Appendix A

Technical Appendices

A.1 Coastal Erosion Allowances (Setback)

266000 266500 267000 267500

6826500 6826000 6825500 6825000 6824500

Disclaimer and Data Sources

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Data Sources:

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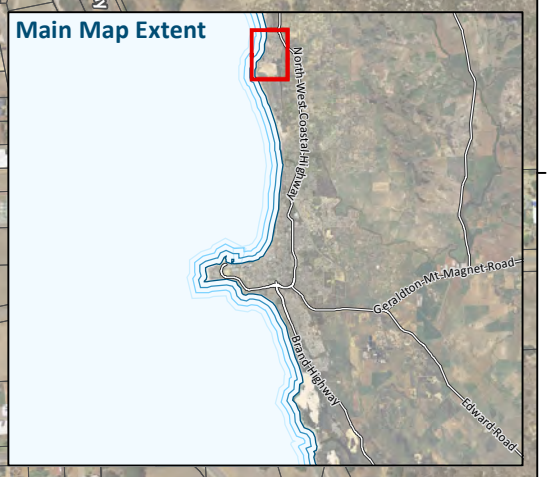
- Town Beach to Drummond Cove Inundation & Coastal Processes Study (MRA 2016).
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent



Cadastral boundary

Coastal compartment extent

Coastal processes setbacks

- Present Day
- 2030
- 2070
- 2110

Drummond Cove Road
Drummond Cove
Waterfront Circuit
Whitehill Road
Hester Street
Tailer Street
Reef Boulevard
Hillview Drive
Stillwater Avenue
Windward Way
Surfside Terrace
Glenfield Beach Drive
Mistral Crest
Drummond Cove
Glenfield

Baird. Innovation Engineered.

Figure 1 of 12	**Coastal Hazard Mapping : Coastal Processes Allowance (Erosion Setback), Drummond Cove**	**Plan Number:** **EP17-099(01)--F08a**	N
Project:	Geraldton CHRMAP Project	Drawn: KNM	0 100 200 Metres
Client:	The City of Greater Geraldton	Date: 05/04/2018	Scale: 1:7,000@A3
		Checked: JC	GDA 1994 MGA Zone 50
		Approved: JC	City of Greater Geraldton a vibrant future
		Date: 11/04/2018	

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- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent

North West Coastal Highway

Geraldton-Mt Magnet Road

Brand Highway

Edward Road

Cadastral boundary

Coastal compartment extent

Coastal processes setbacks

Present Day

2030

2070

2110

Drummond Cove

Glenfield

Chapman Road

Glenfield

Sunset Beach

266000 266500 267000 267500

6824000 6823500 6823000 6822500 6822000

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Figure 2 of 12	**Coastal Hazard Mapping : Coastal Processes Allowance (Erosion Setback), Glenfield**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number: **EP17-099(01)--F08a**

Drawn:	KNM
Date:	05/04/2018
Checked:	JC
Approved:	JC
Date:	11/04/2018

N

0 100 200

Metres

Scale: 1:7,000@A3

GDA 1994 MGA Zone 50

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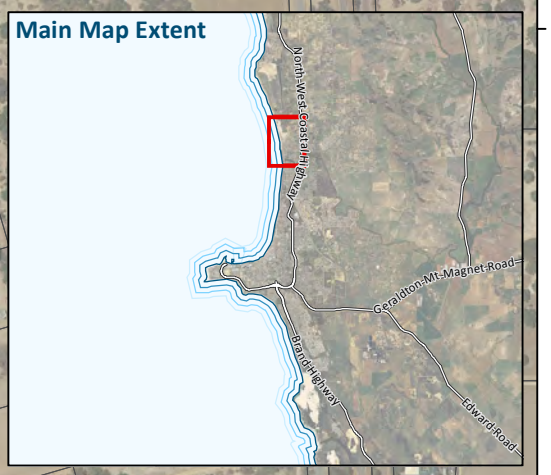
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent



Cadastral boundary
Coastal compartment extent
Coastal processes setbacks
Present Day
2030
2070
2110

Glenfield
Sunset Beach
Swordfish Vista
Sail Boulevard
Whitworth Drive
Volute Street
Bosley Street
Baler Road
Swan Drive
Sunset Beach
Bluff Point

267000 267500 268000 268500
6822000 6821500 6821000 6820500 6820000

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Figure 3 of 12	**Coastal Hazard Mapping : Coastal Processes Allowance (Erosion Setback), Sunset Beach**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number: EP17-099(01)--F08a
Drawn: KNM
Date: 05/04/2018
Checked: JC
Approved: JC
Date: 11/04/2018

N

0 100 200
Metres
Scale: 1:7,000@A3
GDA 1994 MGA Zone 50

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- Town Beach to Drummond Cove Inundation & Coastal Processes Study (MRA 2016).
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent

North-West Coastal Highway
Geraldton-Mt Magnet Road
Brand Highway
Edward Road

Cadastral boundary
Coastal protection structure
Coastal compartment extent
Coastal processes setbacks
Present Day
2030
2070
2110

Swan Drive
Sunset Beach
Bluff Point
Crowtherton Street
Fuller Street
Hungerford Street
Hosken Street
Champion Bay Rise
Kempton Street
Elphick Avenue
Mitchell Street
Morris Street
Webberton Road
Cecily Street
Ord Street
Mabel Street
Trigg Street
Beresford Bluff Point

267000 267500 268000 268500
6820000 6819500 6819000 6818500 6818000 6817500

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Figure 4 of 12	**Coastal Hazard Mapping : Coastal Processes Allowance (Erosion Setback), Bluff Point**	**Plan Number:** EP17-099(01)--F08a Drawn: KNM Date: 05/04/2018 Checked: JC Approved: JC Date: 11/04/2018	N
Project: Geraldton CHRMAP Project		0 100 200 300 Metres Scale: 1:8,000@A3 GDA 1994 MGA Zone 50	City of Greater Geraldton a vibrant future
Client: The City of Greater Geraldton			

Figure 5 of 12	**Coastal Hazard Mapping : Coastal Processes Allowance (Erosion Setback), Beresford**	**Plan Number:** **EP17-099(01)--F08a**	N
Project:	Geraldton CHRMAP Project	Drawn: KNM Date: 05/04/2018 Checked: JC Approved: JC Date: 11/04/2018	0 100 200 Metres Scale: 1:5,000@A3 GDA 1994 MGA Zone 50
Client:	The City of Greater Geraldton		

265000 266000 267000 268000

6815000 6814000 6813000

Disclaimer and Data Sources

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Data Sources:

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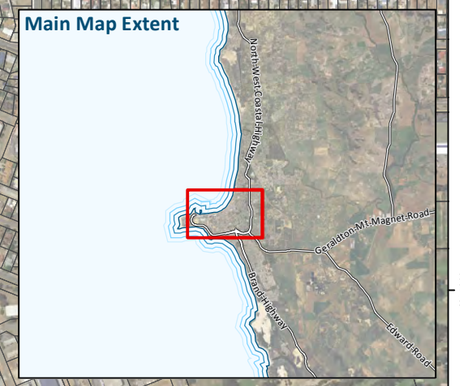
- Town Beach to Drummond Cove Inundation & Coastal Processes Study (MRA 2016).
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent



Cadastral boundary

Coastal protection structure

Coastal compartment extent

Coastal processes setbacks

- Present Day
- 2030
- 2070
- 2110

Geraldton
Beresford
Urch Street
Wittenoom Street
Phelps Street
Chapman Road
George Road
Foreshore Drive
Marine Terrace
Cathedral Avenue
Carson Terrace
Durlacher Street
Carnarvon Terrace
Augustus Street
Portway
Point Street
Monsoon Lane
Shenton Street
Gregory Street
Fitzgerald Street
Growther Street
John Willcock Link
West End / Point Moore
Beachlands
Fraser Street
Mcaleer Drive
Brand Highway
Separation Point Close

Baird. Innovation Engineered.

Figure 6 of 12	**Coastal Hazard Mapping : Coastal Processes Allowance (Erosion Setback), Geraldton**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number: EP17-099(01)--F09a

Drawn: KNM
Date: 05/04/2018
Checked: JC
Approved: JC
Date: 11/04/2018

N

0 200 400
Metres

Scale: 1:12,500@A3

GDA 1994 MGA Zone 50

City of Greater Geraldton a vibrant future

263500 264000 264500

6815000 6814500 6814000 6813500

Disclaimer and Data Sources

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Data Sources:

- Cape Burney to Greys Beach Inundation & Coastal Processes Study (MRA 2017).
- Town Beach to Drummond Cove Inundation & Coastal Processes Study (MRA 2016).
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Cadastral boundary

Coastal protection structure

Coastal compartment extent

Coastal processes setbacks

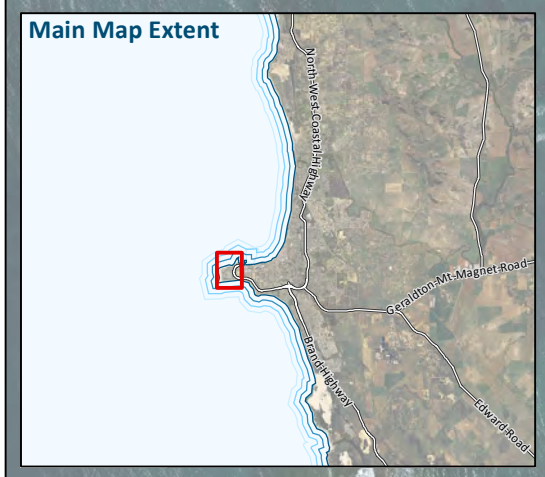
Present Day

2030

2070

2110

Main Map Extent



Geraldton

West End / Point Moore

Captains Crescent

Sextant Lane

Monsoon Lane

Astrolabe Lane

West End / Point Moore Beachlands

Baird.
Innovation Engineered.

Figure 7 of 12	**Coastal Hazard Mapping : Coastal Processes Allowance (Erosion Setback), West End / Point Moore**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number: **EP17-099(01)--F10a**

Drawn: KNM
Date: 05/04/2018
Checked: JC
Approved: JC
Date: 11/04/2018

N

0 100 200
Metres

Scale: 1:5,000@A3

GDA 1994 MGA Zone 50

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Data Sources:
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- Town Beach to Drummond Cove Inundation & Coastal Processes Study (MRA 2016).
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent

Cadastral boundary
Coastal compartment extent
Coastal processes setbacks
Present Day
2030
2070
2110

Marine Terrace
Point Street
Portway
West End / Point Moore
Beachlands
Separation Point Close
Mahomets Flats
North West Coastal Highway
Geraldton-Mt Magnet Road
Brand Highway
Edward Road

264500 265000 265500
6814500 6814000 6813500 6813000 6812500

Baird. Innovation Engineered.

Figure 8 of 12	**Coastal Hazard Mapping : Coastal Processes Allowance (Erosion Setback), Beachlands**	**Plan Number:** **EP17-099(01)--F08a**	N
Project:	Geraldton CHRMAP Project	Drawn: KNM Date: 05/04/2018 Checked: JC Approved: JC Date: 11/04/2018	0 100 200 Metres Scale: 1:6,000@A3 GDA 1994 MGA Zone 50
Client:	The City of Greater Geraldton		City of Greater Geraldton a vibrant future

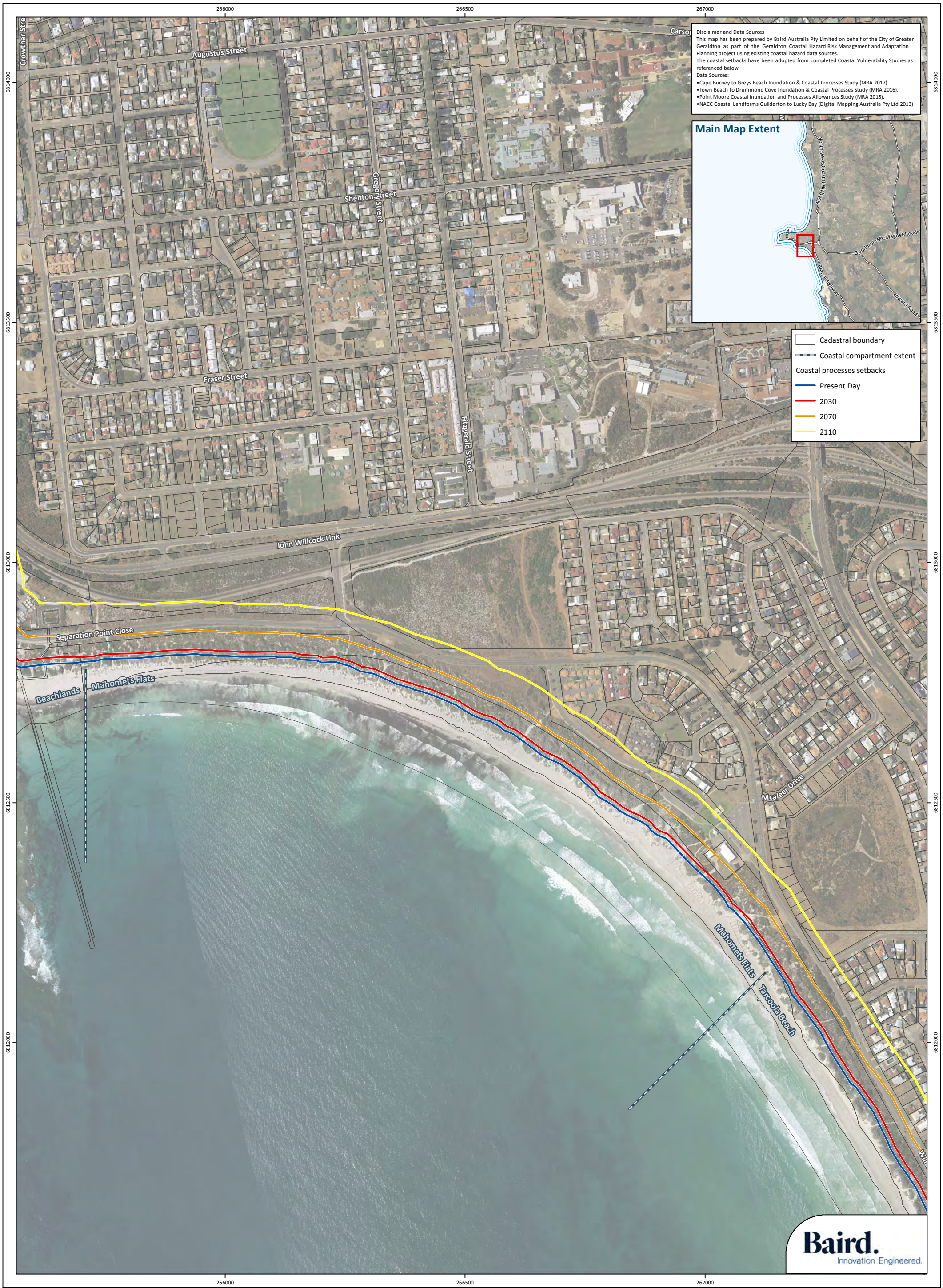

Figure 9 of 12	**Coastal Hazard Mapping : Coastal Processes Allowance (Erosion Setback), Mahomets Flats**	**Plan Number:** **EP17-099(01)--F08a** Drawn: KNM Date: 05/04/2018 Checked: JC Approved: JC Date: 11/04/2018	N	0 100 200 Metres Scale: 1:7,000@A3 GDA 1994 MGA Zone 50
Project:	Geraldton CHRMAP Project			
Client:	The City of Greater Geraldton			

Figure 10 of 12	**Coastal Hazard Mapping : Coastal Processes Allowance (Erosion Setback), Tarcoola Beach**	**Plan Number:** **EP17-099(01)--F08a**	N
Project:	Geraldton CHRMAP Project	Drawn: KNM Date: 05/04/2018 Checked: JC Approved: JC Date: 11/04/2018	0 100 200 300 400 Metres Scale: 1:10,500@A3 GDA 1994 MGA Zone 50
Client:	The City of Greater Geraldton		

Disclaimer and Data Sources

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- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent

North-West Coastal Highway

Geraldton-Mt Magnet Road

Brand Highway

Edward Road

Tarcoola Beach

Southgate Dunes

Brand Highway

Southgate Dunes

Cape Burney

Cadastral boundary

Coastal compartment extent

Coastal processes setbacks

Present Day

2030

2070

2110

268000 268500 269000 269500 270000

6808500 6808000 6807500 6807000 6806500 6806000

Baird. Innovation Engineered.

Figure 11 of 12	**Coastal Hazard Mapping : Coastal Processes Allowance (Erosion Setback), Southgate Dunes**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number: EP17-099(01)--F08a

Drawn: KNM
Date: 05/04/2018
Checked: JC
Approved: JC
Date: 11/04/2018

N

0 100 200 300

Metres

Scale: 1:8,500@A3

GDA 1994 MGA Zone 50

City of Greater Geraldton a vibrant future

269000 269500

6806000 6805500 6805000 6804500

Disclaimer and Data Sources

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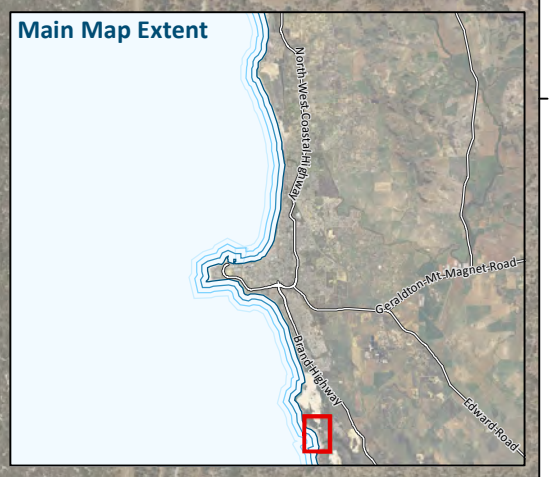
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent



Southgate Dunes

Cape Burney

Greenough River Road

Cape Burney

Cadastral boundary

Coastal compartment extent

Coastal processes setbacks

Present Day

2030

2070

2110

Baird. Innovation Engineered.

