of Sydenham Road for the day.

The work will take one day to complete, weather permitting. We will work between 8 am and 5 pm.

We apologise if this causes any inconvenience.

We will also be working in Winbourne Estate to install level sensing equipment and complete the connections of the tank to the Narrabeen Submain.

Deliveries to site

We will continue to use the No Stopping zone outside our site on the northern side of Sydenham Road. This zone takes up five parking spaces and is used for deliveries.

Additionally, when we have large trucks, cranes or concrete deliveries, we may also need to use about five parking spaces on the southern side of Sydenham Road. We will only take these spaces on the days that we need them.

The finished tank

In the coming weeks, you will notice us restoring the site and beginning to add landscaping along Mitchell and Sydenham Roads.

Figure 1 Artists impression of the landscaping

Towards the end of the project we will also install:

- a street artwork wall which a local artist has been commissioned to paint
- smooth impact resistant and graffiti resistant panels on the remainder of the walls.

To know more

When complete in 2013, the NBSP will reduce the number of times that wastewater overflows into local waterways during heavy rain. It is part of Sydney Water's SewerFix Program to improve the wastewater system and protect public health and the environment.

To know more about the NBSP or what to expect during construction:

Visit Sydney Water Talk, a new online engagement site, on http://sydneywatertalk.com.au/nbsp

Visit: sydneywater.com.au under 'Major Projects'

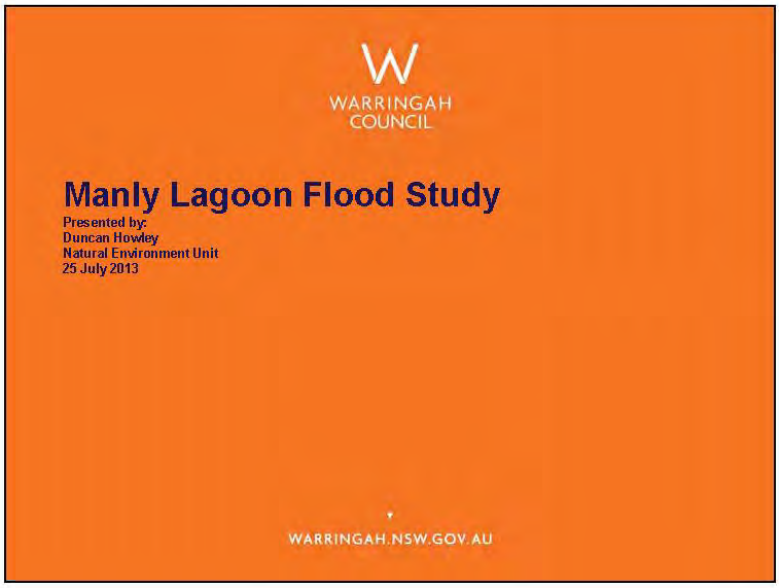
Call: Kelly Unsworth on 1800 656 340

Email: **nbsp@sydneywater.com.au**

In an emergency, call Sydney Water on 13 20 90.

Attachment 3


WARRINGAH
COUNCIL
WARRINGAH.NSW.GOV.AU


WARRINGAH
COUNCIL
Manly Lagoon Flood Study
Presented by:
Duncan Howley
Natural Environment Unit
25 July 2013
WARRINGAH.NSW.GOV.AU

1

Manly Lagoon Flood Study

- Council resolved on 23 April 2013:

9.6 PUBLIC EXHIBITION OF THE FINAL DRAFT MANLY LAGOON FLOOD STUDY

080/13 **RESOLVED**

Cr Regan / Cr Gobert

That Council approves the Draft Manly Lagoon Flood Study (March 2013) to be placed on public exhibition for a period of 28 days.

RESOLVED BY EXCEPTION

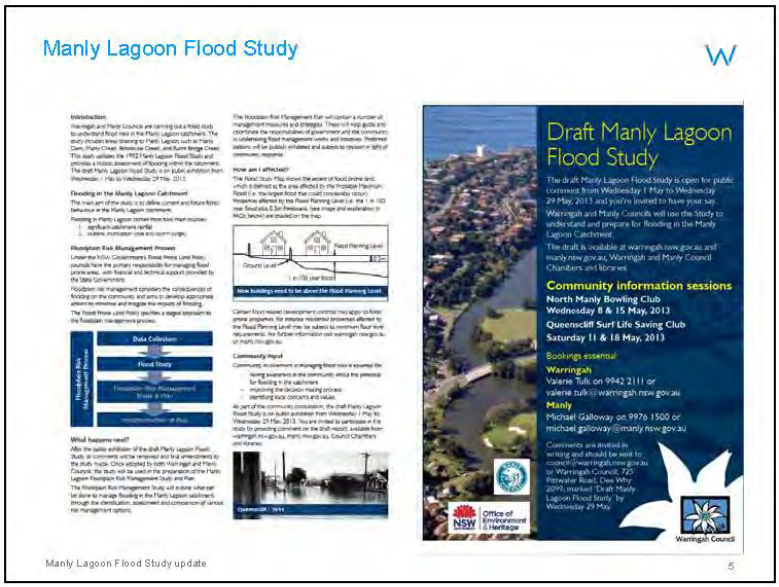
- Public Exhibition: 1 May to 29 May

Manly Lagoon Flood Study update 3

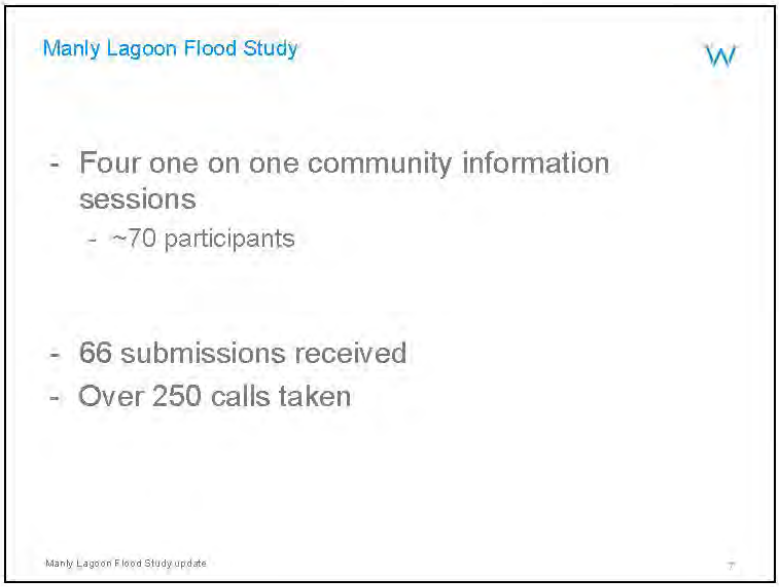
Manly Lagoon Flood Study

- Participation encouraged through:
  - ~6000 Letters and brochure to Warringah and Manly residents
  - Community engagement email
  - One-one-one information sessions
  - Site inspections

Manly Lagoon Flood Study update 4


Manly Lagoon Flood Study
Draft Manly Lagoon Flood Study
The draft Manly Lagoon Flood Study is open for public comment from Wednesday 1 May to Wednesday 29 May, 2013 and you're invited to have your say.
Warringah and Manly Councils will use the Study to understand and prepare for flooding in the Manly Lagoon Catchment.
The draft is available at warringah.nsw.gov.au and manly.nsw.gov.au, Warringah and Manly Council Chambers and libraries.
Community information sessions
North Manly Bowling Club
Wednesday 8 & 15 May, 2013
Queenscliff Surf Life Saving Club
Saturday 11 & 18 May, 2013
Bookings essential
Warringah
Valerie Tulk on 9942 2111 or
valerie.tulk@warringah.nsw.gov.au
Manly
Michael Galloway on 9976 1500 or
michael.galloway@manly.nsw.gov.au
Comments are invited in writing and should be sent to council@warringah.nsw.gov.au or Warringah Council, 725 Pittwater Road, Dee Why 2099, marked 'Draft Manly Lagoon Flood Study' by Wednesday 29 May.
Office of Environment & Heritage
Warringah Council
Manly Lagoon Flood Study update
5

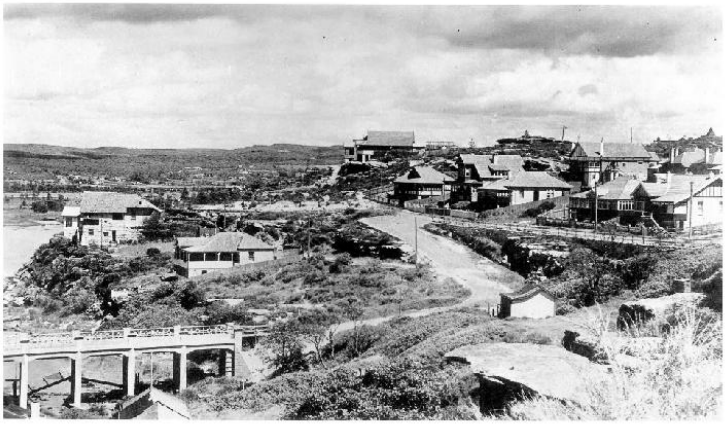

Manly Lagoon Flood Study
Warringah Council
Manly Lagoon Flood Study
About the Study
Community Consultation
Climate Change
Next Stage
Frequently Asked Questions
Contact
About the Study
Warringah Council in partnership with Manly Council has been carrying out a flood study to define the existing flood behaviour in the Manly Lagoon catchment. This study will establish the basis for subsequent floodplain management activities and has been prepared to meet the objectives of the NSW State Government's Flood Policy. The study considers the potential flooding impacts of climate change in line with current State policy and best practice.
Warringah Council has been administering the project with input from Manly Council. BMT WBM, an independent company specialising in flooding and floodplain risk management, has undertaken the study.
The NSW Office of Environment and Heritage is providing financial and technical assistance.
Submissions close Wednesday, 29 May 2013
Visit the Community Consultation tab for more information on how to make a submission and to find out how to make an appointment should you wish to discuss your property in person.
The following documents are now available for public comment, and can be obtained by clicking on them:
Draft Manly Lagoon Flood Study Report
Mapping Compendium
Flood Planning Level Report
Further information about the study can be found at:
Community Guide to the Manly Lagoon Flood Study
Manly Lagoon Flood Study update
6


Manly Lagoon Flood Study
- Four one on one community information sessions
- ~70 participants
- 66 submissions received
- Over 250 calls taken
Manly Lagoon Flood Study update
7


Manly Lagoon Flood Study
- What's next?
- Finalisation of Flood Study Report
- Floodplain Risk Management Study and Plan
Manly Lagoon Flood Study update
8

Attachment 4

1920s



1925

1

1999

1930

2

1940

1951

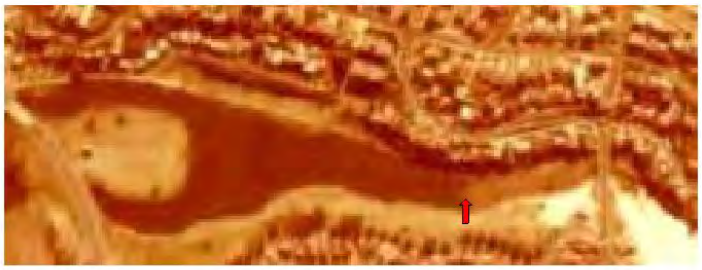
3

1961

1970

4

1977



1982

5

1990

1998

6

2001

2008

7

2011

July 2013

8

Attachment 5

DOES DREDGING IN ICOLL ENTRANCES IMPROVE TIDAL FLUSHING?

Wiecek, D[1] and Floyd, J[1]
[1]Department of Environment and Climate Change, Sydney, NSW

Abstract

Dredging of marine flood tide deltas in selected NSW intermittently closed and open lakes and lagoons (ICOLLs) is carried out by local councils for reasons including reducing foreshore flooding of infrastructure, improving tidal flushing and water quality, and enhancing aquatic biodiversity through increased recruitment. However, due to the difficulty and expense of monitoring these perceived improvements, there is little information available supporting the effectiveness of these dredging programs, with only potential flood mitigation benefits validated via modelling so far. Given the cost of these dredging operations and their potential to negatively impact on the lagoon, the importance of quantifying what improvements are obtained in terms of improving water quality, aquatic biodiversity, and flood mitigation is crucial to making decisions about the overall benefit of the dredging compared to other management alternatives.

As many ICOLLs now have continuous automatic water level recorders, the water level data obtained can be analysed using tidal harmonic analysis to provide a cheap and informative method of comparing tidal response before and after dredging operations to indicate changes in tidal flushing. Case studies from Manly and Narrabeen Lagoons on the northern beaches of Sydney are used to determine what effect dredging has on tidal flushing using the method of tidal harmonic analysis. Dredging programs at both these lagoons remove the intermittent marine sand build up that shoals the lagoon entrance and can eventually lead to closure. The dredging is carried out for the purposes of flood mitigation, enhancing tidal flushing to improve water quality, and increasing aquatic biodiversity. The results of the analyses and the importance of monitoring and review of management programs are discussed.

Introduction

Artificial opening of ICOLL entrances to provide a temporary connection to the ocean occurs at more than 50% of ICOLLs in NSW (Haines, 2006). Such artificial openings are mainly done to limit the impacts of flooding with other reasons including improving water quality and allowing for fish and prawn recruitment. These artificial openings occur through excavation of a pilot channel through the entrance sand bar, which then expands through the outflowing water scouring a larger channel that can remain open for days to months. An extension of this artificial intervention is the dredging (defined as the mechanical removal of sediments in a waterway and disposing of them at a different location) of marine flood tide deltas that build up in the entrance channel to increase the length of time an ICOLL remains open, and assist in successful breakout of the lagoon when the entrance closes. This is a practice that is employed at both Manly and Narrabeen Lagoons on Sydney's Northern Beaches for the purposes of flood mitigation, enhancing tidal flushing to improve water quality, and increasing aquatic biodiversity (Patterson Britton and Partners, 2003a; Cardno Lawson Treloar, 2006).

Although clear benefits in terms of reducing flooding impacts have been shown from modelling changes as a result of entrance dredging to lagoons such as Narrabeen (SMEC, 2002; WBM, 2002a), no information exists on whether the dredging has improved tidal flushing, water quality or increased aquatic biodiversity. Two of the main

reasons for this are that it can be hard to gain meaningful results over short periods of time in such highly variable systems, and it can be very costly to rigorously monitor water quality and biota before and after dredging. However, it would be useful to more accurately quantify changes to tidal flushing/water quality and aquatic biodiversity to be able to weigh up the benefits against potential environmental impacts of entrance dredging practices (Box 1) and the high financial costs. One way to more accurately quantify before and after change in entrance tidal flushing is to analyse changes in tidal response though tidal harmonic analysis.

Box 1: Potential environmental impacts of ICOLL entrance dredging

There are a number of potential environmental impacts that can result from dredging entrances of predominantly closed ICOLLs to create predominantly open conditions, ranging from short-term to long-term. Many of these impacts have flow on effects and resultant ecosystem changes.

Short-term impacts can include (the first three points are dependent of the type of sediment and are less likely in predominantly marine sand):

- Increases in turbidity through suspension of sediments that can smoother seagrass beds and clog fish gills;
- Suspension of sediments placing an oxygen demand on the water column resulting in anoxic events and potential fish kills;
- Release of contaminants contained within sediments with resultant water quality and habitat toxicity implications (highly urbanised ICOLLs only);
- Changes in water circulation patterns, tidal conveyance and strength of currents e.g. increased velocities can lead to direct removal of seagrass beds through scouring, and lower low tide levels can impact upon seagrass through increased exposure; and
- Direct removal of bottom-dwelling animals (benthos) leading to a reduction in available food for other species and processes such as nutrient cycling.

Long-term impacts can include:

- Marinisation of the ICOLL and lower fluctuation and/or lessening of environmental extremes in parameters such as salinity that can lead to changes in seagrass and fish communities, such as an increase in species adapted to more stable marine ecological conditions;
- Introduction and establishment of mangroves at the expense of existing foreshore communities such as saltmarsh; and
- A contraction in the areal extent of fringing wetlands due to invasion of the fringes by dryland adapted species as a result of reduced periods of prolonged inundation.