Figure 12 of 12	**Coastal Hazard Mapping : Coastal Processes Allowance (Erosion Setback), Cape Burney**	**Plan Number:** **EP17-099(01)--F08a**	N
Project:	Geraldton CHRMAP Project	Drawn: KNM	0 100 200 Metres
Client:	The City of Greater Geraldton	Date: 05/04/2018	Scale: 1:5,000@A3
		Checked: JC	GDA 1994 MGA Zone 50
		Approved: JC	City of Greater Geraldton a vibrant future
		Date: 11/04/2018	

A.2 Coastal Inundation Mapping

Disclaimer and Data Sources

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Data Sources:

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- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent

Cadastral boundary

Coastal compartment extent

Innundation depth

- <0.1m
- >0.1m - 0.2m
- >0.2m - 0.4m
- >0.4m - 0.6m
- >0.6m - 0.8m
- >0.8m - 1.0m
- >1.0m - 1.2m
- >1.2m - 1.4m
- >1.4m - 1.6m
- >1.6m - 1.8m
- >1.8m - 2.0m
- >2.0m

Drummond Cove Road
Drummond Cove
Waterfront Circuit
Whitehill Road
Hester Street
Tailer Street
Reef Boulevard
Hillview Drive
Stillwater Avenue
Windward Way
Surfside Terrace
Glenfield Beach Drive
Mistral Crest
Drummond Cove
Glenfield

266000 266500 267000 267500

6826500 6826000 6825500 6825000 6824500

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Figure 1 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 500yr ARI Event, Drummond Cove**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number: EP17-099(01)--F11a
Drawn: KNM
Date: 06/04/2018
Checked: JC
Approved: JC
Date: 09/04/2018

N

0 100 200
Metres

Scale: 1:7,000@A3

GDA 1994 MGA Zone 50

City of Greater Geraldton a vibrant future

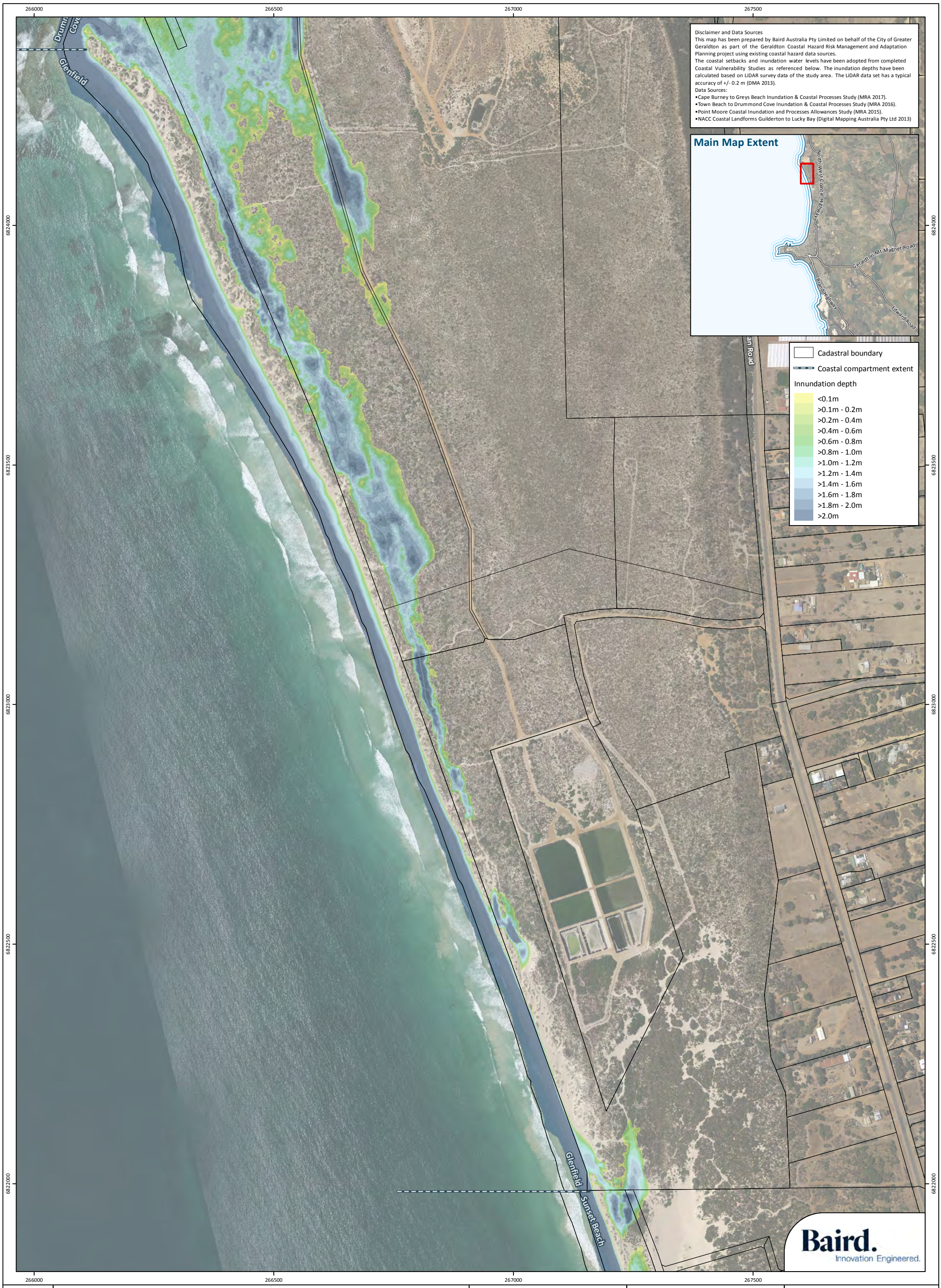

Figure 2 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 500yr ARI Event, Glenfield**	**Plan Number:** **EP17-099(01)--F11a**	N
Project:	Geraldton CHRMAP Project	Drawn: KNM Date: 06/04/2018 Checked: JC Approved: JC Date: 09/04/2018	0 100 200 Metres Scale: 1:7,000@A3 GDA 1994 MGA Zone 50
Client:	The City of Greater Geraldton		City of Greater Geraldton a vibrant future

Disclaimer and Data Sources

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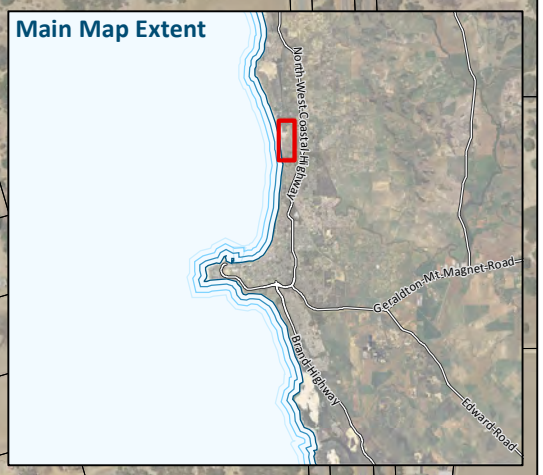
- Town Beach to Drummond Cove Inundation & Coastal Processes Study (MRA 2016).
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent



Cadastral boundary

Coastal compartment extent

Innundation depth

- <0.1m
- >0.1m - 0.2m
- >0.2m - 0.4m
- >0.4m - 0.6m
- >0.6m - 0.8m
- >0.8m - 1.0m
- >1.0m - 1.2m
- >1.2m - 1.4m
- >1.4m - 1.6m
- >1.6m - 1.8m
- >1.8m - 2.0m
- >2.0m

Glenfield

Sunset Beach

Swordfish Vista

Sail Boulevard

Whitworth Drive

Volute Street

Bosley Street

Swan Drive

Baler Road

Sunset Beach

Bluff Point

267000 267500 268000 268500

6822000 6821500 6821000 6820500 6820000

Baird. Innovation Engineered.

Figure 3 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 500yr ARI Event, Sunset Beach**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number:
EP17-099(01)--F11a

Drawn:	KNM
Date:	06/04/2018
Checked:	JC
Approved:	JC
Date:	09/04/2018

N

0 100 200

Metres

Scale: 1:7,000@A3

GDA 1994 MGA Zone 50

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Disclaimer and Data Sources

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Data Sources:

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- Town Beach to Drummond Cove Inundation & Coastal Processes Study (MRA 2016).
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent

North West Coastal Highway
Geraldton-Mt Magnet Road
Brand Highway
Edward Road

Cadastral boundary
Coastal compartment extent

Innundation depth
- <0.1m
- >0.1m - 0.2m
- >0.2m - 0.4m
- >0.4m - 0.6m
- >0.6m - 0.8m
- >0.8m - 1.0m
- >1.0m - 1.2m
- >1.2m - 1.4m
- >1.4m - 1.6m
- >1.6m - 1.8m
- >1.8m - 2.0m
- >2.0m

Swan Drive
Baler Road
Sunset Beach
Bluff Point
Crowtherton Street
Fuller Street
Hungerford Street
Hosken Street
Champion Bay Rise
Kempton Street
Elphick Avenue
Mitchell Street
Webberton Road
Morris Street
Cecily Street
Ord Street
Mabel Street
Trigg Street
Beresford
Bluff Point

267000 267500 268000 268500
6820000 6819500 6819000 6818500 6818000 6817500

Baird. Innovation Engineered.

Figure 4 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 500yr ARI Event, Bluff Point**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number: EP17-099(01)--F11a
Drawn: KNM
Date: 06/04/2018
Checked: JC
Approved: JC
Date: 09/04/2018

N

0 100 200 300
Metres
Scale: 1:8,000@A3
GDA 1994 MGA Zone 50

City of Greater Geraldton a vibrant future

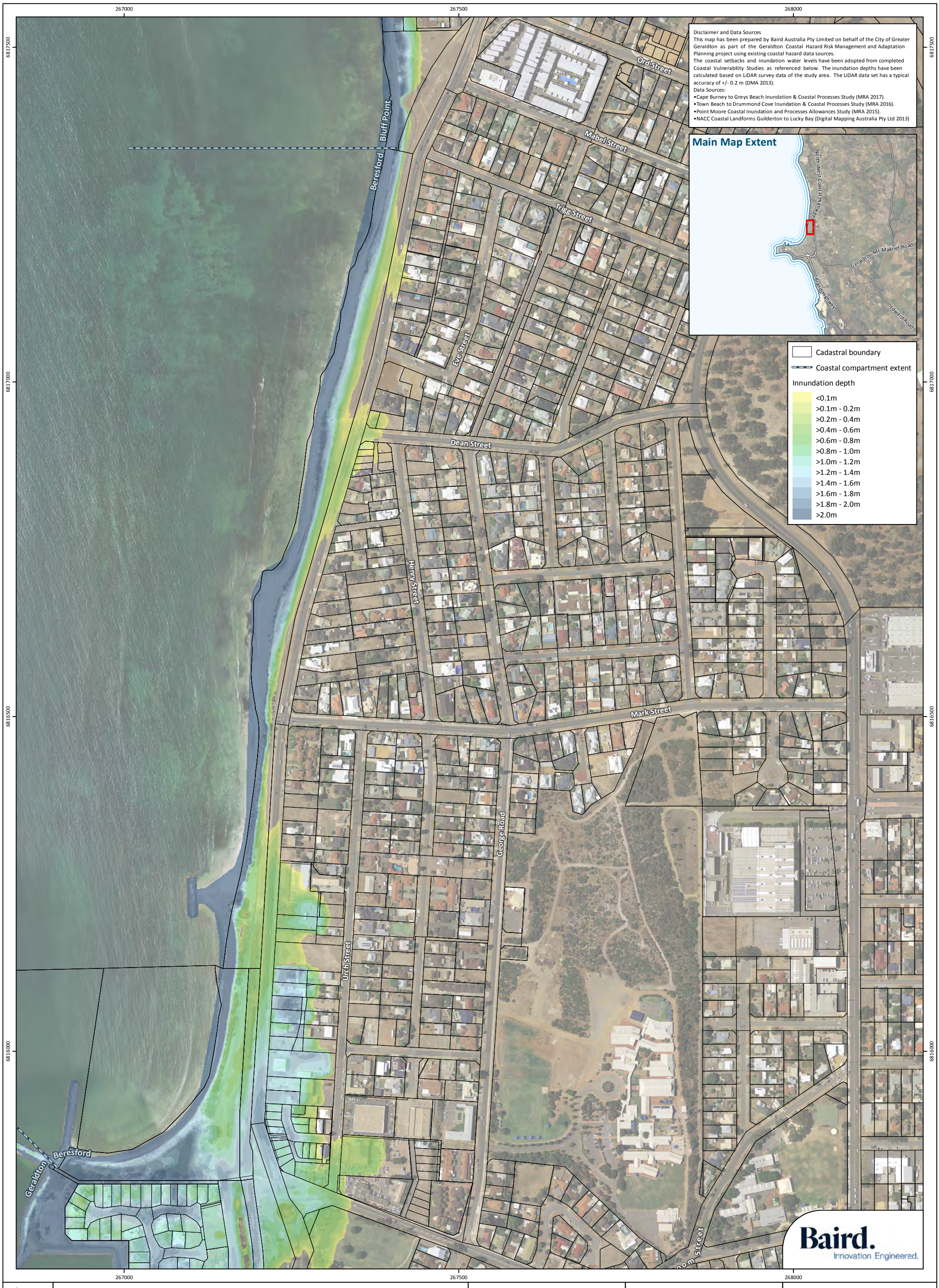

Figure 5 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 500yr ARI Event, Beresford**	**Plan Number:** **EP17-099(01)--F11a**	N
Project:	Geraldton CHRMAP Project	Drawn: KNM Date: 06/04/2018 Checked: JC Approved: JC Date: 09/04/2018	0 100 200 Metres Scale: 1:5,000@A3 GDA 1994 MGA Zone 50
Client:	The City of Greater Geraldton		

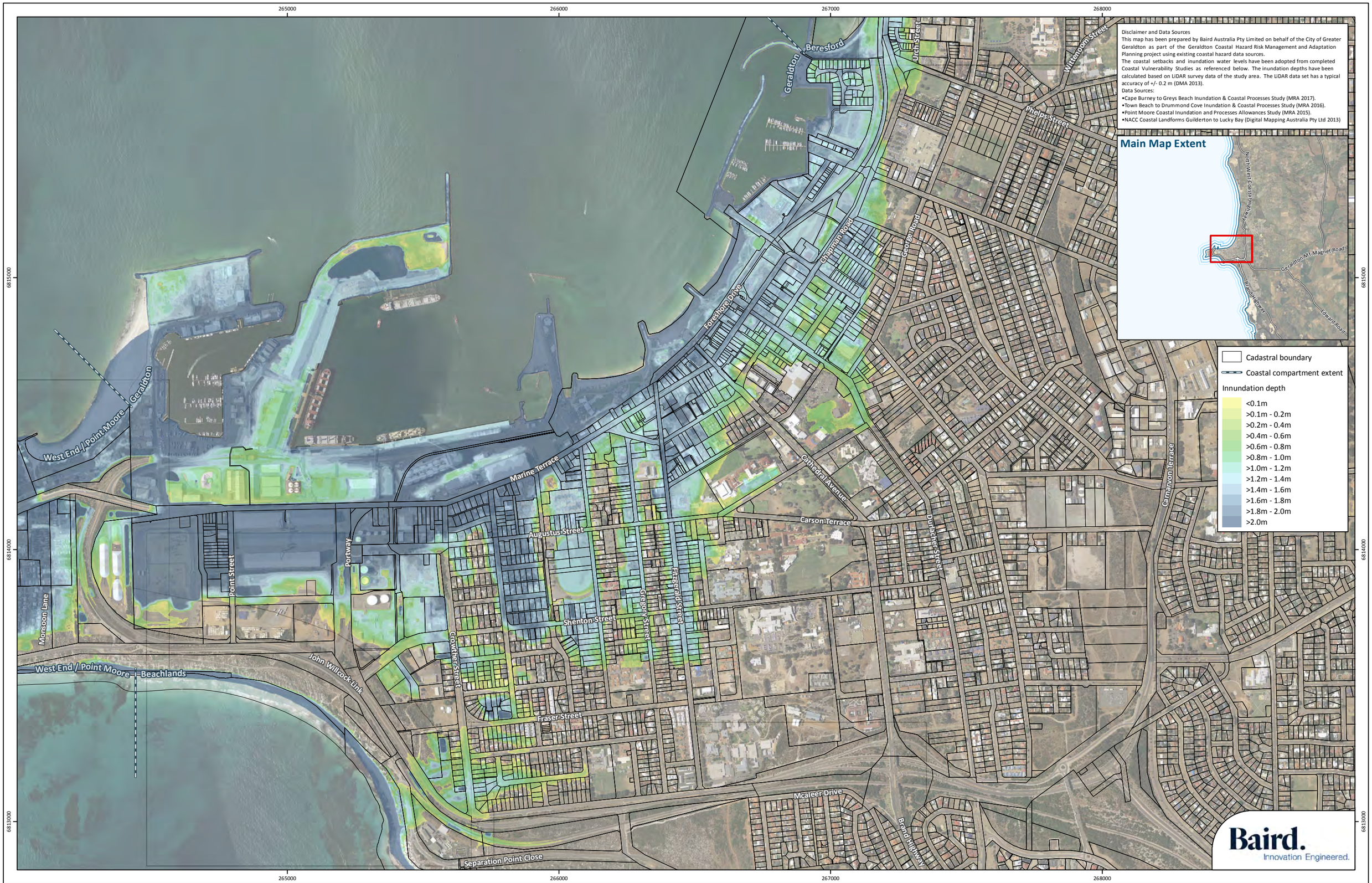

Figure 6 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 500yr ARI Event, Geraldton**	**Plan Number:** **EP17-099(01)--F12a**	N
Project: Geraldton CHRMAP Project		Drawn: KNM	0 200 400 Metres
Client: The City of Greater Geraldton		Date: 06/04/2018	Scale: 1:12,500@A3
		Checked: JC	GDA 1994 MGA Zone 50
		Approved: JC	
		Date: 09/04/2018	

263500 264000 264500

6815000 6814500 6814000 6813500

Disclaimer and Data Sources

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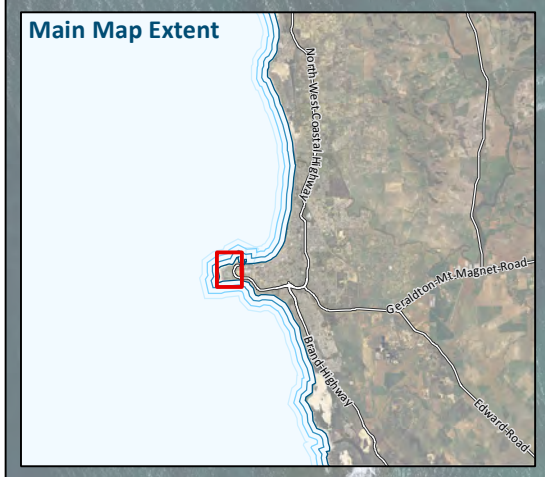
Data Sources:

- Cape Burney to Greys Beach Inundation & Coastal Processes Study (MRA 2017).
- Town Beach to Drummond Cove Inundation & Coastal Processes Study (MRA 2016).
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent



Cadastral boundary

Coastal compartment extent

Innundation depth

- <0.1m
- >0.1m - 0.2m
- >0.2m - 0.4m
- >0.4m - 0.6m
- >0.6m - 0.8m
- >0.8m - 1.0m
- >1.0m - 1.2m
- >1.2m - 1.4m
- >1.4m - 1.6m
- >1.6m - 1.8m
- >1.8m - 2.0m
- >2.0m

Geraldton

West End / Point Moore

Captains Crescent

Sextant Lane

Monsoon Lane

Astrolabe Lane

West End / Point Moore - Beachlands

Baird. Innovation Engineered.

Figure 7 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 500yr ARI Event, West End / Point Moore**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number: **EP17-099(01)--F13a**
Drawn: KNM
Date: 06/04/2018
Checked: JC
Approved: JC
Date: 09/04/2018

N

0 100 200
Metres
Scale: 1:5,000@A3
GDA 1994 MGA Zone 50

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Disclaimer and Data Sources

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Data Sources:

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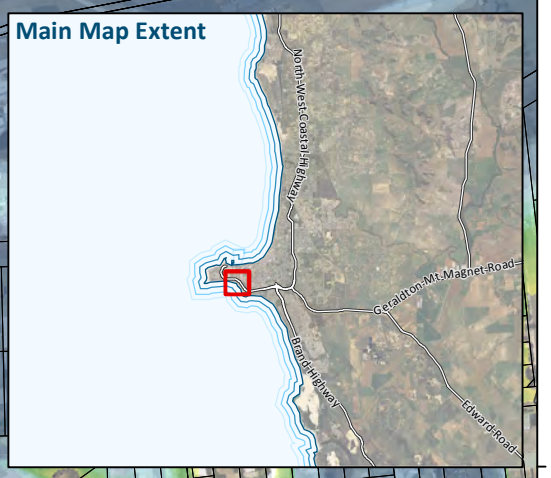
- Town Beach to Drummond Cove Inundation & Coastal Processes Study (MRA 2016).
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent



Cadastral boundary

Coastal compartment extent

Innundation depth

- <0.1m
- >0.1m - 0.2m
- >0.2m - 0.4m
- >0.4m - 0.6m
- >0.6m - 0.8m
- >0.8m - 1.0m
- >1.0m - 1.2m
- >1.2m - 1.4m
- >1.4m - 1.6m
- >1.6m - 1.8m
- >1.8m - 2.0m
- >2.0m

West End / Point Moore

Marine Terrace

Point Street

Portway

Beachlands

Separation Point Close

Mahomets Flats

264500 265000 265500

6814500 6814000 6813500 6813000 6812500

Baird. Innovation Engineered.

Figure 8 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 500yr ARI Event, Beachlands**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number: EP17-099(01)--F11a

Drawn:	KNM
Date:	06/04/2018
Checked:	JC
Approved:	JC
Date:	09/04/2018

N

0 100 200

Metres

Scale: 1:6,000@A3

GDA 1994 MGA Zone 50

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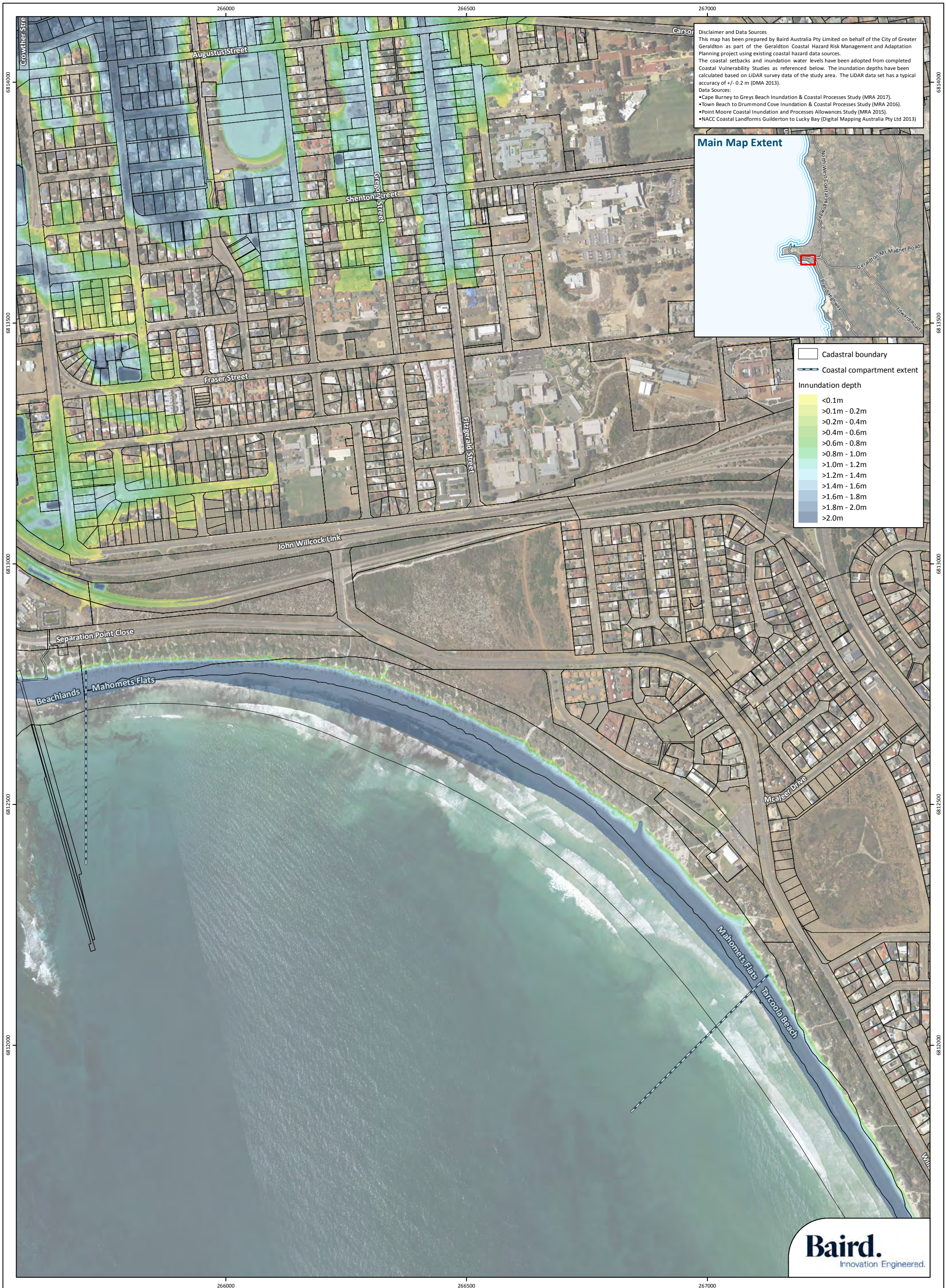

Figure 9 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 500yr ARI Event, Mahomets Flats**	**Plan Number:** EP17-099(01)--F11a Drawn: KNM Date: 06/04/2018 Checked: JC Approved: JC Date: 09/04/2018	N
Project: Geraldton CHRMAP Project			0 100 200 Metres Scale: 1:7,000@A3 GDA 1994 MGA Zone 50
Client: The City of Greater Geraldton			City of Greater Geraldton a vibrant future

Disclaimer and Data Sources

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Data Sources:

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- Town Beach to Drummond Cove Inundation & Coastal Processes Study (MRA 2016).
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent

North West Coastal Highway
Geraldton-Mt Magnet Road
Brand Highway
Edward Road

Cadastral boundary
Coastal compartment extent

Innundation depth
- <0.1m
- >0.1m - 0.2m
- >0.2m - 0.4m
- >0.4m - 0.6m
- >0.6m - 0.8m
- >0.8m - 1.0m
- >1.0m - 1.2m
- >1.2m - 1.4m
- >1.4m - 1.6m
- >1.6m - 1.8m
- >1.8m - 2.0m
- >2.0m

Mahomets Flats
Tarcoola Beach
Olive Street
Hakea Street
Jarrah Street
Willcock Drive
Broadhead Avenue
Highbury Street
Glenview Street
Ackland Road
Barrett Drive
Gantuny Road
Watterson Road
Sarda Street
Columbus Boulevard
Bellimos Drive
Tarcoola Beach Southgate Dunes

Baird. Innovation Engineered.

267000 267500 268000 268500 269000 269500
6812000 6811500 6811000 6810500 6810000 6809500 6809000 6808500

Figure 10 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 500yr ARI Event, Tarcoola Beach**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number:
EP17-099(01)--F11a
Drawn: KNM
Date: 06/04/2018
Checked: JC
Approved: JC
Date: 09/04/2018

N

0 100 200 300 400
Metres
Scale: 1:10,500@A3
GDA 1994 MGA Zone 50

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Data Sources:

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- Town Beach to Drummond Cove Inundation & Coastal Processes Study (MRA 2016).
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent

North West Coastal Highway
Geraldton-Mt Magnet Road
Brand Highway
Edward Road

Cadastral boundary

Coastal compartment extent

Innundation depth

- <0.1m
- >0.1m - 0.2m
- >0.2m - 0.4m
- >0.4m - 0.6m
- >0.6m - 0.8m
- >0.8m - 1.0m
- >1.0m - 1.2m
- >1.2m - 1.4m
- >1.4m - 1.6m
- >1.6m - 1.8m
- >1.8m - 2.0m
- >2.0m

Tarcoola Beach
Southgate Dunes
Brand Highway
Southgate Dunes
Cape Burney

268000 268500 269000 269500 270000

6808500 6808000 6807500 6807000 6806500 6806000

Baird. Innovation Engineered.

Figure 11 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 500yr ARI Event, Southgate Dunes**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number: EP17-099(01)--F11a
Drawn: KNM
Date: 06/04/2018
Checked: JC
Approved: JC
Date: 09/04/2018

N

0 100 200 300
Metres
Scale: 1:8,500@A3
GDA 1994 MGA Zone 50

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269000 269500

6806000 6805500 6805000 6804500

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Data Sources:

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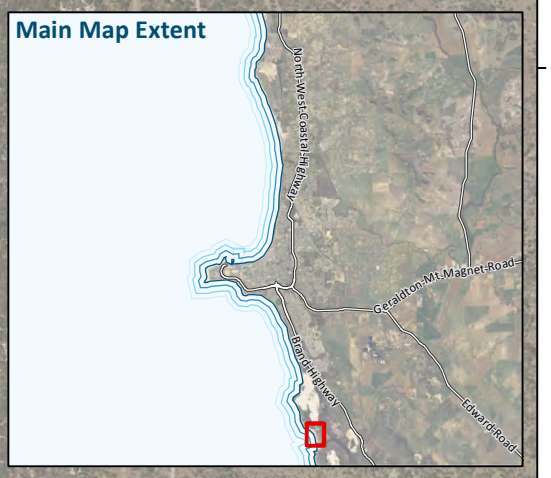
- Town Beach to Drummond Cove Inundation & Coastal Processes Study (MRA 2016).
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent



Cadastral boundary

Coastal compartment extent

Innundation depth

- <0.1m
- >0.1m - 0.2m
- >0.2m - 0.4m
- >0.4m - 0.6m
- >0.6m - 0.8m
- >0.8m - 1.0m
- >1.0m - 1.2m
- >1.2m - 1.4m
- >1.4m - 1.6m
- >1.6m - 1.8m
- >1.8m - 2.0m
- >2.0m

Southgate Dunes

Cape Burney

Greenough River Road

Cape Burney

Baird. Innovation Engineered.

Figure 12 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 500yr ARI Event, Cape Burney**	**Plan Number:** **EP17-099(01)--F11a**	N
Project:	Geraldton CHRMAP Project	Drawn: KNM Date: 06/04/2018 Checked: JC Approved: JC Date: 09/04/2018	0 100 200 Metres Scale: 1:5,000@A3 GDA 1994 MGA Zone 50
Client:	The City of Greater Geraldton		City of Greater Geraldton a vibrant future

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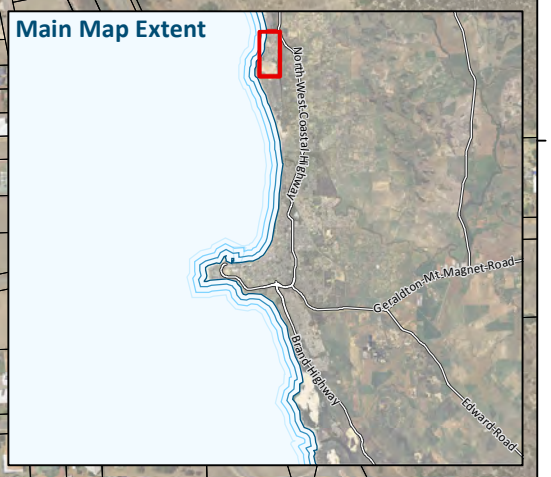
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent



Cadastral boundary

Coastal compartment extent

Innundation depth

- <0.1m
- >0.1m - 0.2m
- >0.2m - 0.4m
- >0.4m - 0.6m
- >0.6m - 0.8m
- >0.8m - 1.0m
- >1.0m - 1.2m
- >1.2m - 1.4m
- >1.4m - 1.6m
- >1.6m - 1.8m
- >1.8m - 2.0m
- >2.0m

Drummond Cove Road
Drummond Cove
Waterfront Circuit
Whitehill Road
Hester Street
Tailer Street
Reef Boulevard
Hillview Drive
Stillwater Avenue
Windward Way
Surfside Terrace
Glenfield Beach Drive
Mistral Crest
Drummond Cove
Glenfield

266000 266500 267000 267500

6826500 6826000 6825500 6825000 6824500

Baird.
Innovation Engineered.

Figure 1 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 100yr ARI Event, Drummond Cove**	**Plan Number:** EP17-099(01)--F37 Drawn: KNM Date: 09/04/2018 Checked: JC Approved: JC Date: 09/04/2018	N 0 100 200 Metres Scale: 1:7,000@A3 GDA 1994 MGA Zone 50
Project: Geraldton CHRMAP Project			
Client: The City of Greater Geraldton			City of Greater Geraldton a vibrant future

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- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent

North West Coastal Highway
Geraldton-Mt Magnet Road
Brand Highway
Edward Road

Cadastral boundary
Coastal compartment extent

Innundation depth
- <0.1m
- >0.1m - 0.2m
- >0.2m - 0.4m
- >0.4m - 0.6m
- >0.6m - 0.8m
- >0.8m - 1.0m
- >1.0m - 1.2m
- >1.2m - 1.4m
- >1.4m - 1.6m
- >1.6m - 1.8m
- >1.8m - 2.0m
- >2.0m

Drummond Cove
Glenfield
Sunset Beach
Road

266000 266500 267000 267500
6824000 6823500 6823000 6822500 6822000

Baird. Innovation Engineered.

Figure 2 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 100yr ARI Event, Glenfield**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number: EP17-099(01)--F37
Drawn: KNM
Date: 09/04/2018
Checked: JC
Approved: JC
Date: 09/04/2018

N

0 100 200
Metres
Scale: 1:7,000@A3
GDA 1994 MGA Zone 50

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Data Sources:

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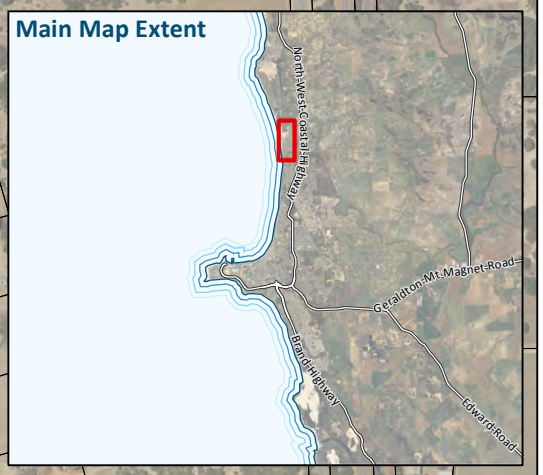
- Town Beach to Drummond Cove Inundation & Coastal Processes Study (MRA 2016).
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent



Cadastral boundary

Coastal compartment extent

Innundation depth

- <0.1m
- >0.1m - 0.2m
- >0.2m - 0.4m
- >0.4m - 0.6m
- >0.6m - 0.8m
- >0.8m - 1.0m
- >1.0m - 1.2m
- >1.2m - 1.4m
- >1.4m - 1.6m
- >1.6m - 1.8m
- >1.8m - 2.0m
- >2.0m

Glenfield

Sunset Beach

Swordfish Vista

Sail Boulevard

Whitworth Drive

Volute Street

Bosley Street

Swan Drive

Baler Road

Sunset Beach

Bluff Point

267000 267500 268000 268500

6822000 6821500 6821000 6820500 6820000

Baird. Innovation Engineered.