Assessing the tidal response from the entrance dredging - tidal harmonic analysis

To determine whether or not the dredging of the marine sand deltas at the entrances to both Manly and Narrabeen Lagoons result in improved tidal exchange between the lagoon and the ocean, water level data from continuous automatic water level recorders in the lagoons was obtained from Manly Hydraulics Laboratory (Queenscliff Bridge Manly Lagoon, and Ocean St Narrabeen Lagoon). These recorders monitor the

rise and fall in lagoon water levels as a response to tides, inflow from rainfall, and oceanic events. Because of the water level variations introduced from rainfall and oceanic events, the use of basic water level data to analyse 'pure' tidal variation (due solely to sun, moon and earth interactions and river tidal characteristics) in estuaries can be difficult, particularly if trying to compare differences before and after an event such as dredging. To obtain meaningful results from the water level data that removes the major rainfall and oceanic events, a technique called 'Tidal Harmonic Analysis' was used.

Tidal Harmonic Analysis is a technique applied to recorded water levels by which the various constituents or "building blocks" that make up the tide are calculated separately (see Box 2 on tides for details). If all the calculated constituents are added together, a close approximation of the original observed tide is produced. But it is useful to just look at the major tidal constituents that contribute most to the observed astronomical tide to compare how they vary between sites or with time. This provides an indicator of how tidal response may be changing, without the 'noise' associated with catchment and oceanic events.

To look at the dynamic behaviour of an estuary, the month to month changes in behaviour of the major constituents are best compared. As major tidal characteristics are related to the monthly lunar cycle, this is really the smallest period that is useful to consider for harmonic analysis. Even the monthly analyses involve a system that is changing over the month, which means that the harmonic results are still only an indicator of response, and not an exact measure. They indicate the average monthly tidal response. In this study, the method of harmonic analysis was extended by taking a monthly (30 day) analysis every 7 days. This provides a 'moving average' type set of results that reduce the errors due to non-tidal short-term changes on the water level. However, this method will not reduce errors due to long-term non-tidal effects where they occur over a significant proportion of the 30 day analysis periods.

M_2 – the main tidal component

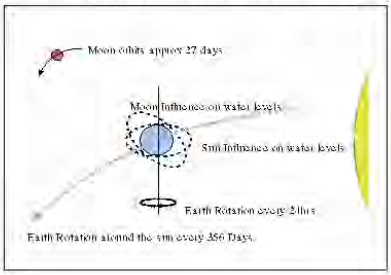
The major constituent of tides that was extracted from each analyses, that show the dominant changes in tidal behaviour is the "principal lunar semidiurnal constituent" (M_2) or main tidal component.

The M_2 constituent represents the dominant lunar influence in conjunction with the earth's rotation on the observed tide and is the major contributor to the tide. In the open ocean, the amplitude of this constituent is around three times the height of the next biggest constituent. Comparing the behaviour of M_2 over time provides an indicator of the tidal penetration into a system. For example, on the results graphs in the following sections, an increase in M_2 means an increase in tidal response and possibly increased tidal flushing.

Box 2: Tides

Tides are the end result of a number of astronomical interactions and the associated gravitational and inertial effects on the earth's surface water. The main influences being:

- the earth's spin,
- the earth's axis tilt,
- the moons orbit around the earth,
- the earth's orbit around the sun, and
- the combination and interactions between all these components and others.



These astronomical features and their interactions each represent a constituent or "building block", which when combined make up the observed tide. It is all these acting simultaneously that generate the tidal water levels we observe such as the twice daily high and low tides, fortnightly tides (where a lake system pumps up and down at spring and neap respectively) and the roughly six monthly King Tides, amongst others.

Understanding ICOLL entrance conditions and its control on tidal flushing

The condition (degree of openness) of the ICOLL entrance determines the tidal behaviour of the system, with maximum conveyance of the tide occurring in an open ICOLL when the entrance is well scoured. Increased tidal conveyance means that more water is moving in and out of the ICOLL every high/low tide cycle (i.e. the tidal prism is increased), which means that the tidal flushing capability is therefore also increased. However, whether or not this translates into improving ICOLL water quality greatly depends on factors such as waterway bathymetry, internal mixing, how much and for how long tidal flushing is increased (residence times), as well as the type and loads of pollutants entering the ICOLL from the catchment and how they are processed within a system (e.g. denitrification processes).

The condition of the ICOLL entrance is determined by four main factors: i) wave climate, ii) discharge of floodwaters, iii) flood tides, and iv) ebb tides. However, other factors such as longshore drift also play a role. To comprehensively understand a tidal harmonic analysis data series, it is therefore important to also have an understanding of wave climate and discharge of floodwaters over the same time period. Wave climate can be inferred by measured wave height. Flood discharge is expensive to measure, and therefore rainfall is used as an indicator of freshwater flow potential in this study. However, in other systems where a rain gauge may not be in close proximity, or for large river catchments where relatively uniform rainfall over the catchment cannot be assumed, this indication may not be as accurate.

Wave height data

Significant wave height data (designated as 'Hsig') for Sydney was obtained from MHL's waverider buoy located offshore of Sydney for the study period. Hsig is the average height of the waves which comprise the highest 33% of waves in a given

sample period (typically 20 to 30 minutes). As the significant wave height is an average of the largest waves over a recording period, it should be noted that some individual waves might be much larger than this.

This value is used in coastal and marine engineering because it is close to what a person will 'measure' by observation, without the benefit of time series data. Also, in many applications of wave data, larger waves are more "significant" (important) than smaller waves. For example, the larger waves in a storm cause the most erosion on a beach and can be responsible for causing considerable infilling of ICOLL entrances with marine sand. Direct sand infilling from littoral drift is linked to wave height (climate), and the potential sediment infill due to flood tides is also enhanced with increased bed stirring, as increased wave height leaves sediment suspended and more easily transported. This process can greatly exacerbate the closure of ICOLL entrances. This then has implications for tidal flushing, which can be reduced as the entrance channel shoals up with sand.

It is important to note that the direction of wave climate and location of near shore sand bars can have an effect on the degree that storm waves exacerbate sand infilling of ICOLL entrances. For example, if the entrance is protected by a headland immediately north or south, waves from this direction will have reduced height and energy at the shoreline through losses associated with refraction around the headland. Hence, two separate storms of the same Hsig with wave climate from two different directions, may not lead to the same level of infilling.

Rainfall data

Daily rainfall data for Middle Creek located in Narrabeen Lagoon catchment, and Allambie Heights located in Manly Lagoon catchment, was obtained from MHL over the study period. Rainfall in an ICOLL catchment can have a considerable bearing on entrance conditions, with relatively large inflows from heavy rainfall having the ability to scour large quantities of marine sand and transport it back to the near shore ocean environment. Conversely, drier periods of below average rainfall, such as has been experienced over the past 5 years over much of south-eastern Australia, can result in ICOLL entrances filling up with marine sand due to a decrease in scouring floodwaters, leading to a greater frequency and longer duration of entrance closure, which has been the case at a number of south coast ICOLLs (e.g. Burrill Lake).

In the comparisons to follow, the daily rainfall was accumulated into weekly rainfall, allowing for the fact that generally a single day rainfall event will not cause extensive scouring of the entrance to an ICOLL unless of very high intensity. Large runoff events are associated with rainfall of sufficient duration to saturate the catchment, then continued rainfall that will result in a greater proportion of water moving across the land surface as runoff rather than infiltrating into the soil profile.

Narrabeen Lagoon entrance dredging

Entrance dredging works

Narrabeen Lagoon is the largest of four ICOLLs located on the northern beaches of Sydney, having a surface area of 2km^2 and a catchment area of approximately 55km^2. The lagoon lies entirely within the Warringah Local Government Area, with the northern foreshore forming the boundary with Pittwater Council. A narrow channel approximately

2km long and typically 150m wide links the main body of the lagoon to the ocean. The lagoon is divided geographically into three distinct areas: the western basin, the central basin, and the eastern channel (Figure 1) (WBM, 2002b). The entrance to Narrabeen Lagoon is intermittently filled with marine sediment when the amount of sand moved into the lagoon entrance by the incoming tide exceeds the amount of sand removed by the outgoing tide. Prior to development, it is thought the lagoon was mostly closed to the ocean (Gordon, 2006).

Due to increasing urbanisation leading to water quality problems and foreshore flooding of properties, a policy of opening the lagoon entrance through entrance dredging works has been practiced since 1975. Eight major entrance dredging works have occurred to date roughly every three to four years, with volumes of material removed up to about 45,000m^3 and costs up to $800,000. The entrance dredging operations are a key action out of the Narrabeen Lagoon Floodplain Management Plan to minimise flooding to surrounding properties. The works are carried out according to the Narrabeen Lagoon Entrance Management Policy (Warringah and Pittwater Councils, 1996), which is currently under review.

The entrance dredging works involve the excavation of marine sediment from the entrance area of the lagoon, on the eastern and western sides of Ocean Street Bridge (Figures 2 and 3). The marine sediment that is excavated is firstly stockpiled and left to drain, then transported by truck to Collaroy/Narrabeen Beach where it is spread as minor beach nourishment (Figure 2).

Narrabeen Lagoon results of tidal harmonic analysis

Continuous water level data was available for assessment for the last four entrance dredging episodes. All four dredging episodes show a clear increase in tidal response of up to 8cm in the main tidal component (M_2), indicating that the dredging improves tidal conveyance into the lagoon. This would improve tidal flushing of the lagoon, particularly the eastern channel and to some extent the central basin. However, it should be noted that an improvement in tidal flushing may have limited benefits to water quality in the western basin of the lagoon, due to long flushing times (75 days for a mean spring tide, 110 days for a mean neap tide) and water quality largely being controlled by the quality of catchment runoff (WBM, 2000).

Detailed explanations of results for each dredging episode are discussed over the following pages, while a complete data series is provided in Appendix A. For all analyses, the top graph shows raw water level data from the Ocean St recorder. Second graph shows 7-day accumulated daily rainfall from Middle Ck, third graph shows the dredging period, the fourth graph shows the M_2 tidal component calculated from a 30 day analysis every 7 days, and the last graph shows significant wave height (Hsig). Data gaps in the Hsig time series indicate failure of instrumentation.

Figure 1: Locality map of Narrabeen Lagoon showing the three geographically divided distinct areas of the western basin, the central basin, and the eastern channel (figure from WBM, 2002b).

Figure 2: Extent of Narrabeen Lagoon entrance dredging area (left shot) (taken from the 2006 REF compiled by Cardno Lawson Treloar). The right photo is of sand nourishment on Collaroy/Narrabeen Beach supplied from the dredged marine flood tide delta.

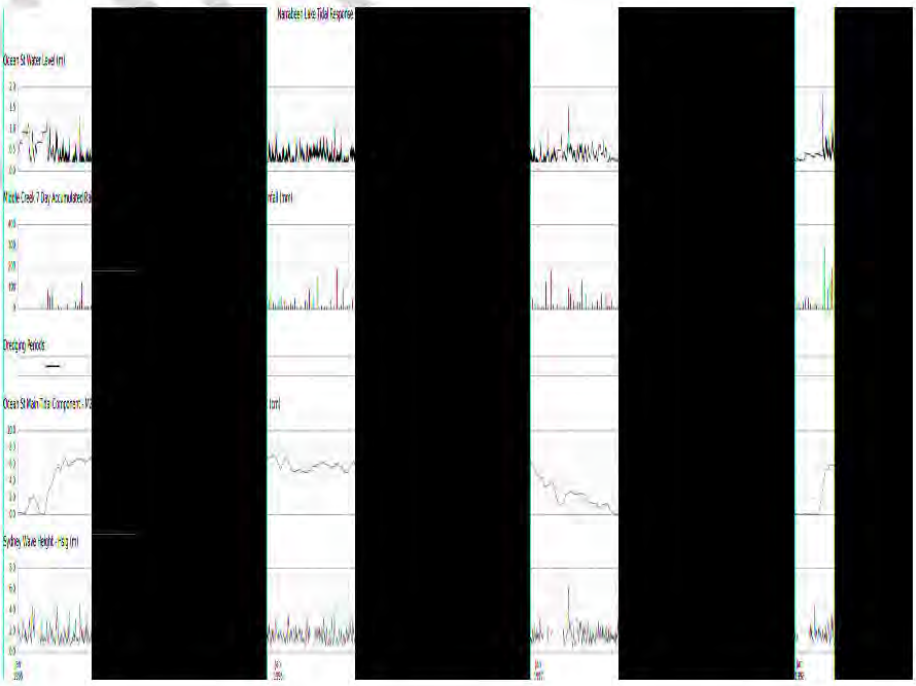
Figure 3: Dredging works in progress west (left photo) and east (right photo) of Ocean St Bridge in Narrabeen Lagoon.

1995 dredging

The 1995 dredging started in May and ran through till July. An immediate increase in tidal response is indicated by the rise in the main tidal component (M_2) from 0cm to over 6cm during and after the dredging. This indicates an improvement in tidal flushing. This improvement lasts till around November 1996, where M_2 starts to dip from 6cm until entrance closure in December 1997. The rise in M_2 in April 1998 associated with significant rainfall is discussed in the 1999 dredging analysis.

Two significant wave height (Hsig) events of about 4m in quick concession in November 1996, with a third event in January 1997, correlate with the dip in M_2. A large storm with a Hsig of over 6m occurred in May 1997, which corresponds to M_2 continuing to drop steadily afterwards until closure in December 1997. These storms would have been responsible for exacerbating the marine sand infilling of the entrance.

As the rainfall recorder only started operation at the end of April 1995, rainfall data could not be included before the dredging begun and correlations cannot be made between the rainfall and M_2. However, as the lagoon water level before dredging was significantly elevated, this would have helped to create a significant breach with associated scouring, most probably initiated by the dredging or significant possible rainfall not logged, which has helped raise M_2 during and after the dredging.

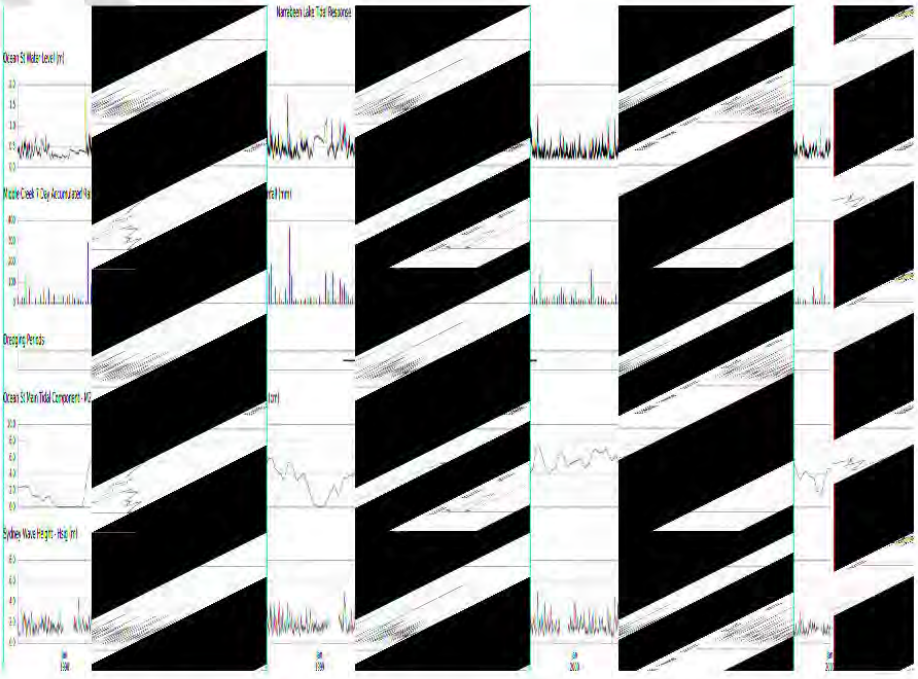


1999 dredging

The 1999 dredging (38,000m^3) started in April and was completed by July. After dredging was completed, M_2 significantly increased from around 2cm to just under 8cm, indicating a strong tidal response and likely improved tidal flushing. Significant rainfall and high water levels leading to breaching of the entrance occur in the months prior to dredging, which would have helped raise M_2 in conjunction with the dredging.

After the initial rise, three episodes of wave activity where Hsig is 4m or greater occur from July to September 1999, and appear to be responsible for a rapid decrease in M_2 from 8cm to 4cm. A period of high rainfall then corresponds to a recovery in M_2 of back to around 6cm, which lasts until June/July 2000. At this point lower rainfall conditions prevail and three Hsig events of 4m occur and M_2 drops to just under 2cm in November 2000. Significant rainfall events then correspond to a recovery in M_2 to around 4-5cm that is maintained until June 2002, which is the start of the next entrance dredging.