Figure 3 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 100yr ARI Event, Sunset Beach**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number:
EP17-099(01)--F37

Drawn:	KNM
Date:	09/04/2018
Checked:	JC
Approved:	JC
Date:	09/04/2018

N

0 100 200

Metres

Scale: 1:7,000@A3

GDA 1994 MGA Zone 50

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Data Sources:

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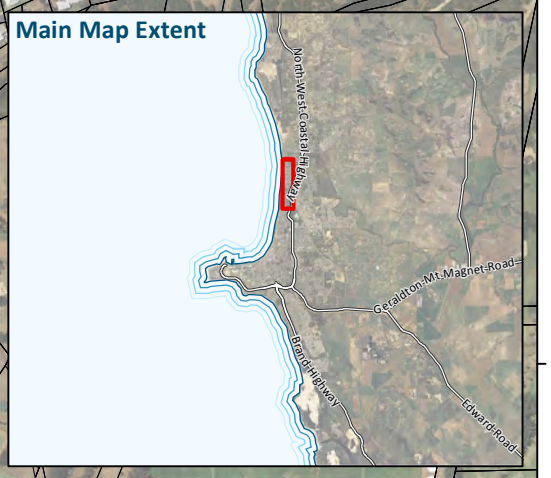
- Town Beach to Drummond Cove Inundation & Coastal Processes Study (MRA 2016).
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent



Cadastral boundary

Coastal compartment extent

Innundation depth

- <0.1m
- >0.1m - 0.2m
- >0.2m - 0.4m
- >0.4m - 0.6m
- >0.6m - 0.8m
- >0.8m - 1.0m
- >1.0m - 1.2m
- >1.2m - 1.4m
- >1.4m - 1.6m
- >1.6m - 1.8m
- >1.8m - 2.0m
- >2.0m

267000 267500 268000 268500

6820000 6819500 6819000 6818500 6818000 6817500

Swan Drive
Sunset Beach
Bluff Point
Baler Road
Crowtherton Street
Fuller Street
Hungerford Street
Hosken Street
Champion Bay Rise
Kempton Street
Elphick Avenue
Mitchell Street
Webberton Road
Morris Street
Cecily Street
Ord Street
Mabel Street
Trigg Street
Beresford
Bluff Point

Baird. Innovation Engineered.

Figure 4 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 100yr ARI Event, Bluff Point**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number: EP17-099(01)--F37
Drawn: KNM
Date: 09/04/2018
Checked: JC
Approved: JC
Date: 09/04/2018

N

0 100 200 300
Metres

Scale: 1:8,000@A3

GDA 1994 MGA Zone 50

City of Greater Geraldton a vibrant future

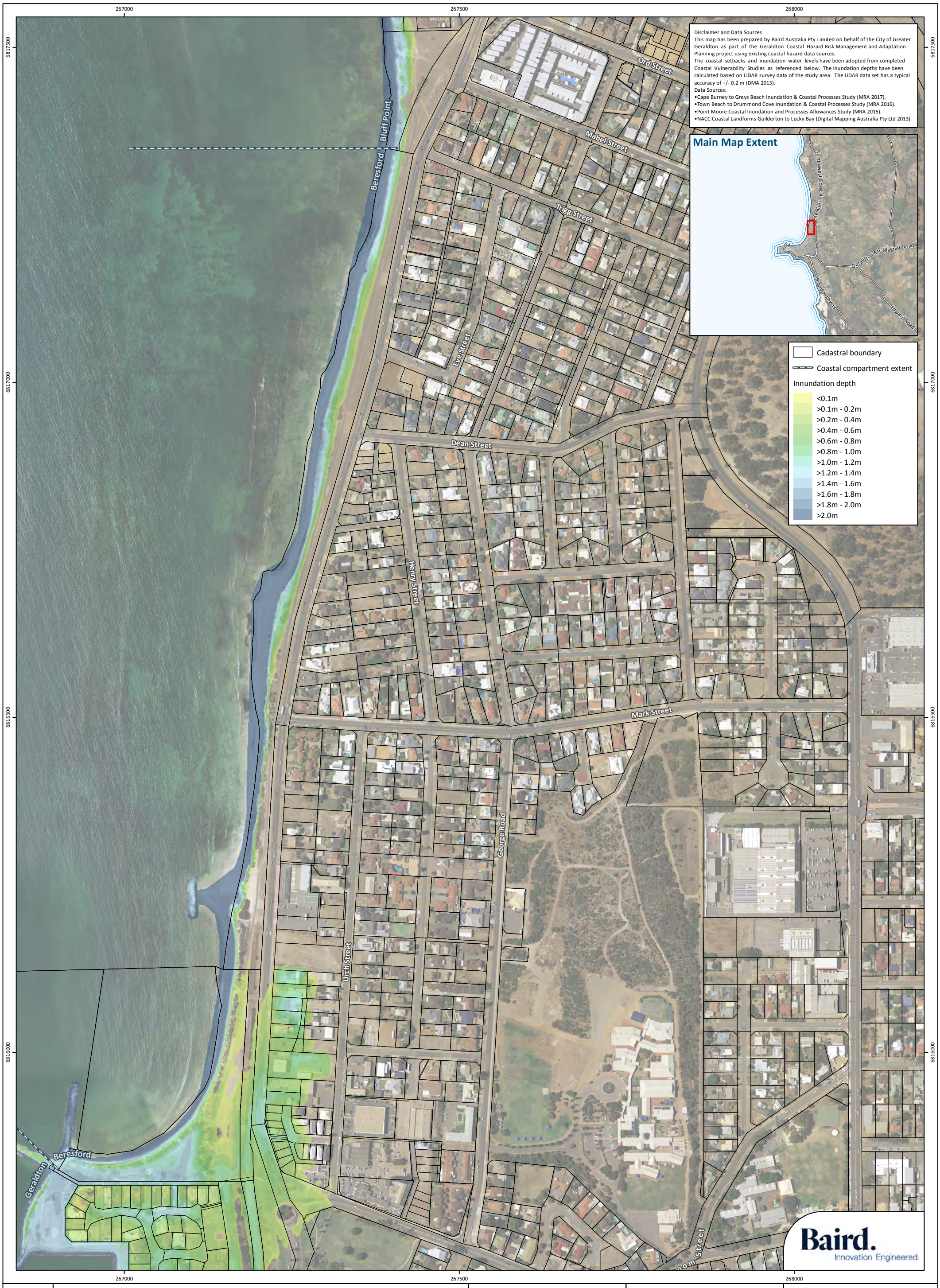


Figure 5 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 100yr ARI Event, Beresford**	**Plan Number:** **EP17-099(01)--F37**	N	0 100 200 Metres
Project: Geraldton CHRMAP Project		Drawn: KNM		Scale: 1:5,000@A3
Client: The City of Greater Geraldton		Date: 09/04/2018		GDA 1994 MGA Zone 50
		Checked: JC		
		Approved: JC		
		Date: 09/04/2018		

City of Greater Geraldton a vibrant future

265000 266000 267000 268000

6815000 6814000 6813000

Disclaimer and Data Sources

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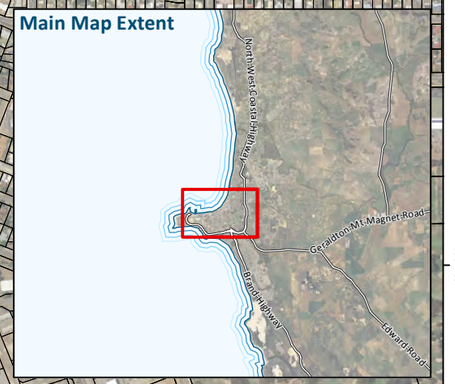
Data Sources:

- Cape Burney to Greys Beach Inundation & Coastal Processes Study (MRA 2017).
- Town Beach to Drummond Cove Inundation & Coastal Processes Study (MRA 2016).
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent



Cadastral boundary

Coastal compartment extent

Innundation depth

- <0.1m
- >0.1m - 0.2m
- >0.2m - 0.4m
- >0.4m - 0.6m
- >0.6m - 0.8m
- >0.8m - 1.0m
- >1.0m - 1.2m
- >1.2m - 1.4m
- >1.4m - 1.6m
- >1.6m - 1.8m
- >1.8m - 2.0m
- >2.0m

Beresford
Geraldton
Urch Street
Whitehorn Street
Phelps Street
Chapman Road
George Road
Foreshore Drive
Geraldton
West End / Point Moore
Marine Terrace
Cathedral Avenue
Carson Terrace
Durlacher Street
Cameron Terrace
Augustus Street
Portway
Point Street
Monsoon Lane
Shenton Street
Gregory Street
Fitzgerald Street
Crowther Street
John Willcock Link
West End / Point Moore
Beachlands
Fraser Street
Mcaleer Drive
Brand Highway
Separation Point Close

Baird.
Innovation Engineered.

Figure 6 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 100yr ARI Event, Geraldton**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number:
EP17-099(01)--F38

Drawn:	KNM
Date:	09/04/2018
Checked:	JC
Approved:	JC
Date:	09/04/2018

N

0 200 400
Metres

Scale: 1:12,500@A3

GDA 1994 MGA Zone 50

City of Greater Geraldton a vibrant future

263500 264000 264500

6815000 6814500 6814000 6813500

Disclaimer and Data Sources

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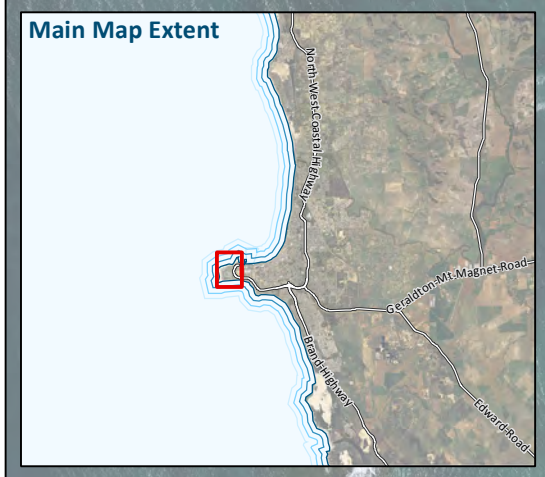
The coastal setbacks and inundation water levels have been adopted from completed Coastal Vulnerability Studies as referenced below. The inundation depths have been calculated based on LiDAR survey data of the study area. The LiDAR data set has a typical accuracy of +/- 0.2 m (DMA 2013).

Data Sources:

- Cape Burney to Greys Beach Inundation & Coastal Processes Study (MRA 2017).
- Town Beach to Drummond Cove Inundation & Coastal Processes Study (MRA 2016).
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent



Cadastral boundary

Coastal compartment extent

Innundation depth

- <0.1m
- >0.1m - 0.2m
- >0.2m - 0.4m
- >0.4m - 0.6m
- >0.6m - 0.8m
- >0.8m - 1.0m
- >1.0m - 1.2m
- >1.2m - 1.4m
- >1.4m - 1.6m
- >1.6m - 1.8m
- >1.8m - 2.0m
- >2.0m

Geraldton

West End / Point Moore

Captains Crescent

Sextant Lane

Monsoon Lane

Astrolabe Lane

West End / Point Moore - Beachlands

Baird. Innovation Engineered.

Figure 7 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 100yr ARI Event, West End / Point Moore**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number: EP17-099(01)--F39

Drawn: KNM
Date: 09/04/2018
Checked: JC
Approved: JC
Date: 09/04/2018

N

0 100 200
Metres

Scale: 1:5,000@A3

GDA 1994 MGA Zone 50

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Disclaimer and Data Sources

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Data Sources:

- Cape Burney to Greys Beach Inundation & Coastal Processes Study (MRA 2017).
- Town Beach to Drummond Cove Inundation & Coastal Processes Study (MRA 2016).
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent

North West Coastal Highway
Geraldton-Mt Magnet Road
Brand Highway
Edward Road

Cadastral boundary
Coastal compartment extent

Innundation depth

- <0.1m
- >0.1m - 0.2m
- >0.2m - 0.4m
- >0.4m - 0.6m
- >0.6m - 0.8m
- >0.8m - 1.0m
- >1.0m - 1.2m
- >1.2m - 1.4m
- >1.4m - 1.6m
- >1.6m - 1.8m
- >1.8m - 2.0m
- >2.0m

West End / Point Moore
Marine Terrace
Point Street
Portway
Beachlands
Separation Point Close
Mahomets Flats

264500 265000 265500
6814500 6814000 6813500 6813000 6812500

Baird. Innovation Engineered.

Figure 8 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 100yr ARI Event, Beachlands**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number: EP17-099(01)--F37
Drawn: KNM
Date: 09/04/2018
Checked: JC
Approved: JC
Date: 09/04/2018

N

0 100 200
Metres
Scale: 1:6,000@A3
GDA 1994 MGA Zone 50

City of Greater Geraldton a vibrant future

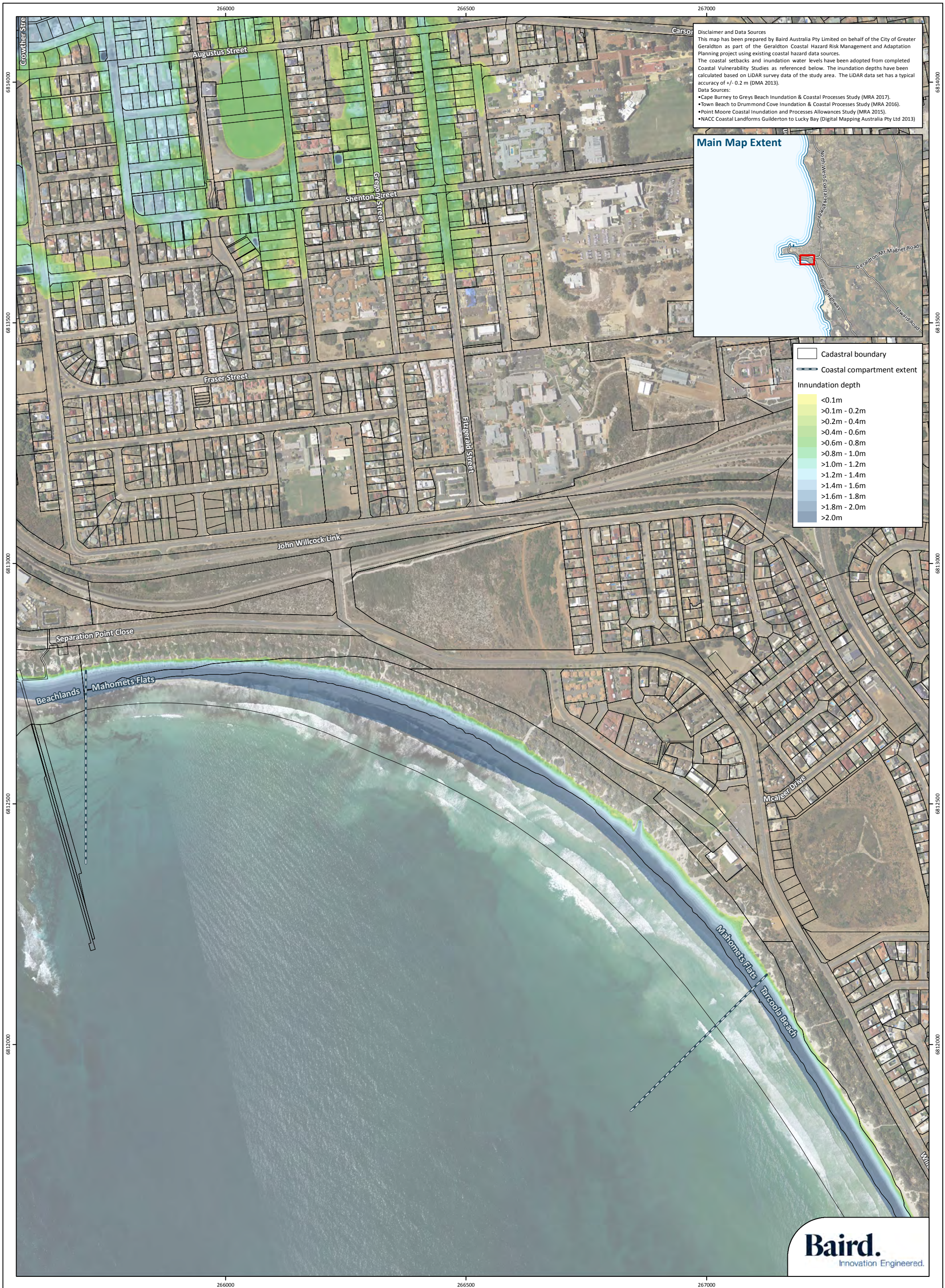

Figure 9 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 100yr ARI Event, Mahomets Flats**	**Plan Number:** **EP17-099(01)--F37** Drawn: KNM Date: 09/04/2018 Checked: JC Approved: JC Date: 09/04/2018	N	0 100 200 Metres Scale: 1:7,000@A3 GDA 1994 MGA Zone 50
Project:	Geraldton CHRMAP Project			
Client:	The City of Greater Geraldton			

Figure 10 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 100yr ARI Event, Tarcoola Beach**	**Plan Number:** **EP17-099(01)--F37**	N	0 100 200 300 400 Metres
Project:	Geraldton CHRMAP Project	Drawn: KNM		Scale: 1:10,500@A3
Client:	The City of Greater Geraldton	Date: 09/04/2018		GDA 1994 MGA Zone 50
		Checked: JC		
		Approved: JC		
		Date: 09/04/2018		

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Data Sources:

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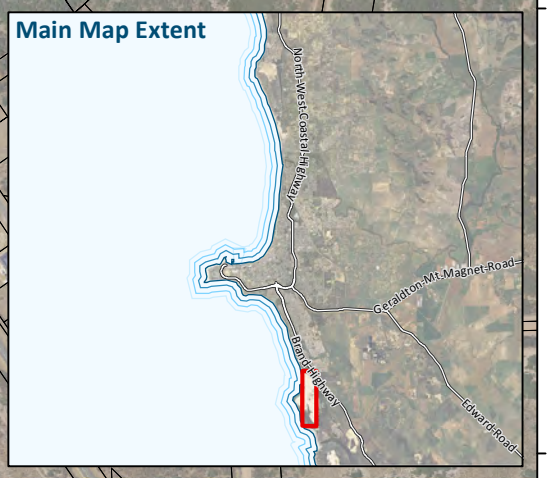
- Town Beach to Drummond Cove Inundation & Coastal Processes Study (MRA 2016).
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent



Cadastral boundary

Coastal compartment extent

Innundation depth

- <0.1m
- >0.1m - 0.2m
- >0.2m - 0.4m
- >0.4m - 0.6m
- >0.6m - 0.8m
- >0.8m - 1.0m
- >1.0m - 1.2m
- >1.2m - 1.4m
- >1.4m - 1.6m
- >1.6m - 1.8m
- >1.8m - 2.0m
- >2.0m

Tarcoola Beach

Southgate Dunes

Brand Highway

Southgate Dunes

Cape Burney

268000 268500 269000 269500 270000

6808500 6808000 6807500 6807000 6806500 6806000

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Figure 11 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 100yr ARI Event, Southgate Dunes**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number: **EP17-099(01)--F37**

Drawn: KNM
Date: 09/04/2018
Checked: JC
Approved: JC
Date: 09/04/2018

N

0 100 200 300

Metres

Scale: 1:8,500@A3

GDA 1994 MGA Zone 50

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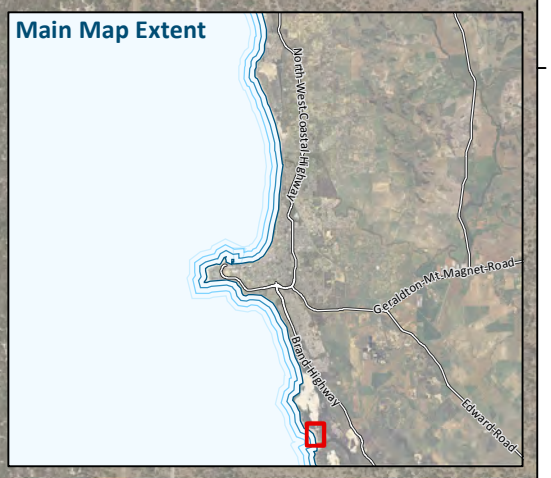
Data Sources:

- Cape Burney to Greys Beach Inundation & Coastal Processes Study (MRA 2017).
- Town Beach to Drummond Cove Inundation & Coastal Processes Study (MRA 2016).
- Point Moore Coastal Inundation and Processes Allowances Study (MRA 2015).
- NACC Coastal Landforms Guilderton to Lucky Bay (Digital Mapping Australia Pty Ltd 2013)

Main Map Extent



Cadastral boundary

Coastal compartment extent

Innundation depth

- <0.1m
- >0.1m - 0.2m
- >0.2m - 0.4m
- >0.4m - 0.6m
- >0.6m - 0.8m
- >0.8m - 1.0m
- >1.0m - 1.2m
- >1.2m - 1.4m
- >1.4m - 1.6m
- >1.6m - 1.8m
- >1.8m - 2.0m
- >2.0m

Southgate Dunes

Cape Burney

Greenough River Road

Cape Burney

269000 269500

6806000 6805500 6805000 6804500

Baird. Innovation Engineered.

Figure 12 of 12	**Coastal Hazard Mapping : 2110 Coastal Inundation Depth 100yr ARI Event, Cape Burney**	**Plan Number:** **EP17-099(01)--F37** Drawn: KNM Date: 09/04/2018 Checked: JC Approved: JC Date: 09/04/2018	N
Project: Geraldton CHRMAP Project		0 100 200 Metres Scale: 1:5,000@A3 GDA 1994 MGA Zone 50	City of Greater Geraldton a vibrant future
Client: The City of Greater Geraldton			

A.3 Coastal Asset Mapping

Disclaimer and Data Sources
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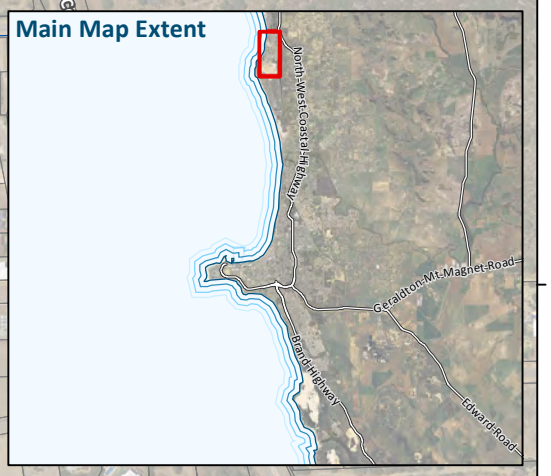
Main Map Extent



Drummond Cove Road
Drummond Cove
Waterfront Circuit
Bayside Boulevard
Whitehill Road
Hester Street
Trailer Street
Reef Boulevard
Hillview Drive
Stillwater Avenue
Windward Way
Sunside Terrace
Glenfield Beach Drive
Mistral Crest
Drummond Cove
Glenfield

- Cadastral boundary
- Coastal compartment extent
- Playgrounds
- CGG Buildings
- Carparks
- Pathways
- Existing gas main
- Playground Equipment

Watercorp
- Water pipe
- Sewer
- Sewer pump station

Western power
- Overhead line
- Underground cable

TPS zoning
- Environmental conservation
- Foreshore
- Public open space
- Public purposes
- Residential
- Tourism
- Urban development

266000 266500 267000 267500
6826500 6826000 6825500 6825000 6824500

Baird. Innovation Engineered.

Figure 1 of 12	**Coastal Asset Mapping, Drummond Cove**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number:
EP17-099(01)--F25b
Drawn: KNM
Date: 09/11/2018
Checked: JC
Approved: JC
Date: 09/11/2018

N

0 100 200
Metres
Scale: 1:7,000@A3
GDA 1994 MGA Zone 50

City of Greater Geraldton a vibrant future

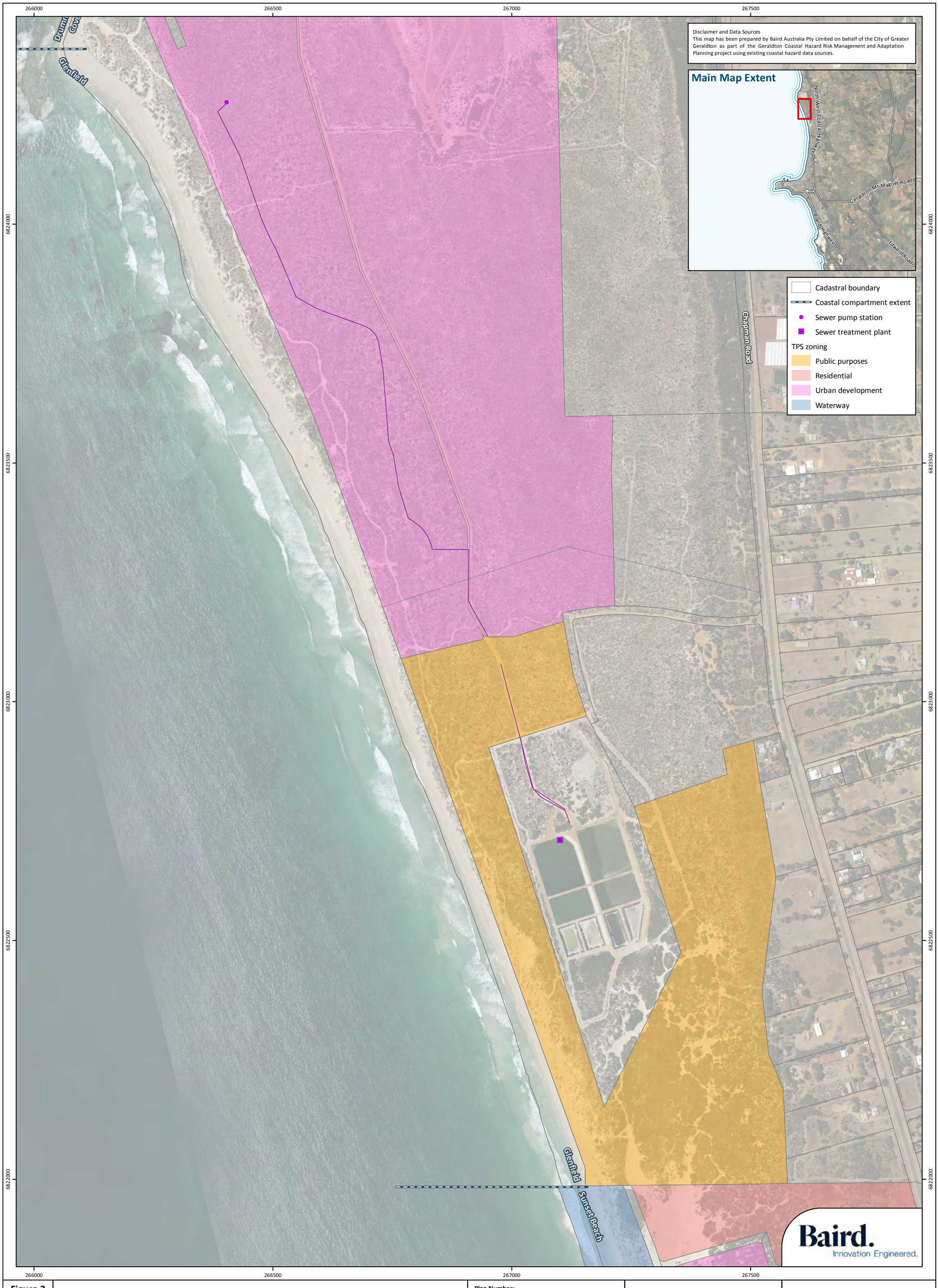


Figure 2 of 12	**Coastal Asset Mapping, Glenfield**	**Plan Number:** **EP17-099(01)--F25b**	N
Project:	Geraldton CHRMAP Project	Drawn: KNM Date: 09/11/2018 Checked: JC Approved: JC Date: 09/11/2018	0 100 200 Metres Scale: 1:7,000@A3 GDA 1994 MGA Zone 50
Client:	The City of Greater Geraldton		City of Greater Geraldton a vibrant future

Disclaimer and Data Sources
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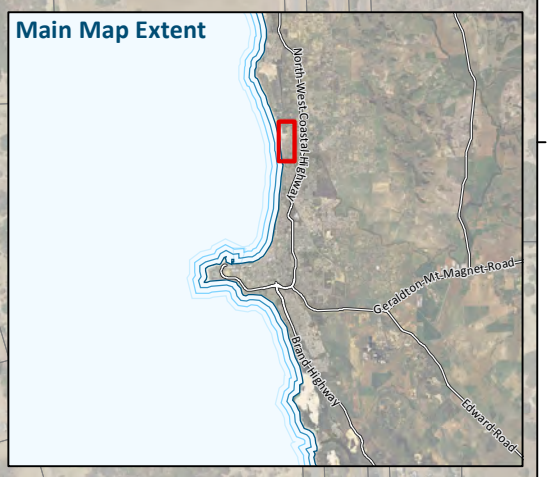
Main Map Extent



- Cadastral boundary
- Coastal compartment extent
- Playgrounds
- CGG Buildings
- Carparks
- Pathways
- Existing gas main
- Playground Equipment

Watercorp
- Water pipe
- Sewer
- Sewer pump station

Western power
- Overhead line
- Underground cable

TPS zoning
- Civic & community
- Foreshore
- Public open space
- Public purposes
- Residential
- Rural
- Tourism
- Urban development
- Waterway

Glenfield
Sunset Beach
Swordfish Vista
Sail Boulevard
Whitworth Drive
Volute Street
Bosley Street
Swan Drive
Baler Road
Sunset Beach
Bluff Point
CHAPMAN RIVER

267000 267500 268000 268500
6822000 6821500 6821000 6820500 6820000

Baird. Innovation Engineered.

Figure 3 of 12	**Coastal Asset Mapping, Sunset Beach**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number:
EP17-099(01)--F25b
Drawn: KNM
Date: 09/11/2018
Checked: JC
Approved: JC
Date: 09/11/2018

N

0 100 200
Metres
Scale: 1:7,000@A3
GDA 1994 MGA Zone 50

City of Greater Geraldton a vibrant future

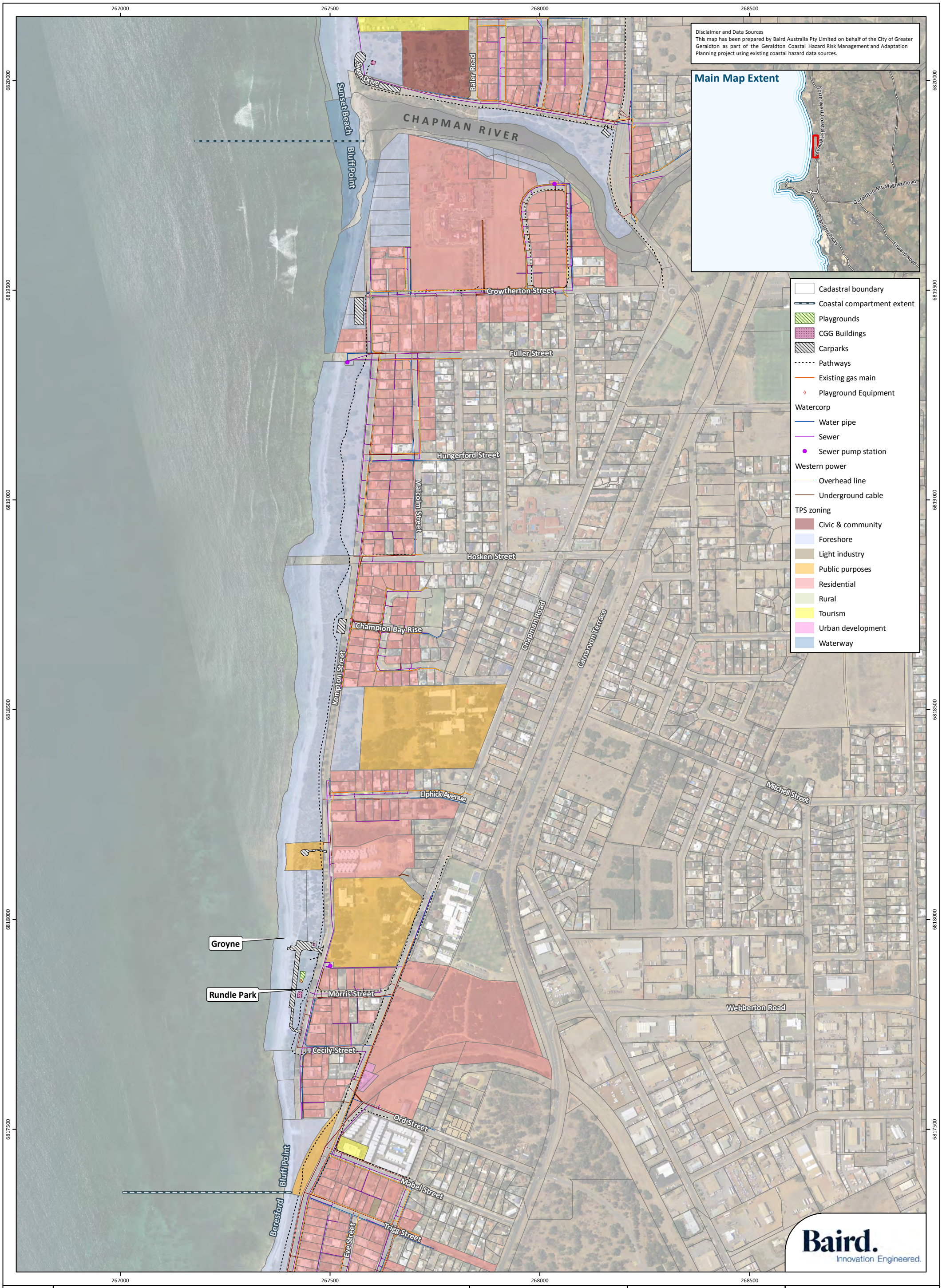


Figure 4 of 12	**Coastal Asset Mapping, Bluff Point**	**Plan Number:** **EP17-099(01)--F25b**	N
Project:	Geraldton CHRMAP Project	Drawn: KNM Date: 09/11/2018 Checked: JC Approved: JC Date: 09/11/2018	0 100 200 300 Metres Scale: 1:8,000@A3 GDA 1994 MGA Zone 50
Client:	The City of Greater Geraldton		City of Greater Geraldton a vibrant future

267000 267500 268000

6817500 6817000 6816500 6816000

Disclaimer and Data Sources
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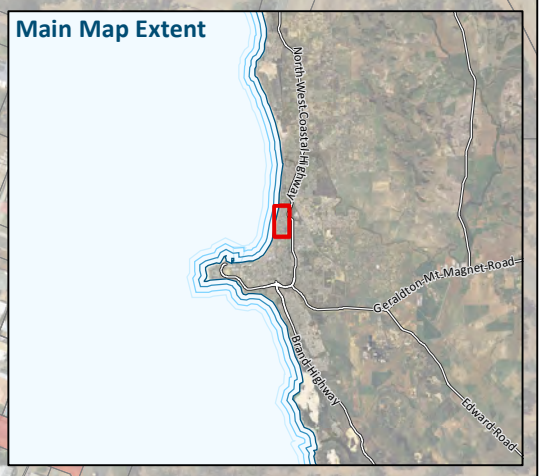
Main Map Extent



Ord Street
Bluff Point
Beresford
Mabel Street
Eve Street
Trigg Street
Dean Street
Mark Street
George Road
Simpson Street
Urch Street
Geraldton Beresford

- Cadastral boundary
- Coastal compartment extent
- Playgrounds
- Carparks
- Pathways
- Existing gas main
- Playground Equipment
- Artwork

Watercorp
- Water pipe
- Sewer
- Sewer pump station

Western power
- Overhead line
- Underground cable

TPS zoning
- Foreshore
- Light industry
- Mixed use
- Public open space
- Public purposes
- Residential
- Tourism
- Waterway

Baird. Innovation Engineered.