The other notable change to tidal response occurs in May 1998, where M_2 increases to 6cm as it did after the 1995 dredging episode. This corresponds to a period of significant rainfall and high water level of nearly 2m, which would have generated floodwaters and significant scouring potential resulting in removal of sand from the entrance channel. After the large rainfall events, M_2 drops to below 4cm but is again raised to just under 6cm by another significant period of rainfall in August. This is despite significant wave activity where Hsig is consistently 3-4m over a period of about four months. A period of low rainfall begins in September, which corresponds to a rapid drop in M_2 in October until entrance closure in December 1998. This shows that the scouring effects of heavy rainfall floodwaters can increase tidal response to the same degree as the entrance dredging, but in this case, the increase is short lived compared to the dredging.



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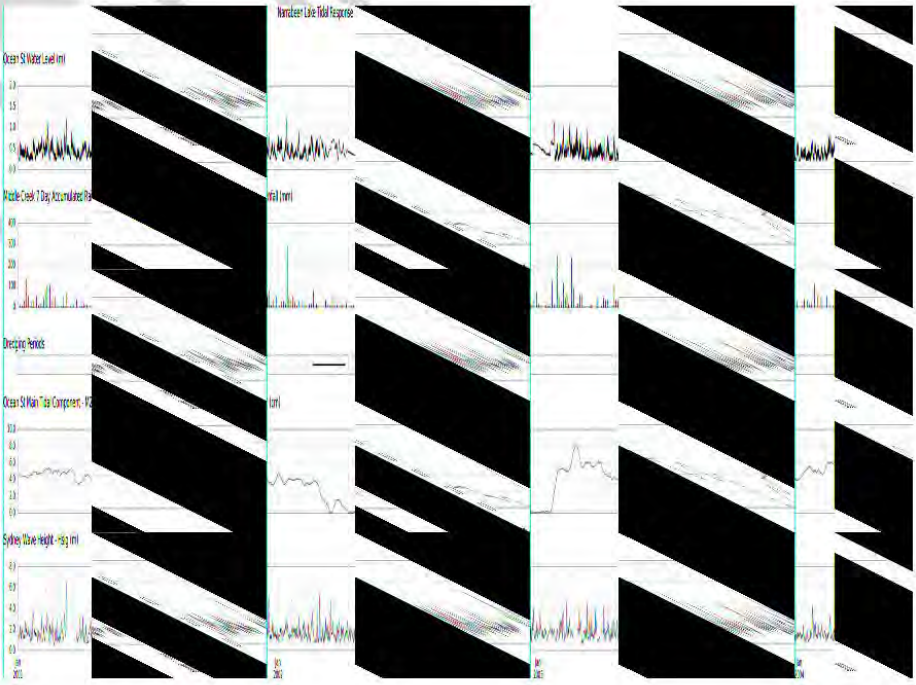
2002 dredging

The 2002 entrance dredging (38,000m^3) started in June and was completed in October. During the dredging operation around the end of June 2002, significant storms with Hsig greater than 5m occurred. These storms correspond to a dip in M_2 from 4cm to 0cm with entrance closure around August 2002. The effect of the storms on causing the dip in M_2 is supported by documentation of significant infilling of the completed dredged area occurring, in the post completion report for the 2002 dredging (Patterson Britton & Partners, 2003b). A survey of the completed dredged area had been completed just prior to the storms and another survey was carried out after the storms to assess their impact. The surveys showed that about 4000m^3 of sand infilled the entrance as a result of the storms over one weekend (Patterson Britton & Partners, 2003b).

After completion of the dredging in October, the lagoon remained closed until enough rainfall occurred to raise the water level to the artificial opening trigger level. This occurred in March 2003 and was followed by consistent rainfall until June resulting in M_2 increasing to 8cm.

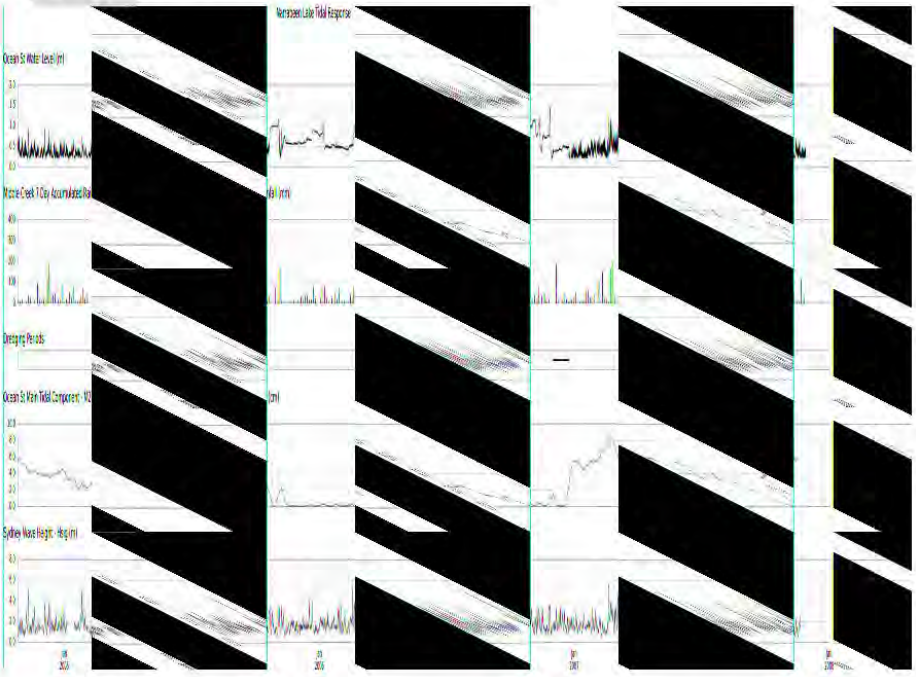


2006 dredging

The 2006 entrance dredging (45,000m^3) started in late September and was completed in early December. After completion of the dredging, M_2 initially decreased slightly from just under 6cm to just over 4cm in February 2007, before increasing in response to heavy rainfall to a maximum of 8cm in June.

The water level and M_2 show that the lagoon is predominantly closed from August 2005 to August 2006. The lagoon is opened through artificial breaching four times over this period, with the first three breachings at water levels of about 1.2m having no effect on M_2 due to rapid entrance closure. This correlates to a period of low rainfall with no significant rainfall events. It is only after the last artificial breaching in early September where rainfall raised the lagoon water level to about 1.5m, 0.3m above the normal opening trigger level, that a noticeable effect on M_2 is shown. This breaching was responsible for scouring about 6000m^3 of sediment from the entrance and resulted in the original entrance dredging amount proposed being reduced by the same amount (Warringah Council, 2006). This highlights the importance of setting opening trigger levels as high as possible to maximise scouring potential where this type of intervention is needed for flood mitigation purposes.

Significant storms, with Hsig up to nearly 6m, were experienced over the June 2007 long weekend and result in M_2 decreasing to below 6cm by August. Cameron and Morris (2007), who also are presenting a paper dealing with Narrabeen Lagoon entrance dredging at this conference, surveyed the entrance area shortly before and after these storms. Initial analyses report sediment infilling of around 2000m^3 on the flood shoal east of Ocean St Bridge (with corresponding shoal infilling west of Ocean St Bridge also found, but yet to be confirmed if all due to the storm), which would have been responsible for the drop in M_2. It is highly likely that the scouring effect of floodwaters from the significant amount of rainfall experienced at the same time as the storms would have countered the amount of infilling from large waves, which could have potentially negated the dredging.



Manly Lagoon entrance dredging

Entrance dredging works

Manly Lagoon is an ICOLL situated at the boundary of Warringah and Manly Council Local Government Areas in Sydney's northern beaches area. It has a catchment area of 18km^2 and a waterway area of 0.1km^2. The catchment is highly urbanised with about 60% of land use considered urban. The remaining land use is open space which includes two golf courses and playing fields adjacent to the lagoon. The Lagoon has a restricted outlet to the sea through a constructed low flow channel approximately 3.3m wide by 1.8m high at the northern end of Queenscliff Beach that allows permanent tidal exchange.

Historically, the lagoon's fringing wetlands where reclaimed for rubbish dumps and are now playing fields (Patterson Britton and Partners, 1995). This has resulted in a reduced tidal prism, and importantly flood storage volume. This reduced flood storage volume combined with the permanent tidal exchange through the low flow pipes, results in the loss of scouring potential that occurs when ICOLL water levels are raised high enough to breach the entrance berm and open the ICOLL to the ocean.

The Manly Lagoon Estuary Management Plan completed in 1998 describes the lagoons poor water quality as the fundamental environmental issue and as such water quality remediation is the primary focus of the Plan and its management strategies. One of the strategies outlined in the Plan to address water quality (and other) issues is for selective dredging/deepening of the lagoon. To implement this strategy, five sites within the lagoon have been identified for dredging works and are currently under consideration, including the entrance.

Since the adoption of the Plan in 1998, entrance dredging has occurred three times, with costs as high as $120 000 for dredging and disposal. The works involve the removal of marine sand (ranging from 1500m^3 to 6300 m^3) that has entered the lagoon under wave and tidal action upstream of the Queenscliff Bridge (Figure 3). Dredged sand is then used to nourish Manly Ocean Beach. The Statement of Environmental Effects (Patterson Britton and Partners, 2003a) for the works notes the benefits of the dredging as "The removal of marine sand would improve tidal exchange between the lagoon and the ocean, remove any restrictions to fish passage, and avoid continued sand migration upstream smothering aquatic vegetation".

Manly Lagoon results of tidal harmonic analysis

Continuous water level data was available for assessment of all three entrance dredging episodes. Unlike Narrabeen Lagoon, the dredging episodes do not show a clear increase in tidal response in the main tidal component (M_2). This indicates that the dredging is unlikely to improve tidal flushing of the lagoon. Patterns are evident for M_2 changing in relation to significant wave height (Hsig) events and large rainfall periods, but are not always as clear as they were for Narrabeen Lagoon. The low flow pipes that allow permanent tidal exchange into the lagoon appear to result in a fairly constant tidal regime, that is not noticeable effected by dredging, but can be lowered short term by sand infilling exacerbated by large waves, and increased short term by the scouring effects of heavy rainfall-induced flood discharges.

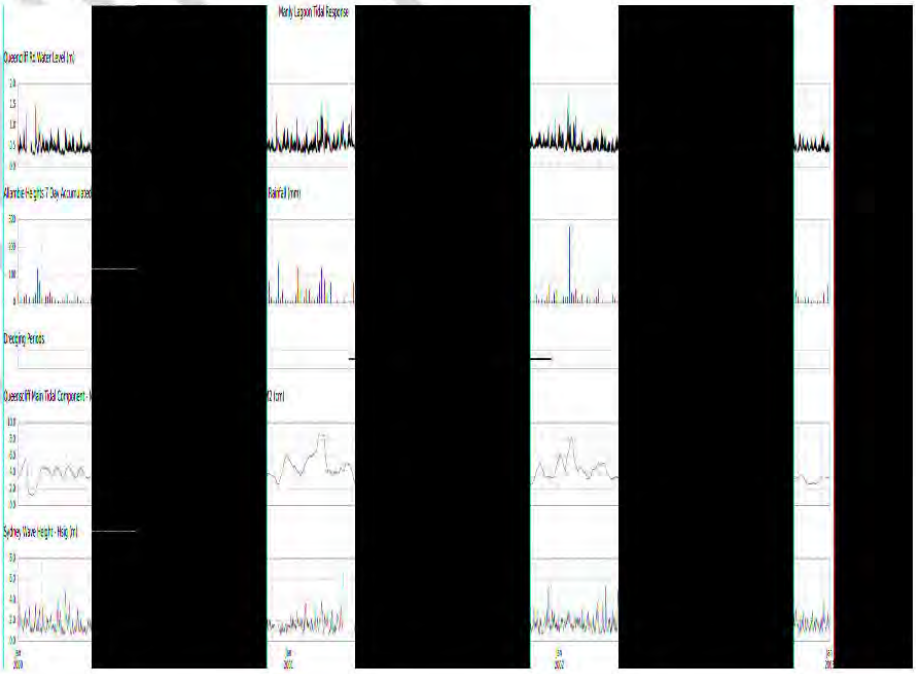
Detailed explanations of results for each dredging episode are discussed over the following pages, while a complete data series is provided in Appendix B. For all

analyses, the top graph shows raw water level data from the Queenscliff Bridge recorder. Second graph shows 7-day accumulated daily rainfall from Allambie Heights, third graph shows the dredging period, the fourth graph shows the M_2 tidal component calculated from a 30 day analysis every 7 days, and the last graph shows significant wave height (Hsig). Data gaps in the Hsig time series indicate failure of instrumentation.

Figure 3: Marine sand built up in the entrance area of Manly Lagoon before dredging, August 2005 (Top left). Dredging is done through a bulldozer pushing sand up against the shore then piled up by an excavator (Middle left). After the marine sand has been dredged, August 2006, showing the sand stockpile on the shore. Discoloration is due to estuarine fines (Bottom left). Signage produced by Manly Council illustrating the location of dredging, scope of works and the benefits of the dredging (right).

2001 dredging

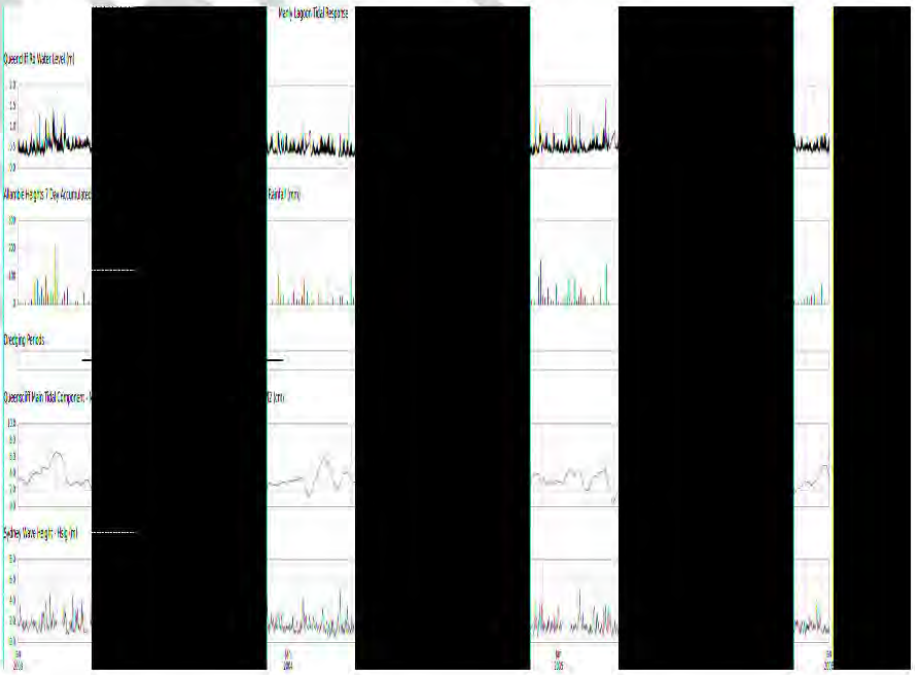
The 2001 dredging (1500m^3) started in August and ran through till early December. M_2 peaks twice over the displayed record indicating improvements in tidal flushing, both times corresponding with significant rainfall events (April/May 2001 and February 2002). There is a significant reduction in the tidal response in September after dredging started, but the cause has not been determined. There is no overall improvement evident comparing M_2 before and after dredging. On average over the graphed time period below, M_2 appears to fluctuate at around 4cm, such as from April to December 2000. It is slightly lower over the period from July 2002 to January 2003, possibly due to low rainfall and two Hsig events of about 5m over this period of time. Dominant increases in M_2 correspond to rainfall events only.



2003 dredging

The 2003 dredging (1500m^3) started in September and ran through till early December. M_2 peaks twice over the displayed record. The first corresponds to a significant period of rainfall in May 2003, where M_2 rises to over 6cm, with the second in May 2004 where M_2 rises again to about 6cm but does not correlate with any significant rainfall or dredging. There is no change in M_2 evident when comparing before and after dredging, which stays fairly constant at around 3cm. The three times when M_2 drops to about 2cm or under (March and July 2004, and April 2005) are all associated with Hsig events of 4-5m.

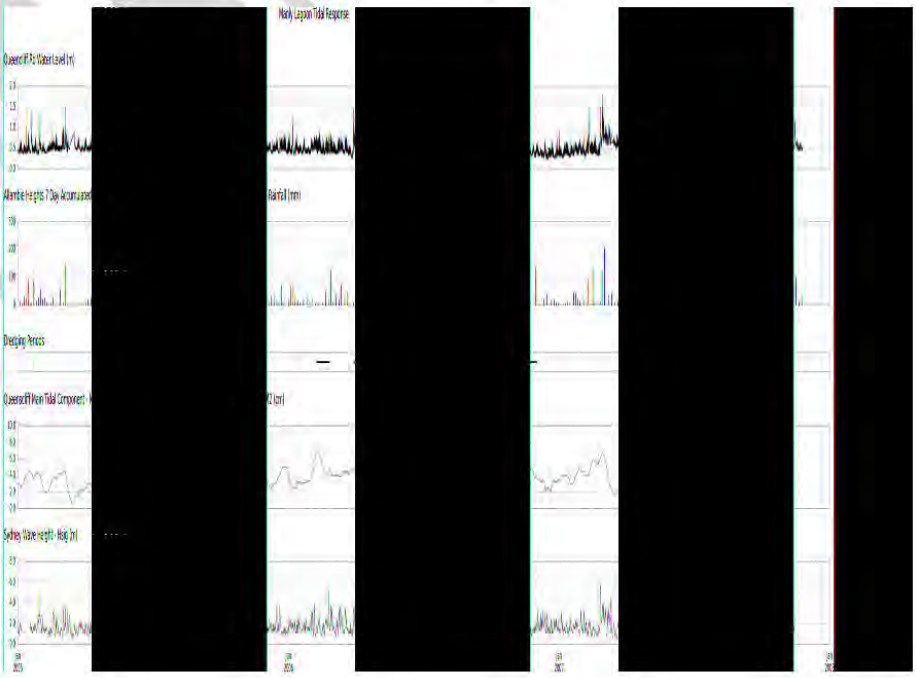
Over this period, we see the only closures/significant tidal restriction of the lagoon, which occur in March 2004 and August 2005 as shown on the Queenscliff Rd water level data plot. Due to the short term of the closure/restriction, a zero M_2 is not recorded due to a month long analysis period.



2006 dredging

The 2006 dredging (6300m^3) commenced mid April and was completed in two stages, the last finishing at the beginning of October. M_2 peaks twice over the period, corresponding to the start of the dredging in April 2006 (M_2 = 7cm) and towards the end of the data series in June 2007 (M_2 = 7cm), which corresponds to significant rainfall. It is doubtful that the dredging is responsible for the increase in April, as M_2 peaks right at the start of dredging, and throughout the first stage of dredging M_2 decreases to 4cm and remains at this level after the dredging. After the second period of dredging, that also coincides with a significant rainfall event, M_2 decreases to 2cm in November 2006, possibly due to a period of about six medium Hsig events. As with Narrabeen Lagoon, the significant storms over June where Hsig reaches about 6m and subsequent Hsig event of well over 4m in July correlate with M_2 decreasing to about 2cm.

As with the other two dredging episodes, it appears unlikely that the dredging has lead to any increase in tidal response.



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Conclusions

The results from the tidal harmonic analysis illustrate the differences in response to dredging, as well as from rainfall and storm events, between Narrabeen and Manly Lagoons. While a clear pattern of improvement in tidal response can be seen after the dredging at Narrabeen Lagoon, this is not demonstrated for Manly Lagoon. Hence, the entrance dredging program at Narrabeen Lagoon is likely to have tidal flushing as well as flooding benefits (albeit these can be short lived). However, at Manly Lagoon tidal flushing benefits are not apparent, as the low flow pipes are a major control on tidal response and limit the variation as a result of disturbances such as dredging and storm waves.

Another important result is that rainfall events which result in significant floodwaters and high lagoon water level, have the ability to increase tidal response to the same degree as the dredging at Narrabeen Lagoon, and appear to be the only means of increasing tidal response at Manly Lagoon. This also highlights the importance of setting ICOLL opening trigger levels as high as possible to maximise scouring potential where this type of intervention is needed for flood mitigation purposes.

Monitoring the effectiveness of a particular management approach is crucial to determining whether or not the desired outcomes are being met. The results from this study will help both the Narrabeen Lagoon and Manly Lagoon Estuary Management Committees weigh up the benefits versus costs and potential benefits and impacts of the dredging programs.

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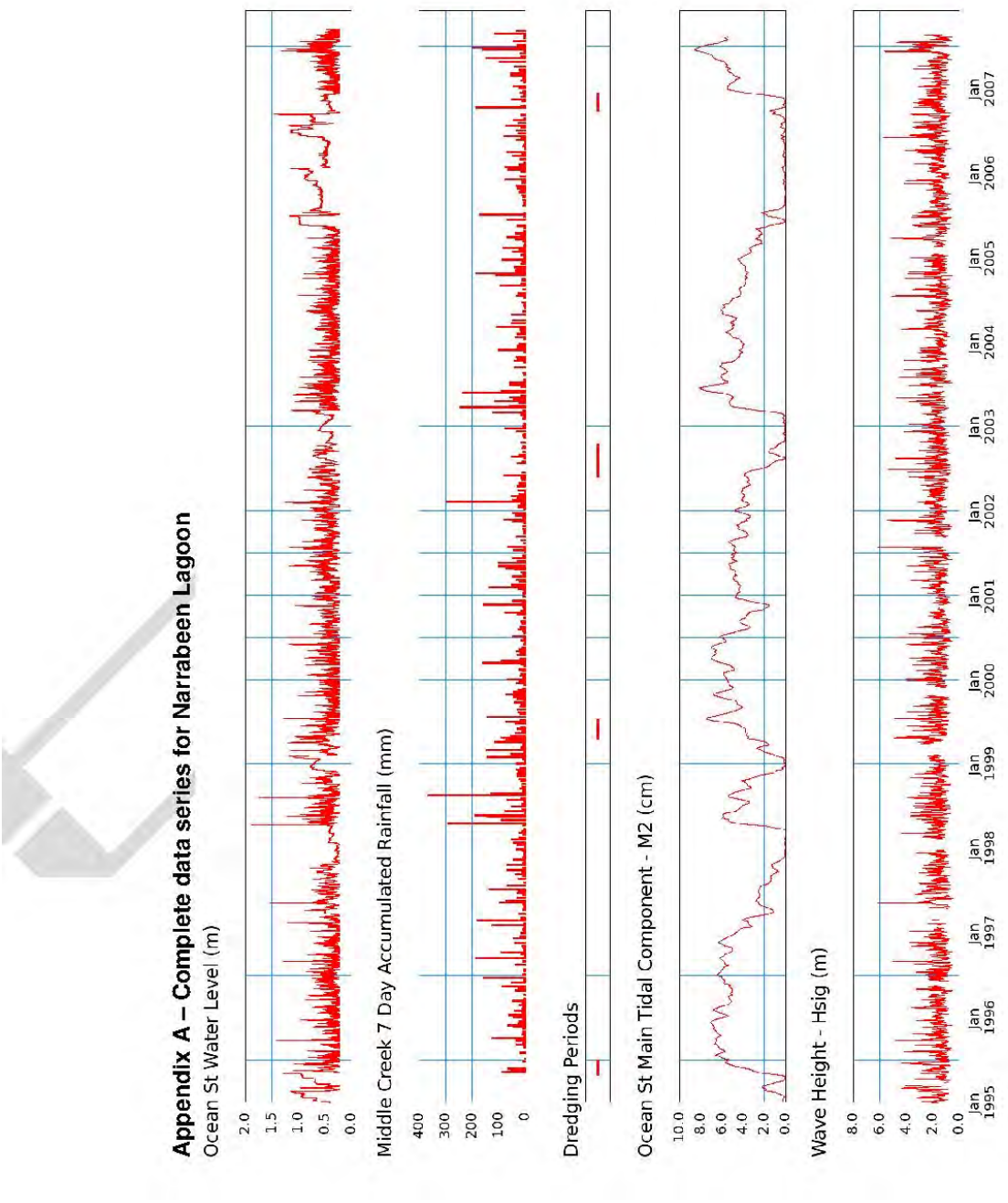
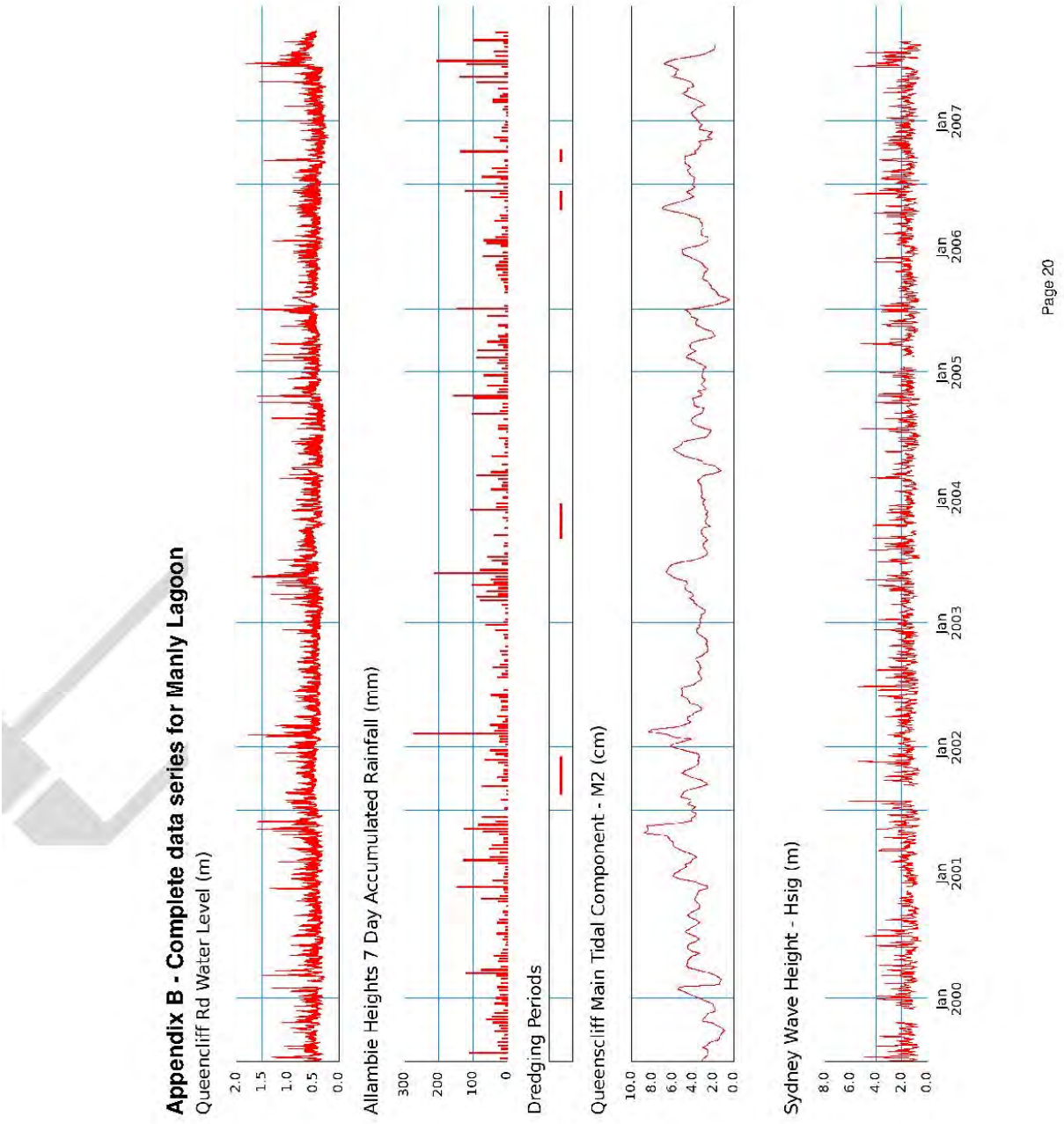

Appendix A – Complete data series for Narrabeen Lagoon
Ocean St Water Level (m)
2.0
1.5
1.0
0.5
0.0
Middle Creek 7 Day Accumulated Rainfall (mm)
400
300
200
100
0
Dredging Periods
Ocean St Main Tidal Component - M2 (cm)
10.0
8.0
6.0
4.0
2.0
0.0
Wave Height - Hsig (m)
8.0
6.0
4.0
2.0
0.0
Jan 1995
Jan 1996
Jan 1997
Jan 1998
Jan 1999
Jan 2000
Jan 2001
Jan 2002
Jan 2003
Jan 2004
Jan 2005
Jan 2006
Jan 2007
Page 19

Appendix B - Complete data series for Manly Lagoon



Attachment 6

Monitoring: The Last Step in the Estuary Management Planning Process?

Authors
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John Floyd (Senior Natural Resource Officer, Estuaries, Department of Natural Resources)
Paul Smith (Water Cycle Management Team Leader, Manly Council)

Summary

Monitoring and review is the 'last' of eight steps in the NSW Government estuary management planning process. In reality it is not the last but part of an iterative process. Monitoring and review is essential to determine if implementation of management actions is effective and providing the expected benefits and whether or not changes to the estuary management plan and its objectives are required. An example of monitoring and the analysis and interpretation of collected data is provided for Manly Lagoon, a small coastal lagoon on Sydney's northern beaches. Selective dredging in the lagoon is an action outlined in the estuary management plan completed in 1998. Dredging of a marine sand delta upstream of a constructed low flow channel at the entrance has occurred three times since 1998. With the lagoon suffering from poor water quality, the main perceived justification for the removal of the sand is that it will result in improved tidal exchange between the lagoon and the ocean thereby improving water quality. To test this, water level data obtained from two continuous automatic water level recorders in the lagoon were compared before, during and after the dredging for the three dredging episodes using harmonic analysis. The results show that tidal water levels in the lagoon are the same before and after dredging for two of the three dredging episodes, with only a small improvement in the third helped by frequent subsequent rainfall events. This has implications for other sites within the lagoon where dredging is also proposed to improve tidal mixing.

Figure 1: Aerial view of Manly Lagoon.

Estuary Management Planning and Monitoring Success

In NSW estuary management is coordinated through the Department of Natural Resources (DNR) Estuary Management Program, as described in the NSW Government Estuary Management Manual (NSW Government, 1992). The Manual describes eight steps to be followed for the development and implementation of an estuary management plan (EMP), with the final step involving monitoring and review to gauge the success or otherwise of implementation activities and revise the plan accordingly. With over 75% of the states estuaries now managed by Council Estuary Management Committees that coordinate the preparation and implementation of adopted EMPs, it is timely to highlight the importance of effective monitoring and review.

Monitoring and reviewing EMPs and their individual actions is crucial to determining whether they are successful and meeting intended outcomes, and if not, what needs to change. Reporting on the implementation of the EMP has numerous other benefits. It provides recognition of the work carried out to date and raises community awareness of estuary management issues, outcomes and achievements. Other reasons for undertaking monitoring activities include to:

- detect non-compliance with regulatory requirements,
- provide data for scientific analysis of environmental change over time,
- provide essential data for plan review, and
- facilitate ongoing improvements in management practice.

The information obtained by monitoring needs to feed into reviewing the EMP to determine whether the Plan's objectives remain valid, and whether the Plan's management practices remain appropriate for meeting those objectives. This will ensure continuing relevance in the face of emerging conditions and issues, improved understanding of estuarine processes and the benefits of particular management practices, new technologies, and shifts in community values, priorities and government policy.

Figure 2: Water quality monitoring occurring in a coastal lagoon.

Current Manly Lagoon Remediation

Manly Lagoon is an intermittently closed and open lake/lagoon (ICOLL) situated at the boundary of Warringah and Manly Councils in Sydneys northern beaches area. It has a catchment area of 18km^2 and a waterway area of 0.1 km^2. The catchment is highly urbanised with about 60% of land use considered urban. The remaining land use is open space which includes two golf courses and playing fields adjacent to the lagoon. The Lagoon has a restricted outlet to the sea through a constructed low flow channel approximately 3.3m wide by 1.8m high at the northern end of Queenscliff Beach that allows permanent tidal exchange.

Figure 3: The low flow channel at the entrance to Manly Lagoon.

The Manly Lagoon Estuary Management Plan completed in 1998 describes the lagoons poor water quality as the fundamental environmental issue and as such water quality remediation is the primary focus of the Plan and its management strategies. One of the strategies outlined in the Plan to address water quality (and other) issues is for selective dredging/deepening of the lagoon. The Plan also describes the means of assessing this strategy as undertaking water flow and flushing monitoring and a water quality monitoring program. To implement this strategy, five sites within the lagoon have been identified for dredging works and are currently under consideration.