Figure 5 of 12	**Coastal Asset Mapping, Beresford**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number:
EP17-099(01)--F25b
Drawn: KNM
Date: 09/11/2018
Checked: JC
Approved: JC
Date: 09/11/2018

N

0 100 200
Metres
Scale: 1:5,000@A3
GDA 1994 MGA Zone 50

City of Greater Geraldton a vibrant future

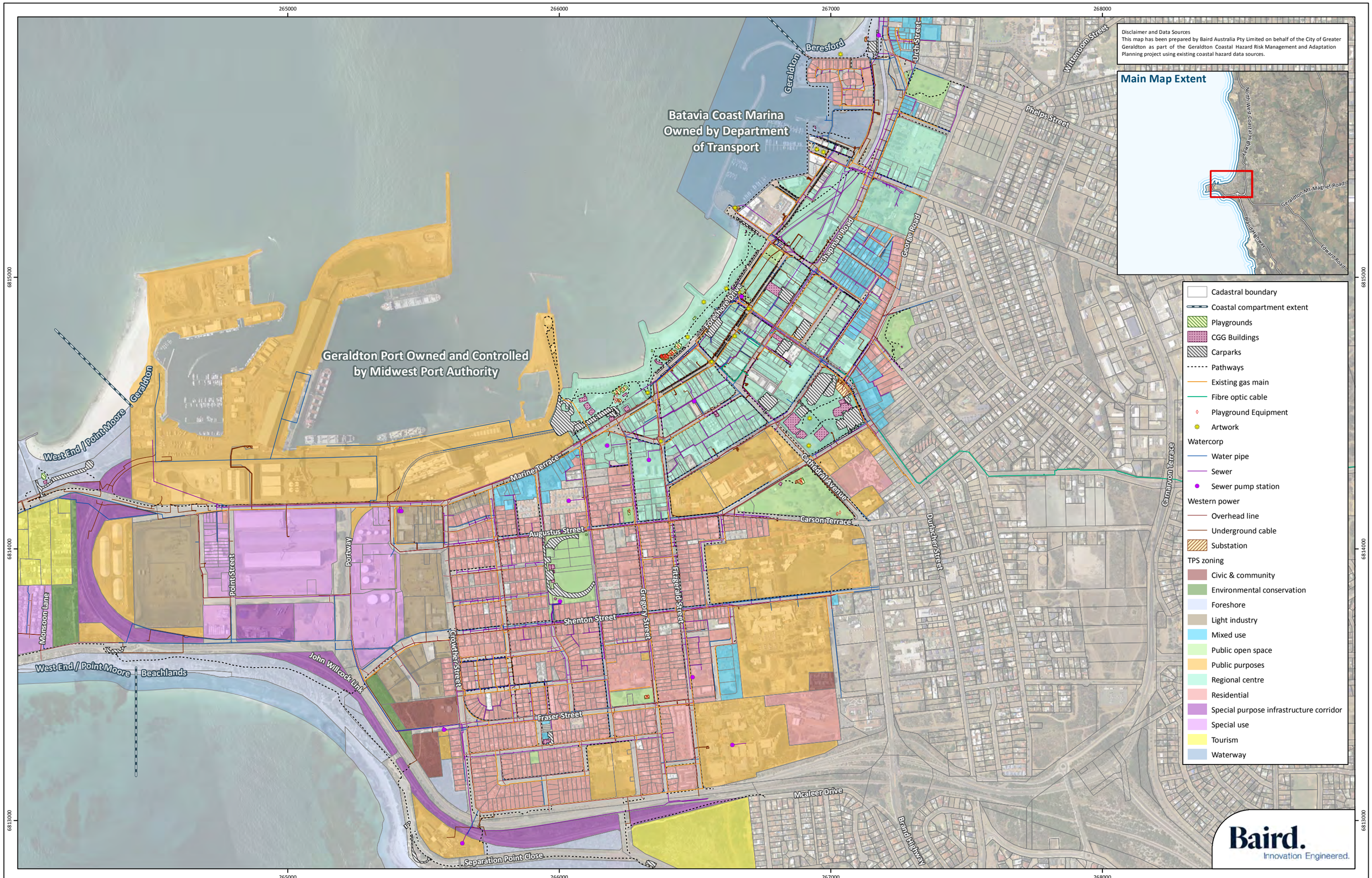


Figure 6 of 12 — **Coastal Asset Mapping, Geraldton**

Project: Geraldton CHRMAP Project

Client: The City of Greater Geraldton

Plan Number: EP17-099(01)--F26b

Drawn:	KNM
Date:	09/11/2018
Checked:	JC
Approved:	JC
Date:	09/11/2018

N

0 200 400 Metres

Scale: 1:12,500@A3

GDA 1994 MGA Zone 50

City of Greater Geraldton — a vibrant future

Disclaimer and Data Sources
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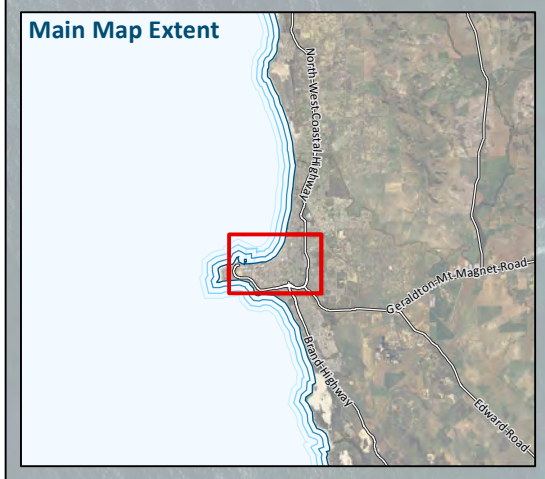
Main Map Extent



- Cadastral boundary
- Coastal compartment extent
- Playgrounds
- CGG Buildings
- Carparks
- Pathways
- Existing gas main
- Playground Equipment
- Artwork

Watercorp
- Water pipe

Western power
- Overhead line
- Underground cable

TPS zoning
- Environmental conservation
- Foreshore
- Light industry
- Public purposes
- Residential
- Special purpose infrastructure corridor
- Special use
- Tourism
- Waterway

263500 264000 264500
6815000 6814500 6814000 6813500

Geraldton
West End / Point Moore
Captains Crescent
Sextant Lane
Monsoon Lane
Astrolabe Lane
West End / Point Moore Beachlands

Baird. Innovation Engineered.

Figure 7 of 12	**Coastal Asset Mapping, West End / Point Moore**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number:
EP17-099(01)--F27b
Drawn: KNM
Date: 09/11/2018
Checked: JC
Approved: JC
Date: 09/11/2018

N

0 100 200
Metres
Scale: 1:5,000@A3
GDA 1994 MGA Zone 50

City of Greater Geraldton a vibrant future

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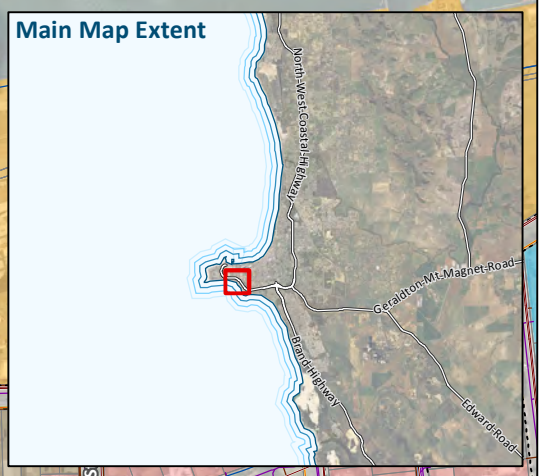

264500 265000 265500

6814500 6814000 6813500 6813000 6812500

West End / Point Moore

Marine Terrace

Point Street

Portway

Crowther St

West End / Point Moore

Beachlands

Separation Point Close

Beachlands

Mahomets Flats

- Cadastral boundary
- Coastal compartment extent
- Carparks
- Pathways
- Existing gas main

Watercorp
- Water pipe
- Sewer
- Sewer pump station

Western power
- Overhead line
- Underground cable

TPS zoning
- Civic & community
- Environmental conservation
- Foreshore
- Light industry
- Mixed use
- Public open space
- Public purposes
- Residential
- Special purpose infrastructure corridor
- Special use
- Waterway

Baird. Innovation Engineered.

Figure 8 of 12	**Coastal Asset Mapping, Beachlands**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number:
EP17-099(01)--F25b
Drawn: KNM
Date: 09/11/2018
Checked: JC
Approved: JC
Date: 09/11/2018

N

0 100 200
Metres
Scale: 1:6,000@A3
GDA 1994 MGA Zone 50

City of Greater Geraldton a vibrant future

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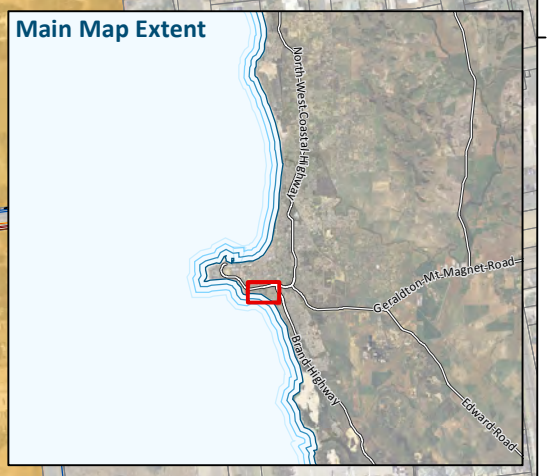


Cadastral boundary
Coastal compartment extent
Playgrounds
CGG Buildings
Carparks
Pathways
Existing gas main
Playground Equipment

Watercorp
Water pipe
Sewer
Sewer pump station

Western power
Overhead line
Underground cable

TPS zoning
Civic & community
Foreshore
Light industry
Mixed use
Public open space
Public purposes
Regional centre
Residential
Special purpose infrastructure corridor
Tourism

Crowther Stre
Augustus Street
Shenton Street
Gregson Street
Fraser Street
Fitzgerald Street
John Willcock Link
Separation Point Close
Beachlands
Mahomets Flats
Mcaleer Drive
Olive Street
Mahomets Flats
Tarcoola Beach

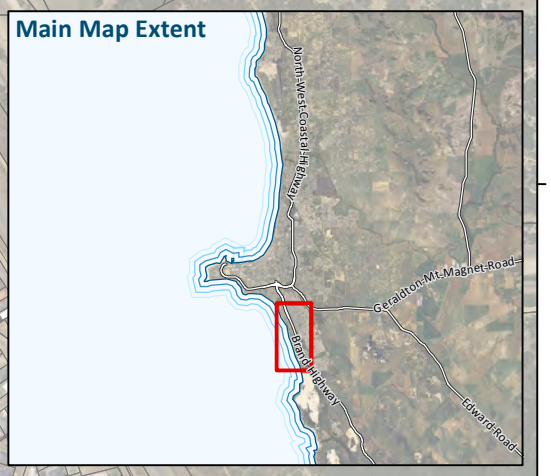
266000 266500 267000
6814000 6813500 6813000 6812500 6812000

Baird.
Innovation Engineered.

Figure 9 of 12	**Coastal Asset Mapping, Mahomets Flats**	**Plan Number:** **EP17-099(01)--F25b**	N
Project:	Geraldton CHRMAP Project	Drawn: KNM	0 100 200 Metres
Client:	The City of Greater Geraldton	Date: 09/11/2018	Scale: 1:7,000@A3
		Checked: JC	GDA 1994 MGA Zone 50
		Approved: JC	City of Greater Geraldton a vibrant future
		Date: 09/11/2018	

Disclaimer and Data Sources
This map has been prepared by Baird Australia Pty Limited on behalf of the City of Greater Geraldton as part of the Geraldton Coastal Hazard Risk Management and Adaptation Planning project using existing coastal hazard data sources.

Main Map Extent



Cadastral boundary
Coastal compartment extent
Playgrounds
CGG Buildings
Carparks
Pathways
Existing gas main
Playground Equipment
Watercorp
Water pipe
Sewer
Sewer pump station
Western power
Overhead line
Underground cable
TPS zoning
Environmental conservation
Foreshore
Public open space
Residential
Scheme boundary
Tourism

Mahomets Flats
Tarcoola Beach
Olive Street
Hakea Street
Jarrah Street
Willcock Drive
Broadhead Avenue
Highbury Street
Glenview Street
Ackland Road
Barrett Drive
Gaudarup Rd
Watterson Road
Sandy Street
Columbus Boulevard
Bellimos Drive
Tarcoola Beach Southgate Dunes

267000 267500 268000 268500 269000 269500
6812000 6811500 6811000 6810500 6810000 6809500 6809000 6808500

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Figure 10 of 12	**Coastal Asset Mapping, Tarcoola Beach**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number: EP17-099(01)--F25b
Drawn: KNM
Date: 09/11/2018
Checked: JC
Approved: JC
Date: 09/11/2018

N

0 100 200 300 400
Metres
Scale: 1:10,500@A3
GDA 1994 MGA Zone 50

City of Greater Geraldton a vibrant future

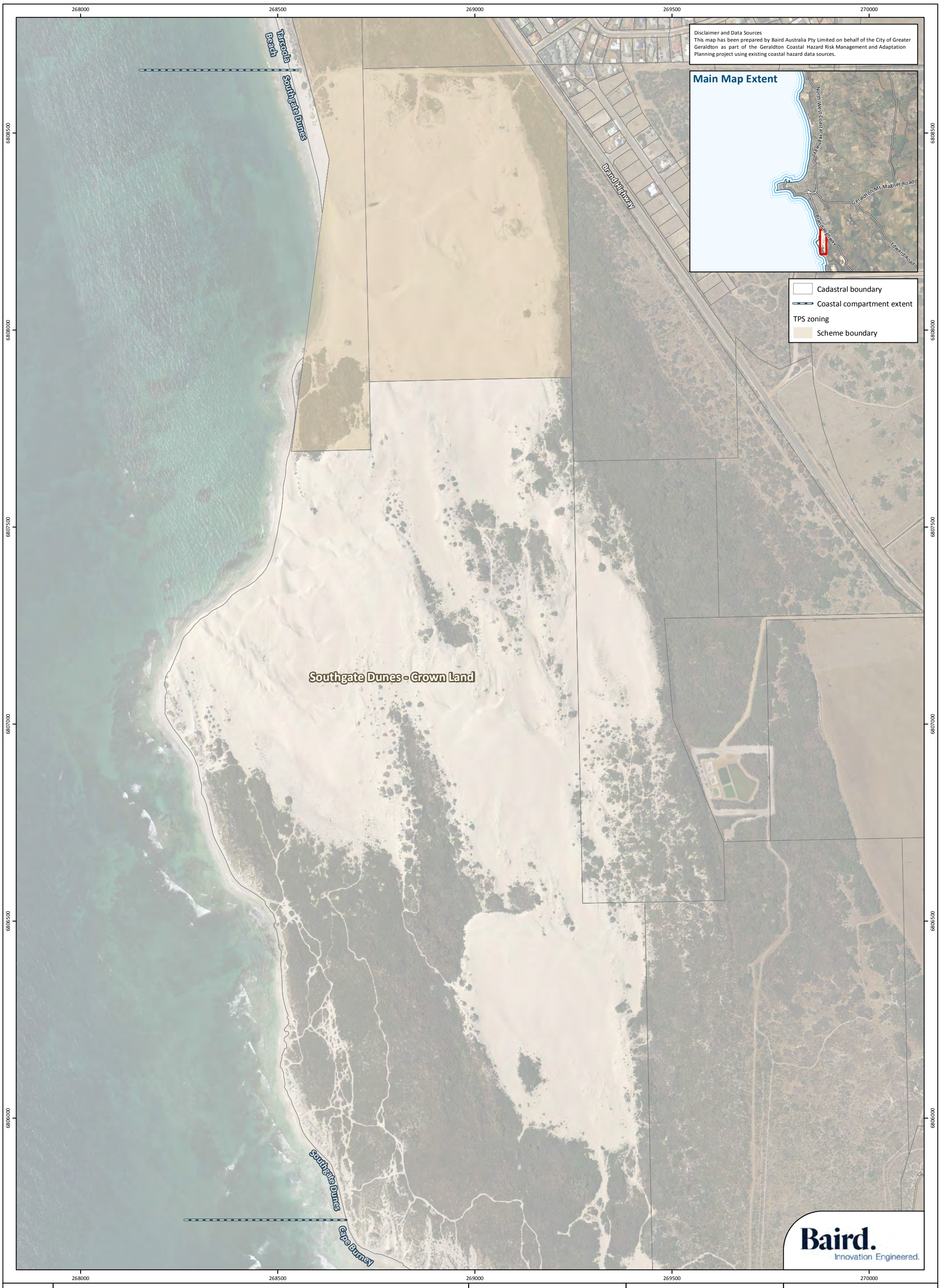

Figure 11 of 12	**Coastal Asset Mapping, Southgate Dunes**
Project:	Geraldton CHRMAP Project
Client:	The City of Greater Geraldton

Plan Number:
EP17-099(01)--F25b
Drawn: KNM
Date: 09/11/2018
Checked: JC
Approved: JC
Date: 09/11/2018

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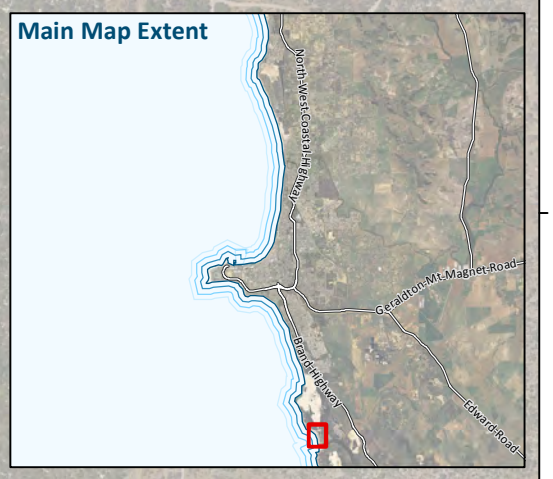
Metres
Scale: 1:8,500@A3
GDA 1994 MGA Zone 50

City of Greater Geraldton
a vibrant future

269000
269500
6806000
6805500
6805000
6804500

Disclaimer and Data Sources
This map has been prepared by Baird Australia Pty Limited on behalf of the City of Greater Geraldton as part of the Geraldton Coastal Hazard Risk Management and Adaptation Planning project using existing coastal hazard data sources.