Since the adoption of the Plan in 1998, dredging has only occurred at Site 5. The works involve the removal of marine sand (ranging from 1500m^3 to 6300 m^3) that has entered the lagoon under wave and tidal action. These works have now been conducted three separate times with costs as high as $120 000 for dredging and disposal (Table 1). The Statement of Environmental Effects (Patterson Britton and Partners Pty Ltd, 2003) for the works notes the benefits of the dredging as "The removal of marine sand would improve tidal exchange between the lagoon and the ocean, remove any restrictions to fish passage, and avoid continued sand migration upstream smothering aquatic vegetation".

Table 1: Dates of Site 5 dredging events, volume of sand removed, and cost of the dredging and disposal.

Dredging Event	Date Started	Date Finished	Volume sand removed m^3	Cost of Dredging and disposal
1	20/08/01	30/11/01	1,500	$30,000
2	05/09/03	10/12/03	1,500	$35,000
3a	18/04/06	6/6/06	2,800	$41,000
3b	7/9/06	6/10/06	3,500	$120,000 (Increased costs due to excavation of material inappropriate for beach deposition)

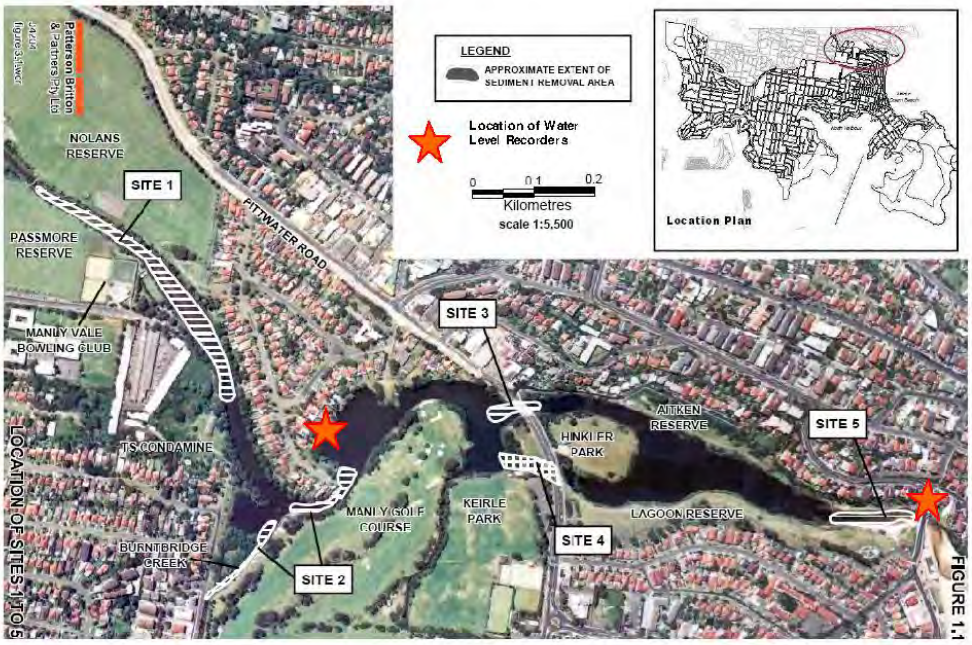


Figure 4: The location of the five remediation sites where dredging is proposed and the two water level recorder locations.

Figure 5: Marine sand built up in the entrance area of Manly Lagoon before dredging, August 2005 (Site 5).

Figure 6: After the marine sand has been dredged, August 2006, showing the sand stockpile on the shore. Discoloration is due to estuarine fines.

Proposed Monitoring in Manly Lagoon - The Big Picture

It is now understood that in order to improve ecosystem health and meet water quality criteria in highly urbanised coastal lagoons, authorities must not only attempt to reduce stormwater pollution from catchment landuses, but also repair the legacy from over 100 years of pollutant deposition. Indeed this was the focus of the Manly Lagoon Estuary Management Plan. To do this, an integrated, at-source to end of pipe, treatment train has been developed for Manly Lagoon involving stormwater pollutant interception via chemical, physical and biological interventions coupled with in-stream rehabilitation including the dredging discussed in this paper.

To validate this holistic approach and capture the variables involved with monitoring, a mix of at-source, to end of pipe, spatial and temporal monitoring procedures will be implemented by Manly and Warringah Councils in partnership with DNR. The use of real-time, phone telemetry monitoring stations positioned across the lagoon, at different depths, will allow for an assessment of change in relation to tidal exchange, pollutant stratification and speciation within the lagoon. Targeted grab sampling will provide for a temporal assessment of change between eight sites drawing upon over 20 years of data. Profiling of the sediment *in-situ* and the stockpile of sediments post dredging provides a measure of pollutant load removal (kg / pollutant of heavy metals, nutrients, sediments and hydrocarbons). Biological monitoring at sections across the lagoon will provide an ultimate measure of improvement in ecosystem health and progress towards water quality criteria.

The integrated nature of the sampling approach provides a greater benefit than the monitoring components undertaken in isolation. As data emerges from the program, the consortium in charge of Manly Lagoon's management will build on existing knowledge, review the effectiveness of management approaches and adapt them accordingly based on a better understanding of the variables and benefits of dredging and catchment works.

Figure 7: Signage produced by Manly Council illustrating the scope of works and the benefits of the Site 5 dredging.

Figure 8: During the entrance dredging. Dredging is done through a bulldozer pushing sand up against the shore then piled up by an excavator.

Monitoring the Success of the Dredging - Tidal Harmonic Analysis

To determine whether or not the dredging of the marine sand delta at the entrance to Manly Lagoon will result in improved tidal exchange between the lagoon and the ocean, water level data from two continuous automatic water level recorders in the lagoon was obtained from Manly Hydraulics Laboratory. These recorders monitor the rise and fall in lagoon water levels as a response to tides, inflow from rainfall, and oceanic events. Because of the water level variations introduced from rainfall and oceanic events, the use of basic water level data to analyse 'pure' tidal variation (due solely to sun, moon and earth interactions and river tidal characteristics) in estuaries can be difficult, particularly if trying to compare differences before and after an event such as dredging. To obtain meaningful results from the water level data that removes the major rainfall and oceanic events, a technique called Tidal Harmonic Analysis was used.

Tidal Harmonic Analysis is a technique applied to recorded water levels by which the various constituents or "building blocks" that make up the tide are calculated separately (see Box 1 on tides for details). If all the calculated constituents are added together, a close approximation of the original observed tide is produced. But it is useful to just look at the major tidal constituents that contribute most to the observed astronomical tide to compare how they vary between sites or with time. This provides an indicator of how tidal response may be changing, without the 'noise' associated with catchment and oceanic events.

To look at the dynamic behaviour of an estuary, the month to month changes in behaviour of the major constituents are best compared. As major tidal characteristics are related to the monthly lunar cycle, this is really the smallest period that is useful to consider for harmonic analysis. Even the monthly analyses involve a system that is changing over the month, which means that the harmonic results are still only an indicator of response, and not an exact measure. They indicate the average monthly tidal response.

The major constituents of tides that were extracted from the analyses for month to month changes in behaviour for this study are the "principal lunar semidiurnal constituent" (M_2) or main tidal component, and the "Lunisolar synodic fortnightly constituent" (MSf) or fortnightly tide.

M_2 – Main Tidal Component
The M_2 constituent represents the dominant lunar influence in conjunction with the earth's rotation on the observed tide and is the major contributor to the tide. In the open ocean, this constituent is around three times the size of its nearest. Comparing the behaviour of M_2 over time provides an indicator of the tidal penetration into a system. For example, on the graphs shown, an increase in M_2 means an increase in tidal response and possibly increased tidal flushing.

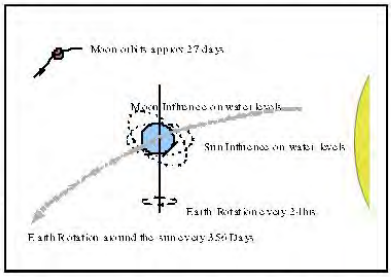
MSf – Fortnightly Tide
The MSf constituent represents the influence on the lunar orbit, which directly creates the spring-neap tidal or fortnightly tide characteristics. In coastal lagoons that generally have relatively restricted entrances and shallow inlet channels, the spring neap cycle creates a varying mean water level. This water level is higher during the spring tides, and lower during the neap and is a consequence of frictional effects of the inlet channel. As frictional effects increase the effect can be greater. The MSf constituent is a measure of this behaviour and can be very significant. On the graphs shown, decreases in MSf indicate reduced frictional effects and often correlate with an associated increase in M_2 and possibly improved flushing.

Reliability of the Analysis
As the plots of M_2 and MSf for both Queenscliff Bridge and Riverview Parade data sets very closely match each other, even though they are different data sets from two separately calibrated water level recorders, we can be certain that there is a high level of precision (the degree of repeatability among a series of individual results) with the tidal harmonic analysis.

Box 1: Tides

Tides are the end result of a number of astronomical interactions and the associated gravitational and inertial effects on the earth's surface water. The main influences being:

- the earth's spin,
- the earth's axis tilt,
- the moons orbit around the earth,
- the earth's orbit around the sun, and
- the combination and interactions between all these components and others.



These astronomical features and their interactions each represent a constituent or "building block", which when combined make up the observed tide. It is all these acting simultaneously that generate the tidal water levels we observe such as the twice daily high and low tides, fortnightly tides (where a lake system pumps up and down at spring and neap respectively) and the roughly six monthly King Tides, amongst others.

Figure 9: Map of the Site 5 remediation area showing the location and extent of dredging.

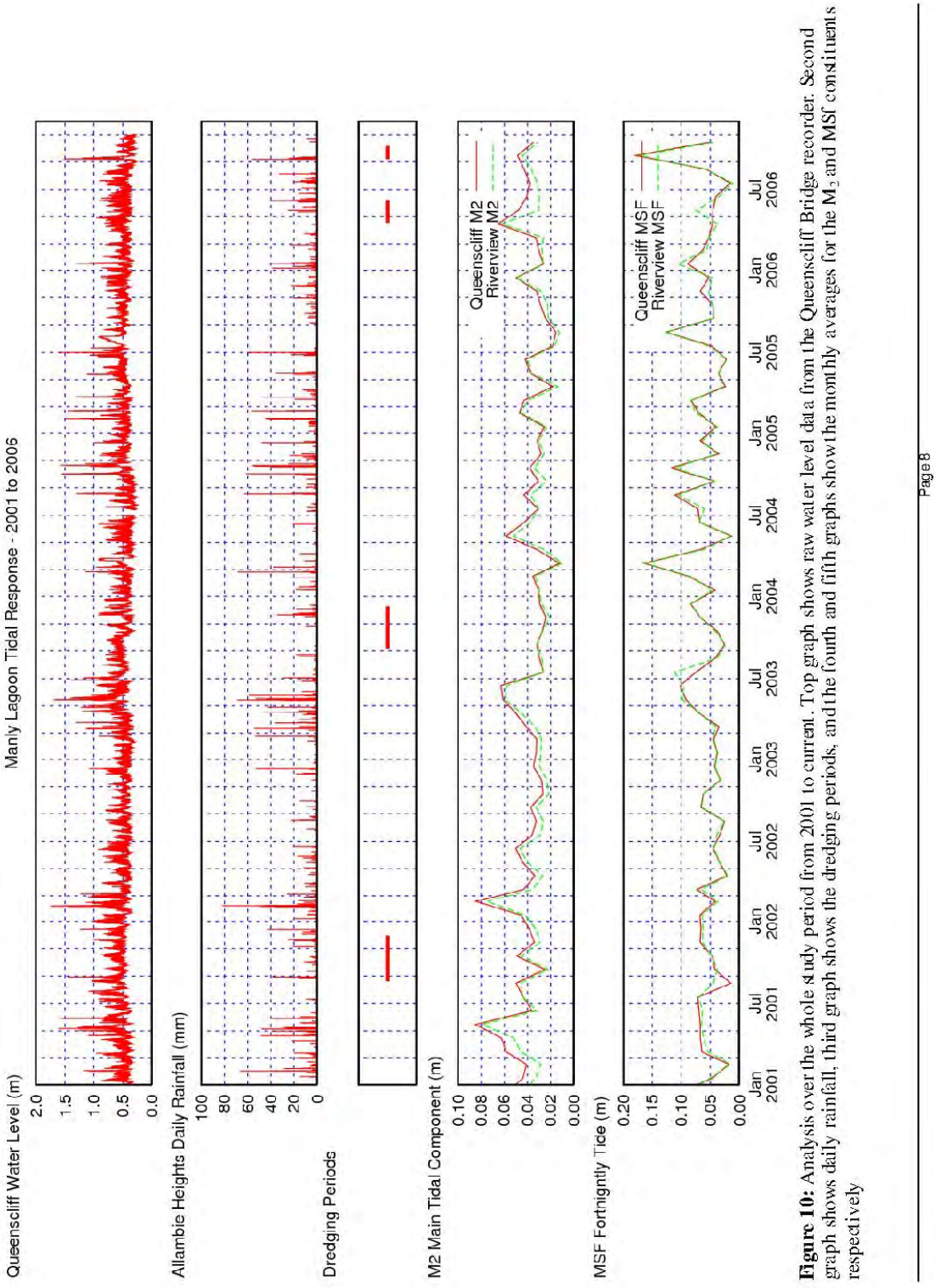


Figure 10: Analysis over the whole study period from 2001 to current. Top graph shows raw water level data from the Queenscliff Bridge recorder. Second graph shows daily rainfall, third graph shows the dredging periods, and the fourth and fifth graphs show the monthly averages for the M_2 and MSf constituents respectively

Results - August 2001 Dredging

Dredging (1500m^3) started in August and ran through till early December. The period of dredging is relatively quiet in terms of rainfall, with only minor rain events in the catchment. Because of this the water level record is dominated by the tidal signal.

The Main Tidal (M_2) Component peaks twice over the year record indicating improvements in tidal flushing, both times corresponding with significant rainfall events (improvements in flushing after the rainfall most likely as a result of flood waters scouring sand out of the entrance channel). The May rainfall is not big but is over a significant period, whilst the February event is nearly twice as big but over a shorter period. There is a significant reduction in the tidal response for September after dredging started, with no overall improvement evident comparing before and after dredging.

The Fortnightly Tide (MSf) results show little change over the whole year. However, two dips are observed that could indicate lower entrance friction and possibly better flushing. The first dip in the MSf at the start of the dredging does not seem to have corresponded to an increase in M_2 and therefore no increase in flushing is likely. The second dip during February in conjunction with the significant rain event shows a corresponding increase in M_2 that indicates improved tidal flushing.

Overall, the tidal response of the estuary appears to have not changed at all due to the dredging, indicating no improvement in tidal flushing. Significant rainfall events that increase entrance scouring appear to have a far greater influence on improving tidal flushing then the dredging.

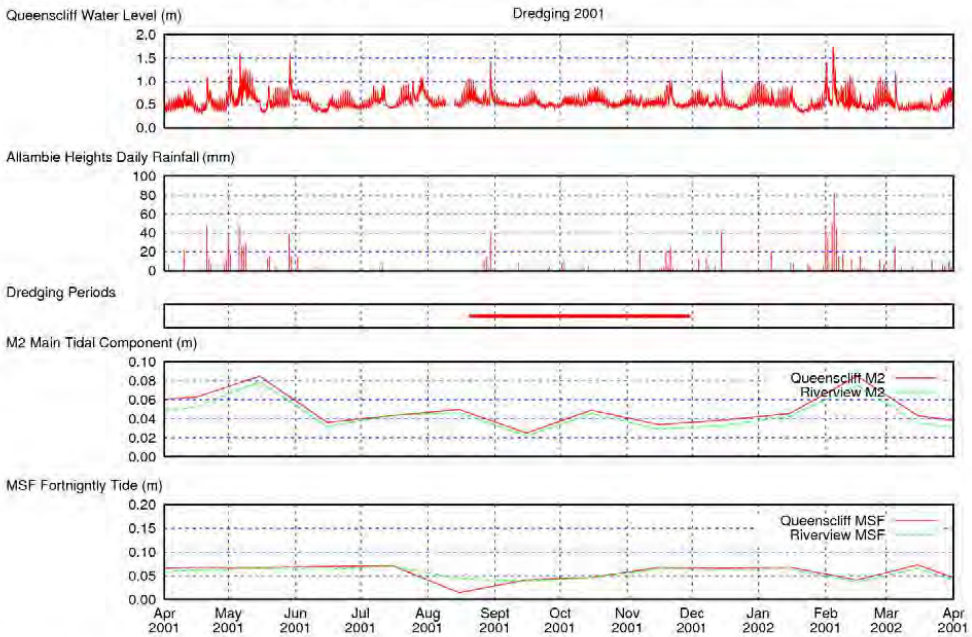


Figure 11: Analysis of the 2001 dredging episode. Top graph shows raw water level data from the Queenscliff Bridge recorder. Second graph shows daily rainfall, third graph shows the dredging period, and the fourth and fifth graphs show the monthly averages for the M_2 and MSf constituents respectively.

Results - September 2003 Dredging

Dredging (1500m^3) started in September and ran through till early December. The water level records show what appears to be a lowering of the water level in the Lagoon, during the dredging period. The rainfall records indicate that the actual dredge period was relatively dry with only a small rainfall event towards the end of the period. Significant rainfall events were observed both early and late in the yearly records.

The Main Tidal (M_2) Component show that the tidal response is more or less steady over the dredging period through to February indicating no improvement in tidal flushing as a result of the dredging. In March it appears that the entrance has been significantly reduced, resulting in a drop of tidal response of nearly 60%. The rainfall event in May provided increased tidal response over May and June, which was nearly double that of the rest of the year.

The Fortnightly Tidal (MSf) response sees a drop during the initial dredge period, possibly indicating a reduction in the entrance frictional response though not enough to see a corresponding increase in tidal response. This is followed by an increase through February and March despite a significant rain event towards the end of February, indicating that possible shoaling of the entrance has occurred due to oceanic events. This behaviour is mirrored by the further reduction in tidal response indicated by the M_2 component.

These analyses again show that the dredging appears to have had minimal effect on the tidal flushing characteristics of the lagoon, and are swamped by the natural variations due to rainfall and coastal oceanic events.

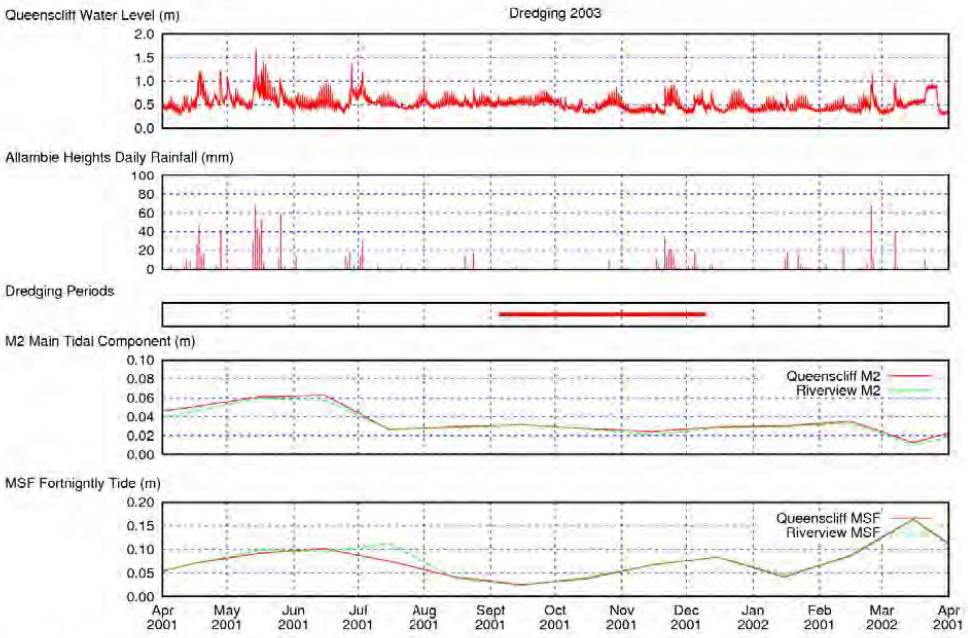


Figure 12: Analysis of the 2003 dredging episode. Top graph shows raw water level data from the Queenscliff Bridge recorder. Second graph shows daily rainfall, third graph shows the dredging period, and the fourth and fifth graphs show the monthly averages for the M_2 and MSf constituents respectively.

Results - April 2006 Dredging

Dredging (6300 m^3) commenced mid April and was completed in 2 stages, the last finishing at the beginning of October. The whole year is interspersed with minor rainfall events, and is particularly dry in the 3 months leading up to the dredging. Persistent medium rainfall (around 20mm) events continued throughout the dredge period. Significant events occur in January and September.

The Main Tidal (M_2) component shows there is an immediate increase in tidal response for April that can be assumed to be linked to the April dredging. Following April the tidal response decreases, which continues into June where it then flattens out and slightly decreases till the end of the record, with an overall increase in tidal response before and after dredging evident.

The Fortnightly Tidal (MSf) response shows a major increase from August to October which is normally associated with increased entrance frictional effects. This does not correspond with the steady increase in M_2 tidal response and is an unexpected result that is probably due to the corresponding rainfall event. As the rainfall event lasts for nearly a week, it possibly mimics the spring neap rise and fall in water level, hence being interpreted as a tidal phenomenon over this period.

This analysis appears to show an immediate impact of entrance dredging on improving tidal flushing, with an overall improvement before and after dredging evident. This improvement would have been assisted by the persistent rainfall events helping to maintain a well scoured entrance and the fact that an extra 4800m^3 of sediment was removed compared to the two previous dredging episodes.

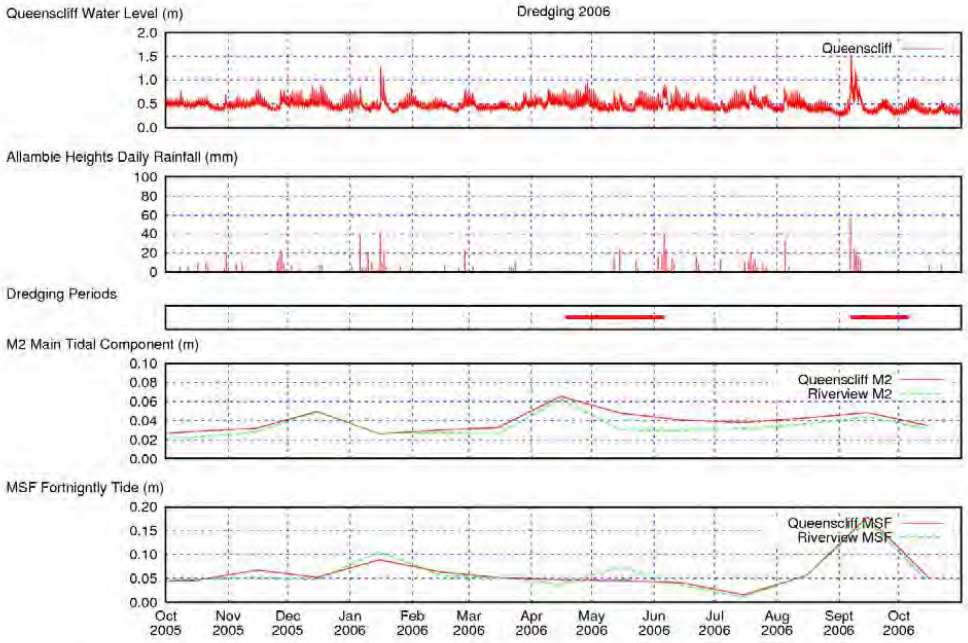


Figure 13: Analysis of the 2006 dredging episode. Top graph shows raw water level data from the Queenscliff Bridge recorder. Second graph shows daily rainfall, third graph shows the dredging period, and the fourth and fifth graphs show the monthly averages for the M_2 and MSf constituents respectively.

Application to other Dredging in Manly Lagoon

One result obtained by analysing the water levels from both automatic recorders was that there is a small difference in water levels between the two recorders. Tidal levels are slighter lower at the upstream Riverview Parade recorder when compared to the entrance recorder at Queenscliff Bridge, indicating some tidal attenuation occurs. This tidal attenuation becomes more pronounced after the last entrance dredging where the tidal levels at Queenscliff Bridge increase while little increase is observed at the Riverview Parade recorder.

It is common belief that a sill under the Pittwater Road Bridge, Site 3, is acting as a barrier to tidal penetration and its removal may benefit water quality in the upper section of the lagoon as a result of increased tidal penetration under the bridge as indicated in the Statement of Environmental Effects for the dredging works (Patterson Britton and Partners Pty Ltd, 2003). As the measured tidal attenuation is only small, any improvements in tidal penetration and water quality as a result of the dredging may be difficult to detect and will be the subject of future analysis and water quality monitoring.

Figure 14: Shot of the bulldozer pushing sediment up into a pile on the shore, June 2006.

Conclusions

The analysis of the benefits of dredging the entrance marine sand delta on improving tidal flushing indicate:

1. Removal of small amounts of marine sand around 1500m^3, as with the first two dredging episodes, appear to have little affect on improving tidal flushing.

2. Major rainfall and oceanic events appear to have a much greater impact on controlling tidal flushing with large rainfall events correlating well with improvements in tidal flushing. This is most probably because the resultant high flows in the lagoon from the rainfall continually scour the entrance channel of marine sand brought in on the incoming tide, creating a well opened channel that allows maximum tidal penetration.

3. A significant amount of sediment needs to be removed (as with the last dredging episode of 6300m^3) before any noticeable improvement in tidal flushing can been seen. However, it is also likely that the regular rainfall events over the period of the dredging have helped the observed improvement.

4. There is some tidal attenuation between Queenscliff Bridge and Riverview Parade.

Recommendations

1. The benefits of future Site 5 entrance dredging works should be openly discussed with the Manly Lagoon Catchment Coordinating Committee (MLCCC), in charge of implementing the Manly Lagoon Estuary Management Plan (EMP). As small improvement in tidal flushing is only evident after significant amounts of sediment are removed, the high costs, as high as $120 000, need to weighed up against the possible benefits and other means of improving water quality in the lagoon.

2. The expected benefits of dredging at Sites 3 and 4 (Pittwater Road Bridge) need to be carefully considered by the MLCCC and again weighed against the high costs. Based on the low tidal attenuation observed between the automatic recorders, an increase in tidal penetration under the bridge and therefore improved flushing upstream of the bridge would be expected to be small. However, wind driven mixing and improved circulation would still be expected to improve water quality after the dredging is completed.

3. The future water quality and biomonitoring currently being discussed between Warringah and Manly Councils in partnership with DNR to specifically look at the changes in water quality and lagoon health as a result of the dredging needs to begin so lessons can be learned and the success or otherwise of the dredging determined.

4. The results from the monitoring should be used to feed into a review of the current Manly Lagoon EMP to ensure its objectives and management practices proposed (e.g. dredging) to meet the objectives, are updated by the latest information and understanding.

References

Patterson Britton and Partners Pty Ltd (2003). *Manly Lagoon rehabilitation works sediment removal from sites 3 and 5, Statement of environmental effects*, Issue No.2 August 2003.

NSW Government (1992). *Estuary Management Manual (Draft)*. New South Wales Government.

Attachment 7

Warringah Council

COUNCIL REPORT COVER SHEET

Agenda deadlines:

Week 2 meeting: 9am Monday, **8 days prior** to meeting

Week 4 meeting: 9am Thursday, **12 days prior** to meeting

SUBJECT:	MINUTES OF THE MANLY LAGOON CATCHMENT COORDINATING COMMITTEE MEETING HELD 14 DECEMBER 2006
COUNCIL MEETING DATE:	13 February 2007
ITEM NO.:	
REPORTING OFFICER:	L Binetsky _____ Signature _____ Date
MANAGER:	Manager Environmental Services _____ Signature _____ Date
DIRECTOR:	Director Customer and Community Services _____ Signature _____ Date
FINANCE MANAGER: *(sign-off required for items affecting Council budget)*	_____ Signature _____ Date

OR

RESPONSIBLE ACCOUNTING OFFICER	_____ Signature _____ Date

9.2 MINUTES OF THE MANLY LAGOON CATCHMENT COORDINATING COMMITTEE MEETING HELD 14 DECEMBER 2006

Reporting Officer

Manager Environmental Management Services

Purpose

To report to Council the Minutes of the Manly Lagoon Catchment Coordinating Committee Meeting held 14 December 2006.

Report

It should be noted in response to the matter raised in Item 4.1 *"...observes suspiciously discoloured water in the Condamine St GPT on weekends..."*, the matter has been referred to Council's Compliance officers for investigation.

Impact on Council Budget

Nil

RECOMMENDATION OF DIRECTOR CUSTOMER AND COMMUNITY SERVICES

That the Minutes of the Manly Lagoon Catchment Coordinating Committee Meeting held on 14 December 2006 be noted and the recommendations contained therein be **ADOPTED**.

Warringah Council™
ABN 31 565 068 406

MINUTES OF THE MANLY LAGOON CATCHMENT COORDINATING MEETING HELD THURSDAY 14 DECEMBER 2006

ATTENDANCE

Mr Dennis Corbett – Chairperson
Councillor Peter Macdonald – Mayor – Manly Council
Councillor Judy Lambert – Manly Council
Mr Danny Wiecek – Dept. Natural Resources – Estuaries
Mr John Gibbons – Save Manly Dam Catchment Committee
Mr Peter White – Warringah Community Representative
Mr Mark Roberts – Manly Lagoon Committee
Mr Steven Firth – Warringah Community Representative
Mr Keith Ralfs – Warringah Chamber of Commerce & Industry Inc.
Mr David Bolton – Manly Community Representative
Mr Paul Smith – Manly Council
Mr David Beharrell – Environment Officer (Projects)
Mrs Leonie Binetsky – Administration Officer

APOLOGIES

Mr Alistair Anderson – Warringah Mall Management
Mr Michael Bradbury – Manly Golf Club
Mr David Barr – Member for Manly

Prior to the adoption of the Minutes from the meeting held on the 12 October 2006, Mr David Bolton stated that, in his opinion, the reported matters discussed in Item 4.2, Total Catchment Management Decision Support Tool was not sufficiently detailed as per the discussions. Mr Bolton submitted an item on this issue for discussion under Business Without Notice. Following these comments the Minutes were noted.

ADOPTION OF MINUTES – Minutes of the Meeting held 12 October 2006
Adopted by Warringah Council on 28 November 2006 were **NOTED**.

DECLARATION OF PECUNIARY AND CONFLICTS OF INTEREST

Nil

DATE OF THE NEXT MEETING

8 MARCH 2007
IN THE FLANNEL FLOWER ROOM
CIVIC CENTRE, DEE WHY
COMMENCING AT 5.00PM

Item 2.1 Proposed Redevelopment Manly Golf Club
Submitted by Greg Britton - Manly Golf Club Consultant

Manly Golf Club (MGC) propose to redevelop Manly Golf Course to address a range of safety, drainage, water supply and course design issues, and at the same time improve the quality of stormwater flowing through the course and improve terrestrial and aquatic habitat.

A brief update on the progress of the proposal will be provided.

Proceedings in Brief

Mr Britton was unable to attend the meeting. However, he was able to provide an update to Council staff who conveyed the information to the Committee. The stormwater concept plan and flood modelling is progressing well and a meeting was convened for Friday 15 December 2006 involving relevant State government authorities.

A further update will be given at the March 2007 meeting.

RECOMMENDATION OF THE COMMITTEE TO COUNCIL

That the information be noted.

Item 2.2 Manly Lagoon Rehabilitation Works
Submitted by David Beharrell – Warringah Council

Sites 1 & 2 - Removal of Sediment between Burnt Bridge Creek & Nolan Reserve (ICMS Objective and Action Number –2.19)

The rehabilitation works at Sites 1 and 2 involve the removal of accumulated sediment with the aim of improving water quality, aquatic ecology, recreation and habitat. The current estimated cost of the works including the disposal of dredged material off-site is approximately $1.6 million.

Warringah Council recently engaged a consultant to undertake sediment investigations to assess the option of separating the sediment into sandy and muddy textured products by means of hydrocycloning. The physical and geochemical properties of the muddy and sandy products will be assessed in order to identify possible re-use and on-site disposal options. This would minimise the volume of material requiring costly off site disposal.

Council Staff and Manly Golf Course representatives met on the 13 November 2006 to discuss possible links between the Site 1 and 2 dredging and the proposed Golf Course redevelopment. These preliminary discussions raised the possibility of using the clean/sandy fill (by-product of physical separation of dredged material) on the golf course and placing the remainder in the side-bays to form wetland areas. There are a number of questions to be answered before this can be considered a viable option. For example:

- Can the material be separated in a cost effective manner?
- Can we use the side-bays? How much fill can the side bays accommodate?
- Will the State Government allow infilling?
- What will the community think?
- Environmental Impacts?