Main Map Extent



Cadastral boundary
Coastal compartment extent
CGG Buildings
Carparks
Watercorp
Water pipe
Western power
Overhead line
TPS zoning
Foreshore
Scheme boundary
Urban development

Southgate Dunes
Cape Burney
Greenough River Road
Cape Burney

Figure 12 of 12 — **Coastal Asset Mapping, Cape Burney**

Project: Geraldton CHRMAP Project

Client: The City of Greater Geraldton

Plan Number: EP17-099(01)--F25b
Drawn: KNM
Date: 09/11/2018
Checked: JC
Approved: JC
Date: 09/11/2018

N

0 100 200
Metres
Scale: 1:5,000@A3
GDA 1994 MGA Zone 50

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A.4 Adaptation Toolbox

Geraldton CHRMAP

Adaptation Toolbox

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Option Type	Option Number	Option Name	Description how it will help	Hazard Type	Multi-criteria and cost benefit analysis	Potential assets
Avoid	AV1	Planning Controls - Special Control Area	Assets will not be placed in locations vulnerable to coastal hazards.	Erosion and Inundation	Financial resources will not be required to be spent on management and adaption.	All assets in the coastal zone.
Planned/Managed Retreat	MR1	Leaving assets unprotected. Remove Assets over Time as Hazard is Realised.	Accept loss following hazard event. Only implement repairs to maintain public safety. Allow for retreat that allows natural recession of the shoreline over the long-term.	Erosion and Inundation	Save the financial resource for better use.	All low cost/temporary/easily relocatable recreation amenities.
Planned/Managed Retreat	MR2	Demolition/removal/relocation of assets from inside hazard area.	This option relevant for assets of low value where it is impractical both technically and financially to design the asset to withstand the impact of the hazards instead of relocating it.	Erosion and Inundation	Allows amenities to be retained realising the social and economic values until such time that the asset needs to be relocated. Can often coincide with asset replacement. This also enables to cost of relocation to be shared with the cost of asset replacement. This reduces the overall cost in present and future time	All low cost/temporary/easily relocatable recreation amenities.
Planned/Managed Retreat	MR3	Prevention of further development/prohibit expansion of existing use rights.	This option would enable existing development and use rights to continue without increasing them, until such time that impacts arise. Specified in a local planning scheme.	Erosion and Inundation	Generally applicable where protection of assets is not viable.	All assets where it is impractical to ultimately implement protection.

Planned/Managed Retreat	MR4	Land Swap	Mechanism whereby the owners of properties at risk of coastal hazard agree to retreat from their property and in exchange are offered an alternative location to develop (ie vacant land)		This option can be implemented provided appropriate land is readily available nearby. This has been implemented in Geraldton recently for coastal properties at risk of erosion at Drummond Cove	Houses and Business Premises
Accommodate	AC1	Notification on title (can also be relevant to (planned/managed retreat and protect options).	As a requirement of any future subdivision or development, the landowner will be required as a condition of planning approval for the landowner to place a notification on the Certificate of Title pursuant to Section 70A of the Transfer of Land Act 1893 to notify prospective purchasers that the lot(s) is located in an area that may be subject to coastal inundation over the next 100 years.	Erosion and Inundation	This option allows vulnerability of asset to hazards to be conveyed to existing and future owners. One means of implementation that is low cost, is through decision-making for subdivision and development.	All assets located within an area vulnerable to the adverse impacts of coastal erosion and inundation within the planning timeframe.
Accommodate	AC2	Design assets to withstand impacts	On land that has been identified as having lower levels of flooding as a result of storm surge (i.e. 500mm or less above natural ground level), it may be considered appropriate to require new developments to have habitable / lettable floor levels (including freeboard) above the identified flood level. .	Erosion and Inundation	This option is aimed at retaining existing assets in locations but reducing the consequences of the inundation hazard. It is cheaper to mitigate the impacts with initial design outcomes as opposed to retrofitting existing assets in the future.	Roads, car parks, residential property, hospitals, aged care facilities, schools, child care facilities, surf life saving clubs
Accommodate	AC3	Emergency evacuation plans	The City to prepare an Emergency Evacuation Plan in the event of a cyclonic / storm surge event to safely evacuate occupants from the City Centre. Such plans are important in managing the safety of community and stakeholders.	Inundation	This option is a low cost option in addressing the consequences of inundation with regard to safety to lives as the impact occurs. Escape routes need to consider safety and access in extreme events, including depth of flooding and velocity of flood waters	Roads (with particular regard to managing traffic flows during an event), car parks, residential property, hospitals, aged care facilities, schools, child care facilities, surf life saving clubs

Accommodate	AC4	Appropriate Finished Floor Levels	Raise finished floor levels above a level determined to provide immunity against flooding in extreme events	Inundation	Can be implemented in new housing, not easily retrofitted to existing properties	Houses and Business Premises
Accommodate	AC5	Filling Land	Raise land levels above a level determined to provide immunity against flooding in extreme events	Inundation	Can be financially viable where the supply of fill is readily and cheaply available. Where suitable sources are not readily available or a considerable distance away, costs are increased. Must consider impacts to surrounding property and aesthetics	Houses
Temporary Protect / Improve Resilience	TPIR1	Coastal Revegetation	Planting along the coastal edge. Providing resilience against wave attack and erosion through reducing wave energy and roots binding the soil together	Erosion	Relatively Low cost, nature based option. Option currently applied at a number of coastal locations by community groups	Eroding shorelines
Temporary Protect / Improve Resilience	TPIR2	Dune Management	Controls to limit impact to dunes (eg preventing vehicle access) or measures to promote sand accumulation (eg sand fences) to act as a buffer against erosion	Erosion and Inundation	Relatively Low cost, nature based option. Option currently applied at a number of coastal locations.	Eroding shorelines and areas in need of inundation protection
Temporary Protect / Improve Resilience	TPIR3	Beach nourishment or replenishment	This option involves the placement of sand on the upper beach face and dunes to re-establish the beach and provide a sediment supply through use of trucks or sand delivered via sand pumping. Currently applied for town beaches and northern beaches (GPA).	Erosion	Where suitable sources are not readily available or a considerable distance away, costs are increased. If the nourishment sand is significantly finer than the existing beach sand the nourishment sand will be lost quickly.	High use beaches and foreshore reserves where retreat is not an option.

Temporary Protect / Improve Resilience	TPIR4	Geotextile Sand Bags – Groynes and Seawalls	This option involves the construction of groynes or seawalls to stop or restrict the movement of sand and provide protection to assets behind the beach/foreshore reserve.	Erosion	Cost needs to be weighed up against the value of the assets being protected. Groynes form a cross-shore barrier that traps sand that moves alongshore. Groynes are not 100% effective as a means of protecting the coast during short-term storm erosion, dependant on the extent of the trapped sediment which offers sacrificial protection.	High use beaches and foreshore reserves where retreat is not an option. Where assets value is high and relocation is not an option.
Protect	PR1	Groynes	This option involves the construction of groynes to stop or restrict the movement of sand around the end of the structure, to provide protection to assets behind the beach/foreshore reserve. They are primarily effective where there is longshore sand supply. Generally permanent rock structures.	Erosion	Groynes could be expensive and change the nature and appearance of the coast. This needs to be weighed up against the value of the assets being protected. Groynes form a cross-shore barrier that traps sand that moves alongshore. Groynes are not 100% effective as a means of protecting the coast during short-term storm erosion, dependant on the extent of the trapped sediment which offers sacrificial protection.	High use beaches and foreshore reserves where retreat is not an option. Where assets value is high and relocation is not an option.
Protect	PR2	Seawalls	This option involves construction usually along an entire section of shoreline. Where a beach is to be retained, this option should generally be accompanied with beach nourishment or replenishment.	Erosion	Seawalls are expensive and change the nature and appearance of the coast. Seawalls protect the land not the beaches. Needs to be accompanied by greater beach nourishment/replenishment, which adds to the cost of option. This needs to be weighed up against the value of the assets being protected.	High use beaches and foreshore reserves where retreat is not an option. Where assets value is high and relocation is not an option.

Protect	PR3	Flood Mitigation Structure	This option involves construction to protect a low-lying section of shoreline providing an impenetrable barrier to protect against an extreme flood level. Can be in the form of a dyke, levee, or a storm surge barrier. Barriers can be removable (eg sandbags)	Inundation	Generally, an Expensive option and requires land area over which the structure can be constructed and consideration of impact on sight lines to the coast. This needs to be weighed up against the value of the assets being protected	High value developed areas where retreat is not an option.
Protect	PR4	Artificial Reefs	Artificial reefs are placed offshore to dissipate wave energy impacting the shore by causing the waves to break. Creates additional beach width on the lee (sheltered) side.	Erosion	Can be an expensive option. Varying success in applications nationally and internationally. Recent example on Gold Coast Qld (Palm Beach) shows this is a potentially viable alternative to hard engineering. Previous studies undertaken for Back Beach Geraldton.	Eroding shorelines

A.5 Economic Analysis

engineering | environmental | economics | engagement

Geraldton Coastal Hazard Risk Management and Adaptation Planning (CHRMAP) Project

Economic Assessment

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Document Control

Ver	Effective Date	Description of Revision	Prepared by:	Reviewed by:
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2	30 May 2018	Draft	TK	RST

Prepared For: City of Geraldton

Project Name: Geraldton CHRMAP Economic Assessment

Rhelm Reference: J1006

Document Location: C:\Dropbox (Rhelm)\Jobs\J1006 - Geraldton CHRMAP\4. Reports\Geraldton CHRMAP Economic Assessment - V1.docx

Client Reference:

Table of Contents

Acronyms

AAD	Annual Average Damage
ABS	Australian Bureau of Statistics
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
AWE	Average Weekly Earnings
BCR	Benefit Cost Ratio
CBA	Cost Benefit Analysis
CHRMAP	Coastal Hazard Risk Management and Adaptation Planning
FYRR	First Year Rate of Return
LGA	Local Government Area
NPV	Net Present Value
NPVI	Net Present Value per Dollar of Capital Investment
OEH	Office of Environment and Heritage
PV	Present Value
IRR	Internal Rate of Return

1 Introduction

The community of the City of Geraldton (Geraldton) is facing the adverse impacts of coastal erosion and inundation on their coastlines. The vulnerability of land use and development within the coastal zone from physical process hazards is expected to increase in the future with the impacts of climate change. The objective of this economic assessment was to provide sufficient information to allow a rational and robust comparison of the various adaptation options to address coastal erosion and inundation.

It is identified that Geraldton coastline is at risk from inundation and erosion over the next 100-years (to 2110). In order to ensure that the coastal hazard is factored into decision-making for future planning requirements, a coastal hazard risk management and adaptation planning (CHRMAP) is being undertaken. The CHRMAP process is a risk-based approach to ensure that the coastal hazard is factored into decision-making for future planning requirements. The CHRMAP project for Geraldton is being developed in consultation with the city of Geraldton council, the local community and a range of stakeholders, and is delivered in accordance with local and national guidelines and standards. This economic assessment forms one component of the overall CHRMAP project, and should be read in conjunction with the CHRMAP report (Baird Australia, 2018).

Geraldton is located 420 km north of Perth in Western Australia with a population of approximately 40,000. For the purpose of CHRMAP reporting and analysis, the Geraldton coastline area is divided into around 12 beach locations across approximately 30km of coast based on geographic and coastal characteristics **(Figure 1).** This economic assessment is undertaken for three coastal management units on the Geraldton coastline. Among them, Bluff Point and Drummond Cove are likely to face severe erosion whereas the Geraldton City Centre is expected to face inundation during storm events.

The Cost Benefit Analysis (CBA) undertaken as part of this report refines the evaluation of a number of options by quantifying the economic value of the various adaptation options considered to mitigate against hazards associated with coastal erosion. The CBA was performed to consider the economic costs and benefits of the coastal protection options, along with the implications of the Base Case for the areas Bluff Point and Drummond Cove.

A quantitative assessment was undertaken for the Geraldton City Centre to evaluate the inundation impact net present value (NPV) of damage for residential, commercial and industrial properties. The present value of total damage as a result of the potential inundation hazard to Geraldton has been evaluated for a 50-year period.

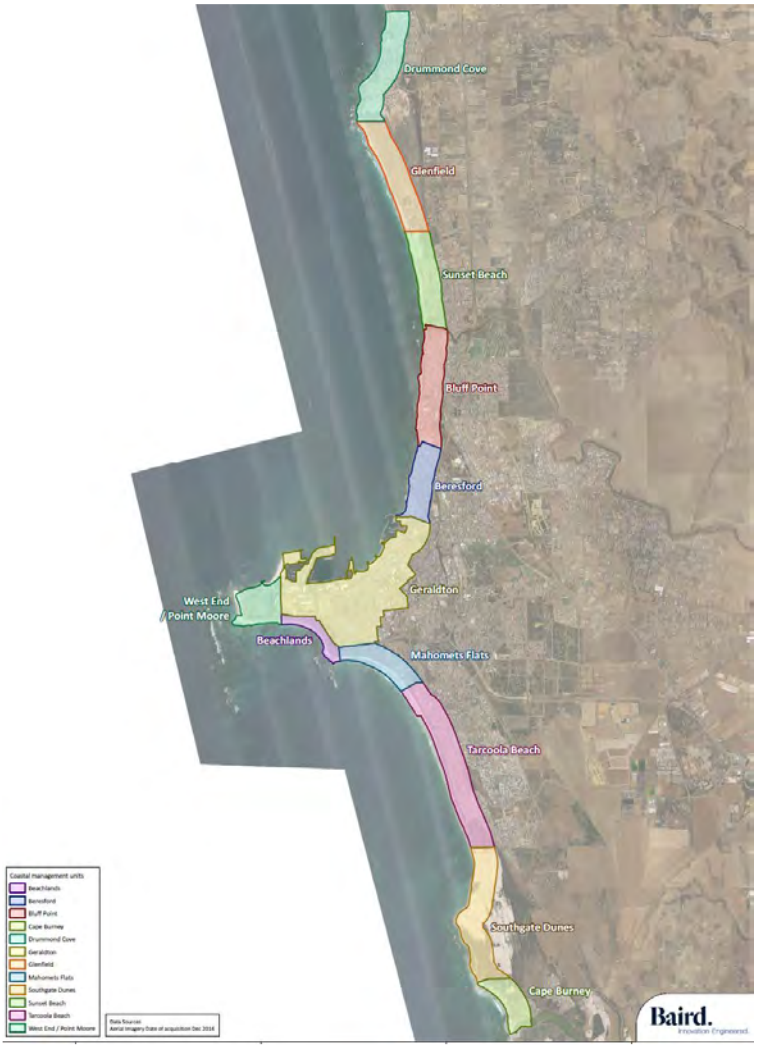

Figure 1-1 Coastal management units

1.1 Study Locations

The study is based on three locations in the City of Geraldton, namely Bluff Point, Drummond Cove and the Geraldton City Centre.

1.1.1 Bluff Point

Bluff Point is a northern coastal suburb of Geraldton with a population of 1,346. The study area for this project is located at the southern part of the suburb. The study area includes residential properties, Rundle Park, coastal pathways and cycling paths that are vulnerable to erosion. **(Figure 1-2)**.

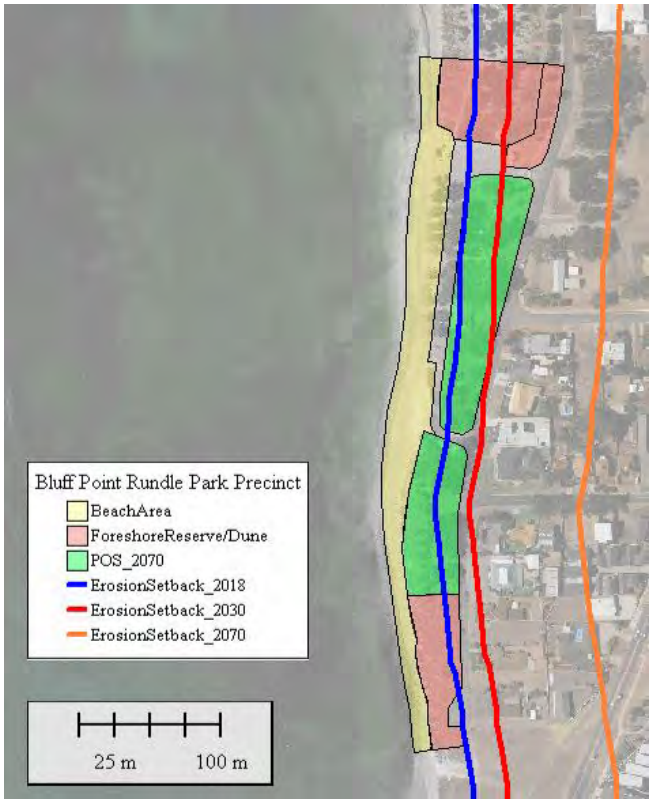

Figure 1-2 Bluff Point study area

1.1.2 Drummond Cove

Drummond Cove is another coastal suburb located 12kms north of Geraldton with a population of 1,477. The study area includes a number of residential properties, a community hall (John Batten Hall), sand dunes and a significant foreshore area. Drummond Cove is experiencing severe erosion currently along the foreshore with roads, houses, infrastructure already being lost. The study area for Drummond Cove is shown in **Figure 1-3**. The adaptation options assessed in this study are only protecting section 1.