A further meeting with relevant State government agencies is planned for the Friday 15 December 2006 to discuss the proposal.

Addiscombe Road Remediation Action Plan
Manly Council has received the Director General's requirements for the Part 3A application for the remediation works in line with the SEPP 2005 Major Projects provision. The consultants are now working with these to finalise documentation and are also finalising the first draft Remediation Action Plan.

Site 3 - Dredging Under and Adjacent to Pittwater Rd Bridge, North Manly
(ICMS Objective and Action Number – 2.16)

On the 2 November 2006, approval was granted for the development application for disposal of the dredged material to Abbott Road, John Fisher Park, Curl Curl.

Warringah Council has invited consultants to provide a quote to assist Council to project manage the Site 3 dredging works and transportation and placement of sediment to Abbott Road, Curl Curl. The consultants have been asked to review tender documentation; obtain necessary construction certificates; ensure necessary approvals have been obtained and are valid; coordinate the tendering and evaluation process for works; coordinates community consultation and supervise the works phase of the project.

Selection of the preferred consultant will take place in early January 2007 with works being anticipated to commence in March/April 2007.

Warringah Council recently invited consultants to provide a quote to undertake three-dimensional tidal water quality modeling to numerically demonstrate the impact of dredging at Site 3 on water quality in Manly Lagoon. The results of the modeling will be made available in early 2007.

Proceedings in Brief

Discussions took place regarding possible links to the proposed redevelopment of Manly Golf Course and Sites 1 and 2 rehabilitation works. It was stated that the results of proposed sediment analysis were integral to any possible synergies between the two projects. The results of the analysis will provide information about the likely end use of the removed dredged material and where it can be located.

In relation to the Addiscombe Road site, Manly Council was requested to submit an update at the next meeting outlining the findings from the remediation action plan.

RECOMMENDATION OF THE COMMITTEE TO COUNCIL

That the information be noted.

Item 2.3 Operation Manly Lagoon
Submitted by David Beharrell - Warringah Council
(ICMS Objective and Action Number –1.7)

Planning for Manly Council's "Sustainability Fair" is still in progress and is anticipated to take place in April 2007.

Warringah Council's new website was launched on the 7 December 2006. From the "Environment" drop down bar, the heading "Water Catchments" contains information about Creeks and Lagoons, Stormwater and Flooding, Coastline and Working with Industry. The website is a work in progress and will soon include a Manly Lagoon Catchment webpage.

RECOMMENDATION OF THE COMMITTEE TO COUNCIL

That the information be noted.

Item 3.1 Appointment of New Community Member
Submitted by David Beharrell – Environment Officer (Projects)

Following Council's advertisement to replace the recently resigned member, four applications were received.

In accordance with Council's Policy "Advisory and Management Committees of Council – Appointment of organisations and committee members" Gov-PL 226 states:

> *Unless an individual community representative is required to have some particular skill or professional training, all nominations satisfying guidelines for a Committee shall be eligible for appointment. Where the number of nominations exceeds the number of individuals required for appointment, the General Manager shall determine the appointment by drawing of lots, with those drawn first being appointed.*

All four applicants were submitted to the General Manager, who drew the name of Mr Steve Firth.

Council is pleased to welcome Mr Steve Firth onto the Committee.

RECOMMENDATION OF THE STAFF TO THE COMMITTEE

That the information be noted.

Proceedings in Brief

At the commencement of the meeting Mr Firth was welcomed onto the Committee. One Committee member asked if the unsuccessful applicants had been notified and he was advised that all applicants had been notified in writing.

RECOMMENDATION OF THE COMMITTEE TO COUNCIL

That the information be noted.

Item 3.2 Entrance Dredging and Lagoon Flushing – Results from Tidal Analysis
Submitted by Daniel Wiecek - DNR
(ICMS Objective and Action Number –2.20)

The Department of Natural Resources in conjunction with Manly Council have recently completed analysis of tidal data in Manly Lagoon to see what difference there is before and after the three dredging episodes that have occurred at the lagoon entrance since 1998.

The analysis concluded that removal of small amounts of marine sand, around 1500m^3, as with the first two dredging episodes, appear to have little effect on improving tidal flushing.

Major rainfall and oceanic events appear to have a much greater impact on controlling tidal flushing with large rainfall events correlating well with improvements in tidal flushing. This is most probably because the resultant high flows in the lagoon from the rainfall continually scour the entrance channel of marine sand brought in on the incoming tide, creating a well opened channel that allows maximum tidal penetration.

A significant amount of sediment needs to be removed (as with the last dredging episode of 6300m^3) before any noticeable improvement in tidal flushing can been seen. However, it is also likely that the regular rainfall events over the period of the dredging have helped the observed improvement.

The recommendations made as a result of the analysis were attached to the Agenda for information

Proceedings in Brief

The Department of Natural Resources and Manly Council staff recently completed an analysis comparing tidal flushing and corresponding entrance clearance works in Manly Lagoon (summary provided in APPENDIX 1).

The following is a summary of the recommendations outlined in the report:

The benefits of future Site 5 entrance dredging works should be openly discussed with the Manly Lagoon Catchment Coordinating Committee (MLCCC). As improvements in tidal flushing are only evident after significant amounts of sediment are removed, at relatively high

costs, the community needs to weigh up the benefits of these works against other means of improving water quality in the Lagoon.

The expected benefits of dredging at Sites 3 and 4 (Pittwater Road Bridge) need to be carefully considered by the MLCCC and again weighed against the high costs. Based on the relatively small difference in tides observed between the water level recorders at opposite ends of the Lagoon, an increase in tidal penetration under the bridge and therefore improved flushing upstream of the bridge would be expected to be small.
The future water quality and biomonitoring, currently being considered by Warringah and Manly Councils in partnership with DNR to specifically look at the changes in water quality and lagoon health as a result of the dredging, needs to be planned carefully and implemented so lessons can be learnt and the success or otherwise of the dredging determined.

It is recognised that there are other potential benefits to the dredging at the entrance and under Pittwater Road Bridge, including removal of contaminated sediment and minor lowering of flooding impacts.

RECOMMENDATION OF THE COMMITTEE TO COUNCIL

That the information be noted.

Item 3.3 Water Quality Monitoring Update
Submitted by Paul Smith – Manly Council
(ICMS Objective and Action Number –1.13G)

Manly Council has been undertaking monitoring of Manly Lagoon in partnership with University of Western Sydney to understand sewage ingress hotspots for facilitating prioritisation of "Sewer Fix" works in the Manly Lagoon Catchment in partnership with Sydney Water's overflow modelling processes. The program also seeks to install real-time, phone telemetry, nutrient (Total Nitrogen and Total Phosphorus) monitoring equipment and has undertaken pollutant speciation and stratification assessments to understand instream interventions including dredging and catchment management works.

The findings of the monitoring will be reported to the MLCCC for regular updates and to the Sydney Water / Manly Council Partnership for facilitation and evaluation of actions in Manly Lagoon and Catchment.

RECOMMENDATION OF THE COMMITTEE TO COUNCIL

That the information be noted.

Item 3.4 Proposed Meeting Dates for 2007
Submitted by David Beharrell – Warringah Council

Bookings have been made for Committee Meetings to be held during 2007. They are to be held on a Thursday as normal commencing at 5.00pm. The dates are:

8 March 2007
14 June 2007
13 September 2007
13 December 2007

These dates are subject to alteration should the need arise.

Proceedings in Brief

The Committee was in agreement with the proposed dates on the understanding that a Special Meeting could be called at any time to discuss urgent matters.

RECOMMENDATION OF THE COMMITTEE TO COUNCIL

That the information be noted.

BUSINESS WITHOUT NOTICE

Item 4.1 Various Questions from the Save Manly Dam Catchment Committee
Submitted by John Gibbons

Q. Is the new water quality testing facility Manly Council is establishing, to be jointly used by both Councils?

A. The Committee was informed that Council staff would discuss the possibilities of joint use of the facility.

Q. Is Warringah Council intending to install samplers to enable water quality monitoring in Brookvale Creek and Manly Creek before they entered the Lagoon?

A. Staff informed the Committee that Warringah undertakes monthly dry weather monitoring downstream of the Condamine St GPT. Council is also looking at potential sites in the LGA to undertake wet weather sampling and downstream of the Condamine St GPT is a priority site.

Q. In response to the issue raised by Mark Roberts, i.e., he often observes suspiciously discoloured water in the Condamine St GPT on weekends, which he felt resulted from illegal discharge into the creek from businesses in the Brookvale industrial area.

Mr Gibbons asked whether Council would consider monitoring water quality at this location to determine whether there was anything untoward occurring?

A. Staff indicated that to determine the type and source of any pollution incident that they need to be notified as soon as possible after the incident is observed. Staff indicated that Council Officer's can be contacted 24 hours a day, 7 days a weeks.

Mr Gibbons suggested that Council might consider developing a monitoring regime that targeted this area during these periods and maybe talk to local streamwatch groups to enlist their help.

RECOMMENDATION OF THE COMMITTEE TO COUNCIL

That the information be noted.

Item 4.2 Manly Lagoon Catchment Water Quality Monitoring
Submitted by David Bolton – Manly Community Representative

Mr Bolton tabled a paper titled, "Manly Lagoon Catchment Water Quality Monitoring" for information and discussion by the Committee (APPENDIX 2)

In summary the main issues/questions raised were whether we can definitively say whether the Lagoon's water quality was getting better. Staff indicated that it is difficult to make a clear statement either way due to the many variables involved and the complexity inherit in making statement about water quality trends. However, staff indicated that they were in the process of collating all existing data in an attempt to undertake a trend analysis of water quality in the lagoon.

Council Officers will provide comments on the six questions tabled by Mr Bolton and provide a report at the next meeting.

RECOMMENDATION OF THE COMMITTEE TO COUNCIL

That the information be noted.

Item 4.3 Exotic Tree Removals
Submitted by Mark Roberts – Manly Lagoon Committee

Mr Roberts brought to the attention of the Committee a number of Coral trees and Coral tree regrowth that required removal. Staff indicated that as part of the ongoing Exotic Tree Removal Program these trees would be removed.

RECOMMENDATION OF THE COMMITTEE TO COUNCIL

That the information be noted.

Councillor Judy Lambert left the meeting at 6.30pm
Mr Keith Ralfs left the meeting at 6.35pm
Councillor Peter Macdonald left the meeting at 6.40pm
Mr Paul Smith left the meeting at 6.45pm
Mr Peter White left the meeting at 6.46pm

The meeting concluded at 7.15pm

Item 3.2 - APPENDIX 1

Entrance Dredging and Lagoon Flushing – Results from Tidal Analysis

The Department of Natural Resources in conjunction with Manly Council have recently completed analysis of tidal data in Manly Lagoon to see what difference there is before and after the three dredging episodes that have occurred at the lagoon entrance since 1998. One of the main reasons for the removal of the sand is that it is believed it will result in improved tidal exchange between the lagoon and the ocean thereby improving water quality. To test this, water level data obtained from two continuous automatic water level recorders in the lagoon were compared before, during and after the dredging for the three dredging episodes using tidal harmonic analysis.

The results of the analysis where presented as a poster at the 15th NSW Coastal Conference held at Coffs Harbour in November this year and the conclusions and recommendations from this poster are outlined below (for further information the paper prepared with the poster for the conference has been attached as an appendix):

Conclusions
Removal of small amounts of marine sand around 1500m^3, as with the first two dredging episodes, appear to have little affect on improving tidal flushing.
Major rainfall and oceanic events appear to have a much greater impact on controlling tidal flushing with large rainfall events correlating well with improvements in tidal flushing. This is most probably because the resultant high flows in the lagoon from the rainfall continually scour the entrance channel of marine sand brought in on the incoming tide, creating a well opened channel that allows maximum tidal penetration.
A significant amount of sediment needs to be removed (as with the last dredging episode of 6300m^3) before any noticeable improvement in tidal flushing can been seen. However, it is also likely that the regular rainfall events over the period of the dredging have helped the observed improvement.
There is some tidal attenuation between Queenscliff Bridge and Riverview Parade.

Recommendations
The benefits of future Site 5 entrance dredging works should be openly discussed with the Manly Lagoon Catchment Coordinating Committee (MLCCC), in charge of implementing the Manly Lagoon Estuary Management Plan (EMP). As small improvement in tidal flushing is only evident after significant amounts of sediment are removed, the high costs, as high as $120 000, need to weighed up against the possible benefits and other means of improving water quality in the lagoon.
The expected benefits of dredging at Sites 3 and 4 (Pittwater Road Bridge) need to be carefully considered by the MLCCC and again weighed against the high costs. Based on the low tidal attenuation observed between the automatic recorders, an increase in tidal penetration under the bridge and therefore improved flushing upstream of the bridge would be expected to be small. However, wind driven mixing and improved circulation would still be expected to improve water quality after the dredging is completed.

The future water quality and biomonitoring currently being discussed between Warringah and Manly Councils in partnership with DNR to specifically look at the changes in water quality and lagoon health as a result of the dredging needs to begin so lessons can be learned and the success or otherwise of the dredging determined.
The results from the monitoring should be used to feed into a review of the current Manly Lagoon EMP to ensure its objectives and management practices proposed (e.g. dredging) to meet the objectives, are updated by the latest information and understanding.

Note: It is recognised that there are other possible benefits to the dredging at the entrance and under Pittwater Road Bridge including removal of pollutants within the sediment and minor lowering of flooding impacts. Also, the need to undertake monitoring of the entire dredging site prior to commissioning works is strongly recommended.

Report prepared by Danny Wiecek (DNR) and Paul Smith (Manly Council)

Item 3.3 - APPENDIX 2

In the interests of a better understanding of "hotspots" - For the information and attention of the Manly Lagoon Catchment Coordinating Committee (14/12/2006)

MANLY LAGOON CATCHMENT WATER QUALITY MONITORING

Background

The Manly Lagoon and Catchment Integrated Catchment Management strategy and Evaluation (Final Report, Volume 2, March 2004) contains a report entitled *"Lagoon Monitoring Review: Quality and Value to Catchment Management"*.

The report summarises water quality monitoring programs identified for Manly Lagoon and its tributaries between 1975 to 2002. Core monitoring programs are Laxton, Cheng, streamwatch/Beachwatch and Manly Hydraulics Lab.

The data pertaining to these programs span the last 10 years and provide a basis for comparing and verifying trends and observations from other monitoring data.

It provides a review of 29 monitoring programs and 42 reports. The purpose of the review is to provide a rapid search and assessment database tool for those with an interest in the function and management of Manly Lagoon.

This database is viewed as being a cyclic adaptive rapid assessment procedure for water quality monitoring programs in the Manly Lagoon subcatchments.

The report states that: "The potential for building on this process for assessing the trends and directions of Manly Lagoon and its subcatchments is high. In this sense the database can serve as the foundations for coordinating and targeting action towards agreed upon hotspots, allow for adaptive management over the seasonal fluctuations of the year and provide a tool for evaluating management practices and drive continual improvement.

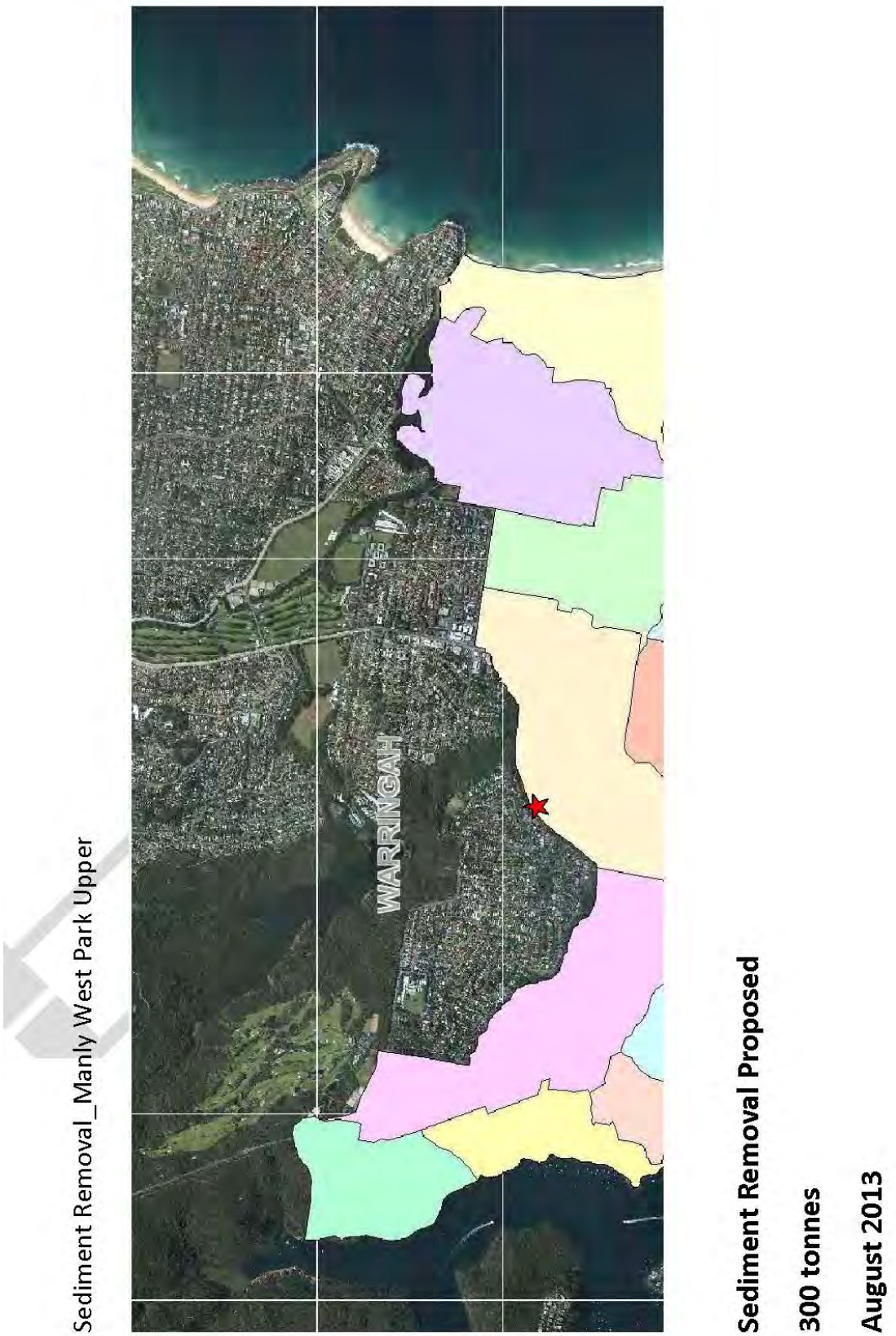
Questions

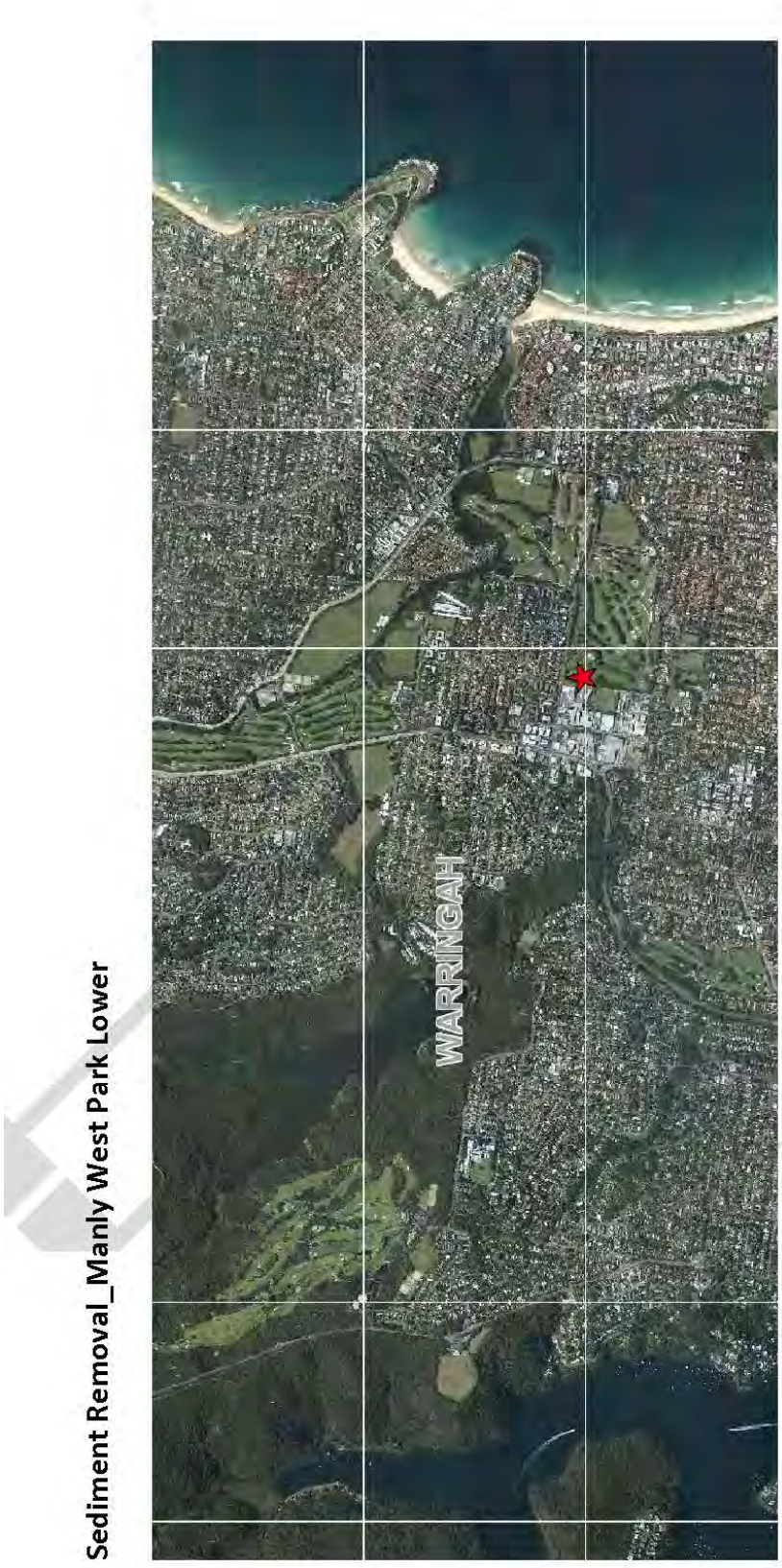
Has this database served as a foundation tool for coordinating and targeting action towards agreed sewage ingress hotspots during discussions with Sydney Water?
Is there an existing map of the "hotspots" in the Catchment?
The report suggests that the monitoring process would benefit from overlaying sewer subcatchments and stormwater subcatchments onto the one GIS system. Has this been achieved yet?
The report highlights a failure to differentiate nutrient concentrations between sewer and stormwater. Are current or proposed Manly and/or Warringah Council monitoring programs able to differentiate between sewer and stormwater when testing for Nutrients?
Is there still on-going testing for Bacteria (Le. faecal coliforms and enterococci) within the Manly Lagoon Catchment? Who conducts these tests and how often? Can the Committee be

provided with a report (summarising water quality monitoring results from 2002 to present) and an evaluation to the Committee of these results and how they, and associated management practices, have increased our understanding of the Manly Lagoon Catchment dynamics and the sewage ingress and nutrient hotspots?

Attachment 8


Sediment Removal_Manly West Park Upper
WARRINGAH
Sediment Removal Proposed
300 tonnes
August 2013


Sediment Removal_Manly West Park Upper
WARRINGAH
Sediment Removal Proposed
300 tonnes
August 2013


Sediment Removal_Manly West Park Lower
WARRINGAH
Sediment Removal
April 2013
354.9 tonnes

Sediment Removal_Manly West Park Lower

Sediment Removal

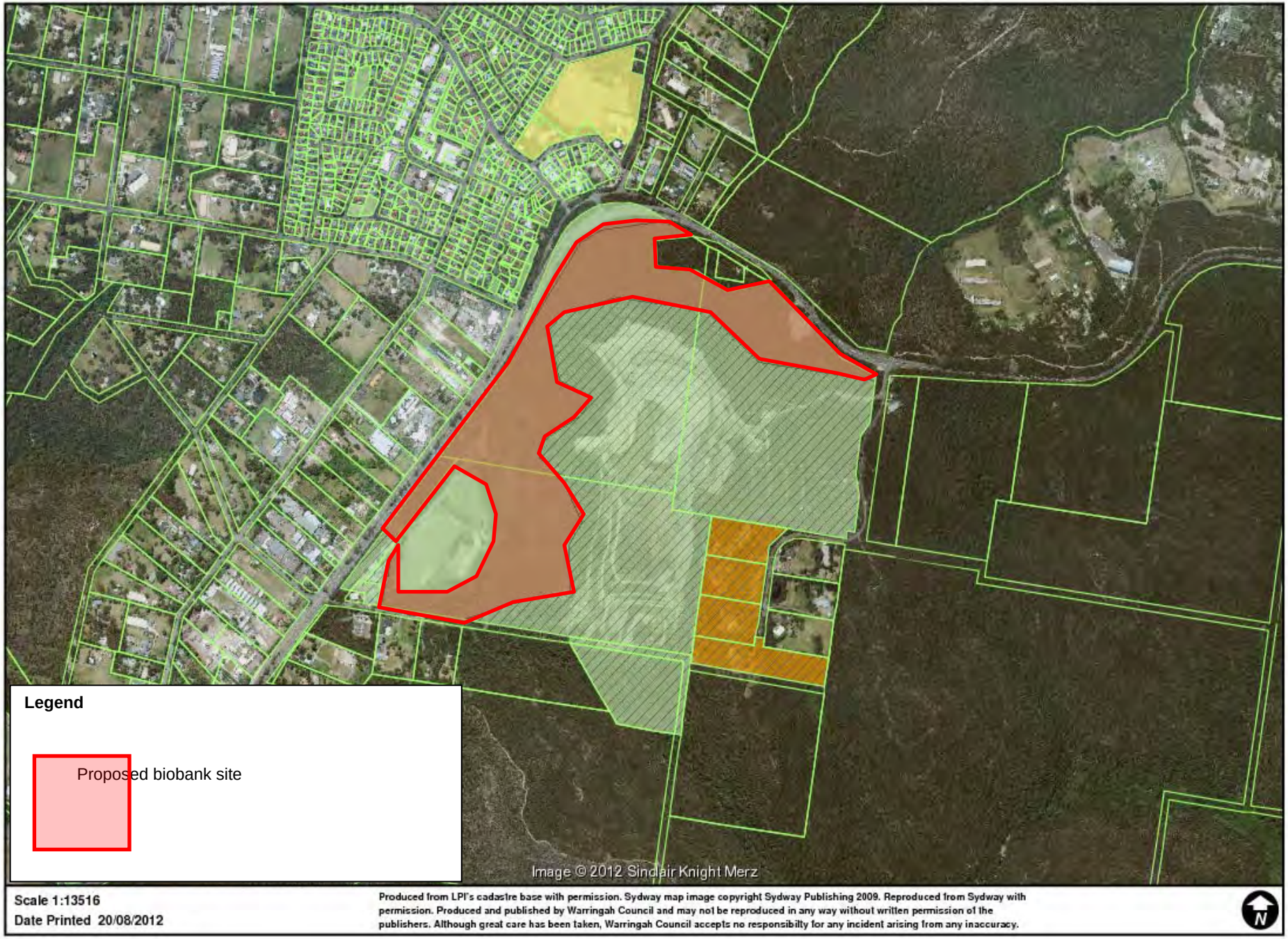
April 2013

354.9 tonnes

Sediment Removal_Manly West Park Lower

Sediment Removal_Manly West Park Lower

Sediment Removal_Manly West Park Lower


Legend
Proposed biobank site
Image © 2012 Sinclair Knight Merz
Scale 1:13516
Date Printed 20/08/2012
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Further information

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BioBanking

Biodiversity Banking and Offsets Scheme

for conservationists

BioBanking is a biodiversity banking and offsets scheme that improves biodiversity and provides funds for landowners to manage their land for conservation. BioBanking is a voluntary scheme that supports landowners to take care of their bushland forever … and pays them to do it.

Department of Environment & Climate Change NSW

What is BioBanking?

BioBanking is a market-based scheme that brings together:

- landowners who create biodiversity credits by establishing a biobank site
- purchasers who buy the credits created.

Purchasers may be conservationists, philanthropists or government departments interested in conserving biodiversity in perpetuity. Developers who need to 'offset' the loss of biodiversity from a development site are also purchasers.

There are two types of biodiversity credits – species credits and ecosystem credits.

Conservationists or philanthropists may decide to target particular threatened species by only buying credits for those species or credits for ecosystems that support them. Conservationists may also choose to focus on a particular geographic region with a view to creating a linked corridor or protecting a vulnerable area.

Behind the scenes

BioBanking applies a consistent scientific methodology to assess biodiversity, whether for a proposed conservation or development site.

The BioBanking Credit Calculator is a computer program that uses the methodology and calculates the number and classes of credits created at a biobank site or those required to offset clearing at a development site.

Three databases underpin the methodology and calculator:

- Vegetation Types Database – describes vegetation types for each of the 13 catchment management authority (CMA) areas in NSW. There are approximately 1600 in total. Vegetation types are used in the methodology as a surrogate for general biodiversity values.
- Vegetation Benchmarks Database – identifies the range of quantitative measures that represent the benchmark condition for each vegetation type
- Threatened Species Profile Database – contains information for all listed threatened species, populations and communities, such as their habitat characteristics, range, response to management actions, life history strategies, survey requirements, and ability to withstand loss in numbers and extent.

The data underpinning the calculator is reviewed and updated on a regular basis. The calculator and all databases are available for free on the BioBanking website.

M. Cutler

How does BioBanking work?

The assessment process

Applications for biobanking agreements (for biobank sites) and biobanking statements (for development sites) must include a site assessment by an accredited BioBanking Assessor using the current version of the calculator.

The credits generated by a biobank site or required by a development site will vary as each site has different vegetation types, conditions and threatened species.

Buying and selling credits

Biodiversity credits are sold by biobank site owners to fund the management of their land. Anyone can purchase biodiversity credits. Purchasers can choose to retire the credits or keep them for possible resale at a later date. If a developer buys credits to offset the effects of a development site, they must retire them so they cannot be traded again.

DECC

M. Wright

Conservationists or philanthropists may decide to target particular threatened species or areas. The biobanking public register lists expressions of interest from landowners wanting to establish biobank sites as well as biodiversity credits available for sale. Both can be searched by CMA subregion, vegetation type and threatened species.

If an expression of interest matches a conservationist's requirements, they may approach the landholder and enter into an option to purchase credits after an assessment is undertaken and a biobanking agreement granted.

Conservationists can publicise the types of credits they are interested in purchasing by submitting a 'credits wanted form' to be included in the 'list of wanted credits' on the BioBanking website.

How much is a credit worth?

Many variables influence how much a credit is worth, such as the underlying value of the land, the condition of the vegetation and the demand for particular credit types. Landowners, or other credit owners, are also allowed to build a profit margin into their credit price.

Land that is close to urban areas (such as on the outskirts of Sydney) may be more expensive and if used for a biobank site may generate credits with higher prices.

The condition of the vegetation on a biobank site will affect the cost of the management actions required, which in turn will affect the credit price required to ensure these actions can be completed.

As BioBanking is a market-based scheme, demand from purchasers and the supply of credits will also affect their price: for example, a credit in high demand from developers may have a higher price than a credit with low demand. The biobanking public register lists expressions of interest, credits available for sale and all past credit transactions, which may help inform negotiations regarding the price of credits.

J. Little

Ensuring improved biodiversity outcomes in perpetuity

A biobanking agreement is registered on the land title of a biobank site to ensure biodiversity is protected and managed forever. When land that includes a biobank site is sold, the new owner takes over the obligations of the biobanking agreement and in return receives the annual payments from the BioBanking Trust Fund.

Biodiversity offset credits must be purchased from a biobank site that has:

- the same vegetation type as the development site
- another vegetation type with the same predicted species, or
- a more cleared vegetation type that contains the same threatened species.

This ensures more endangered ecosystems are not lost in favour of those under less threat.

J. Cooper

Previously, the preferred location for an offset was often on the same site as the development. In some cases this was not practical nor the best use of land close to infrastructure. Sometimes it also led to conflict between development and conservation objectives for the future. BioBanking offers more flexibility for where credits may be obtained, leading to better results for biodiversity.

WARRINGAH COUNCIL