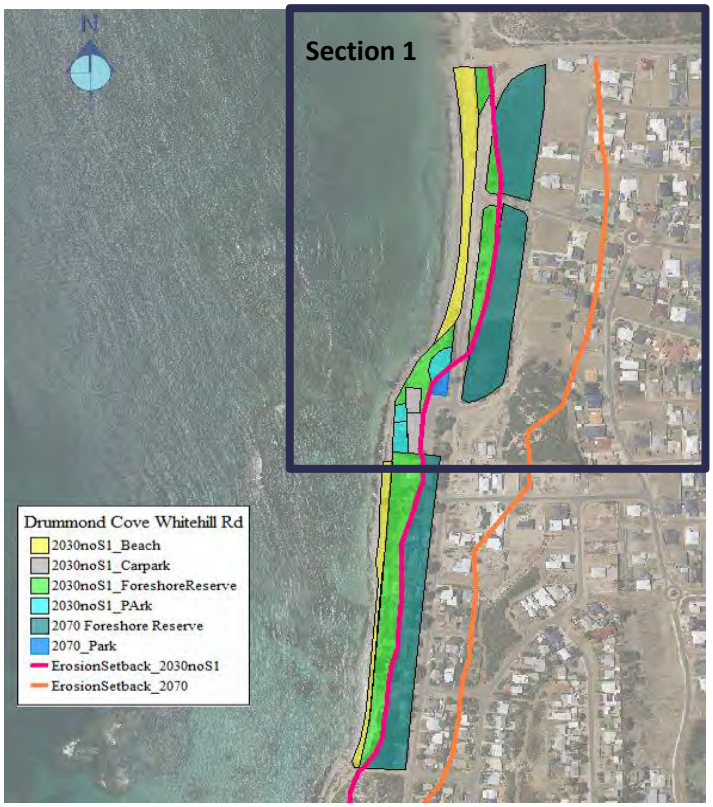

Figure 1-3 Drummond Cove study area

1.1.3 Geraldton

Geraldton City Centre was not identified as susceptible to erosion but is identified to be at risk of coastal inundation hazard under coastal flooding events. The flooding can be caused by a large storm surge generated by a tropical cyclone, which can elevate the ocean level above the normal tidal regime for this area. Geraldton has a small tidal range with the highest astronomical tide level at 0.65m on the Australian Height Datum (AHD) (1.20 m CD) (Baird Australia, 2017). Due to this relatively small tide range, the city's coastal areas are particularly susceptible to storm surge. This area consists of residential, commercial and industrial properties which would be potentially affected by inundation hazards. The study area for Geraldton is given in **Figure 1-4**.

Figure 1-4 Geraldton City Centre study area

2 Available Data

2.1 Geraldton Assets

Relevant data on tangible assets affected by erosion were provided to Rhelm by Baird which includes unit costs of council structures (**Figure 2-1** and **Figure 2-2**).

There are council structures worth of approximately $1.7M in the Bluff Point study area which would be affected by erosion by 2070. These assets include mainly roads, carpark and other park related structures located predominantly in and around the Rundle Park between the beach and the residential property areas. The Drummond Cove study area is larger and also includes a community hall and a number of surrounding facilities. The total value of council structures in Drummond cove is approximately $2.9M which would likely be affected by erosion by 2070.

The Geraldton asset data incorporated within the assessment are given in **Appendix A**.

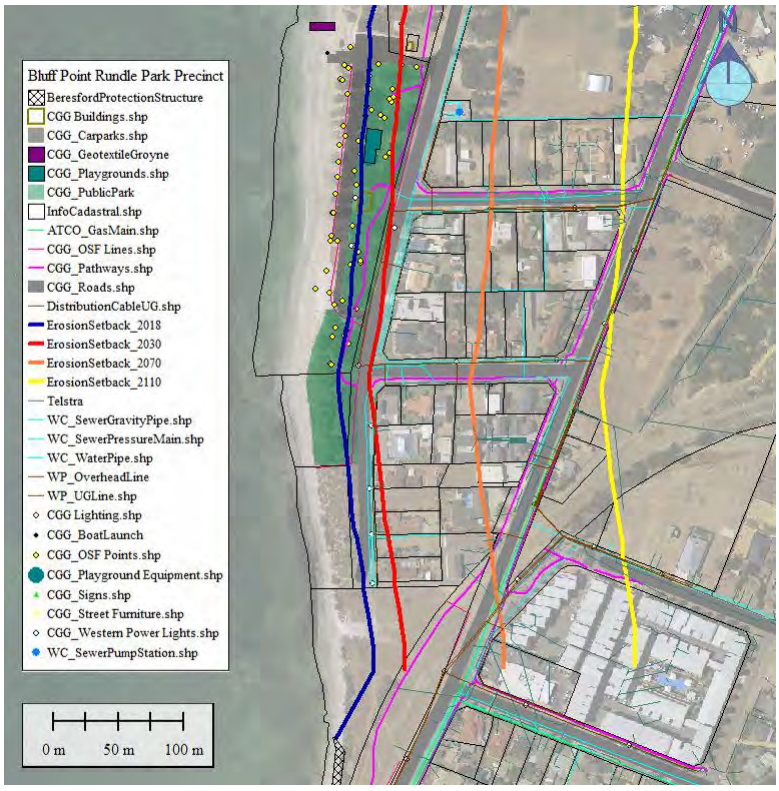

Figure 2-1 Bluff Point assets affected by erosion

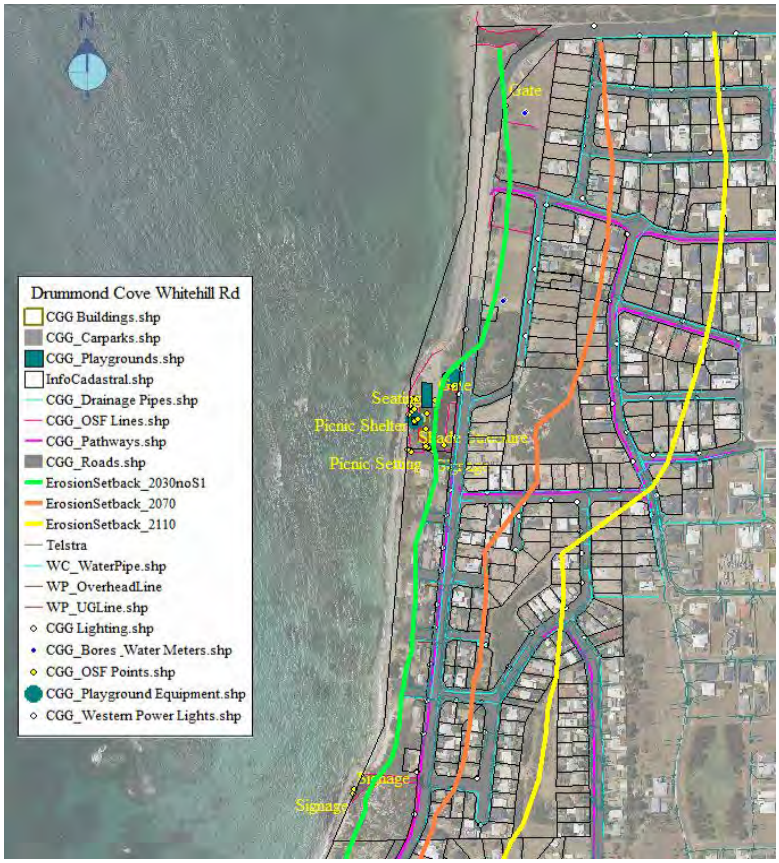

Figure 2-2 Drummond Cove Assets affected by erosion

2.2 Property values

The assessment of the properties affected by coastal hazard has been completed using a GIS based approach undertaken by Baird. The coastal hazard lines for erosion setback were used to determine the number of properties affected through the planning periods of 2030, 2070 and 2110.

A number of residential properties are expected to be affected by coastal erosion in Bluff Point and Drummond Cove areas. The study incorporated publicly available data on median property price for each suburb using values as given in *realestate.com.au*. It is noted that the value of beach front properties may potentially be higher although the suburb wide averages have conservatively been adopted.

2.3 Non-Market Assets

In addition to council assets and residential properties, there are a number of assets within the coastal zone that are unable to be valued at market prices and require estimates of values to be determined through other approaches. In order to incorporate community benefits of various recreational and environmental assets in the study areas, additional academic sources have been used to facilitate the analysis.

The study area predominantly includes the beach, foreshore and parkland areas which represent the recreational and usage values, as well as other *existence* values. At the time of the analysis, there was no data available on the usage of the park or beach in these areas. A literature review was therefore undertaken to determine the value for the beach and parkland areas based on available research in similar areas. There are several studies that are available, but some of these relate more to higher usage or tourism value beaches

(e.g. Gold Coast). Given that both Bluff Point and Drummond Cove are not on a similar tourism scale to these other studies, recreational and non-use values for beach, foreshore and parkland only were considered. A recent study undertaken by Pascoe et al. (2017) which was conducted across both Sydney CBD local government areas (LGAs) and non-Sydney coastal LGAs broke down the non-use values per hectare of a range of coastal areas, including the beach component, as well as dunes, headlands, reefs etc. The non-market values provided in the above study in relation to beaches and dunes were adopted in the analysis.

2.4 Inundation

The coastal inundation hazard has been defined for Geraldton City Centre for a range of average recurrence intervals (ARI) and time periods. These include 20-year, 100-year and 500-year ARI events for 2015, 2030 2070 and 2110 time periods.

The available data included 491 residential properties in the form of houses, group houses, houses/sheds, multi units, vacant residential lots and vacant (development) properties. The majority of the residential properties, among these were houses. Additionally, inundation data based on 269 commercial lots and 66 industrial lots were incorporated in to the analysis. This data was provided by Baird. Inundation was estimated based on overground flooding, and then overfloor flooding was estimated by Baird as being approximately 0.3m above ground.

3 Economic Assessment Methodology

The economic assessment methodology for Bluff Point and Drummond Cove is discussed from **Section 3-1** to **Section 3-3**. The analysis relevant to Geraldton Town Centre is given in **Section 3-4**.

The economic assessments relevant to Bluff Point and Drummond Cove study consider the comparative costs and benefits of each adaptation option against a realistic base case scenario based on the available asset, property and non-market values.

The economic merit of adaptation options was determined by comparing the present value of the change in net economic benefits (compared with the base case) less the change in capital and maintenance costs. The key benefits incorporated within this cost-benefit analysis (CBA) assessment were in the form of savings in property values, asset values and beach values **(Section 3.3)**.

3.1 Key assumptions

For the purposes of this assessment a number of assumptions have been made to facilitate estimation of economic values, these include:

- A discount rate of seven per cent per annum has been applied
- Construction of the options has been assumed to be undertaken in 2021
- Year 2022 has been applied as the year of opening for each scenario (with erosion continuing to occur up to 2022 for each option)
- A benefit evaluation period of 30 years from opening was adopted.
- All values given are in 2017 dollars.

Three recession scenarios were evaluated for each of the options assessed. The assumption relevant to erosion are as follows;

- 2018 – no erosion occurs
- 2030 – the erosion of the shoreline is based on the historical rate (S2) and sea level rise (S3) components including an allowance for uncertainty (0.2m/year). The erosion from the 100-year ARI storm event (S1) is not included. This is on the basis that the probability of this event having occurred within a 12-year period is relatively low
- 2070 - the erosion rate is based on the historical rate (S2) and sea level rise (S3) components including an allowance for uncertainty (0.2m/year). The erosion from the 100-year ARI storm event (S1) is included. This is on the basis that the probability of this event having occurred within a 50-year period is higher

The erosion setback lines are defined for the years 2030, 2070, 2110 as shown in **Figure 2.1** and **Figure 2.2**.

3.2 Base Case

In the absence of the Project, it is assumed that a 'do-minimum' approach would be adopted. The Council would be assumed to take no action to mitigate against the erosion and a planned retreat approach would be adopted instead. Once a property becomes uninhabitable due to coastal erosion, it is assumed that the property would be vacated, and the property owners/ occupiers would be relocated to a safer location within the same LGA. The analysis assumes that, with erosion, the beach would progress backwards and hence the beach area would largely remain the same. The indirect costs associated with the base case include the loss

of park(s), reserve area(s) together with the roads and the properties. Calculation of the above values are discussed in **Section 3.4**

3.3 Options Considered

The CBA examined the implications of six adaptation options against coastal erosion with three options for Bluff Point and four options for Drummond Cove. The adaptation options considered are given in **Table 3-1**. Further details on the derivation of these options is discussed in Baird Australia (2018).

Table 3-1 Adaptation Options considered

	Options	Bluff Point	Drummond Cove
1	Sea wall	x	
2	Sea wall with sand nourishment	x	x
3	Artificial reef with sand nourishment		x
4	Geotextile groynes backed by seawall		x
5	Boat launch with sand nourishment		x
6	Geotextile groyne field with sand nourishment	x	

3.3.1 Sea Wall

The first option considers the installation of a rock revetment of the length of 450m in Bluff Point. The location of the buried sea wall is depicted in **Figure 3-1**. The direct construction costs for the sea wall scenario include construction costs ($3.2M) and maintenance costs ($60,000/year). This option does not include beach nourishment and therefore the analysis assumes the beach area would be progressively lost due to erosion after 2018.

Figure 3-1 Location of Sea Wall (Bluff Point)

3.3.2 Sea wall with Sand Nourishment

This sea wall option relevant to Bluff Point is similar to that given in **Figure 3-1** but includes sand nourishment. The annual cost of implementing a sand nourishment scheme is estimate at $30,000.

The sea wall option relevant to Drummond Cove is 550m in length and shown in **Figure 3-2**. The annual cost of implementing sand nourishment is estimated at $60,000. This option protects all of section 1 of the study area.

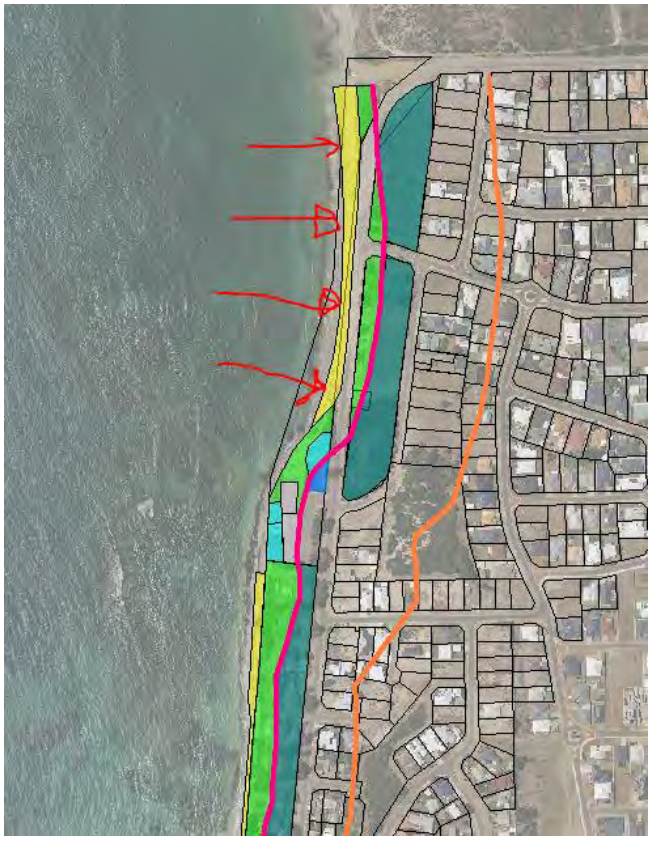

Figure 3-2 Location of Sea Wall (Drummond Cove)

3.3.3 Artificial Reef with Sand Nourishment

The artificial reef is expected to provide enhanced marine opportunities such as fishing, diving, swimming and surfing in the Drummond Cove area. This option has less visual impacts compared to the sea wall and protects only section 1 of the study area **(Figure 3-3)**.

The total construction cost is estimated at $3.5M for an artificial reef of the length of 500m. The annual cost of implementing sand nourishment is estimated at $30,000.

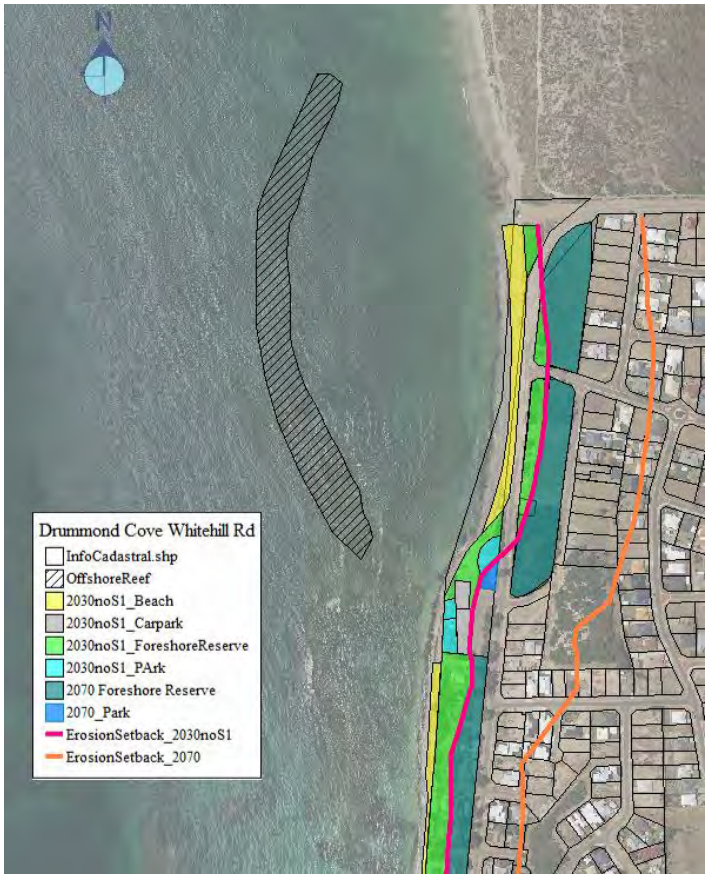

Figure 3-3 Location of the Artificial Reef in Drummond Cove

3.3.4 Geotextile Groynes backed by Seawall

The fourth option consists of three groynes perpendicular to the coastline, located in section 1 of the study area **(Figure 3-4)**. The geotextile groynes structures backed by seawall are expected to improve fishing and diving opportunities as well as potential benefits of surfing and swimming.

The above option protects all of section 1 of the study area. The direct costs include construction cost of the groynes ($360,00) and the sea wall ($2.8M) and a maintenance cost of $63,200 annually (for both seawall and groynes). The sea wall option relevant to the above scenario is 400m in length.

Figure 3-4 Location of Geotextile Groynes in Drummond Cove

3.3.5 Boat Launch with Sand Nourishment

The fifth option includes a safe boat launch for recreational vessels which protect section 1 of the Drummond Cove study area from erosion as given in **Figure 3-5**. The 450m long boat launch is expected to be constructed in two stages with an estimated cost of $3.5M per each stage. The associated annual maintenance cost of the boat launch is $140,00 with an additional $10,000 for sand nourishment annually.

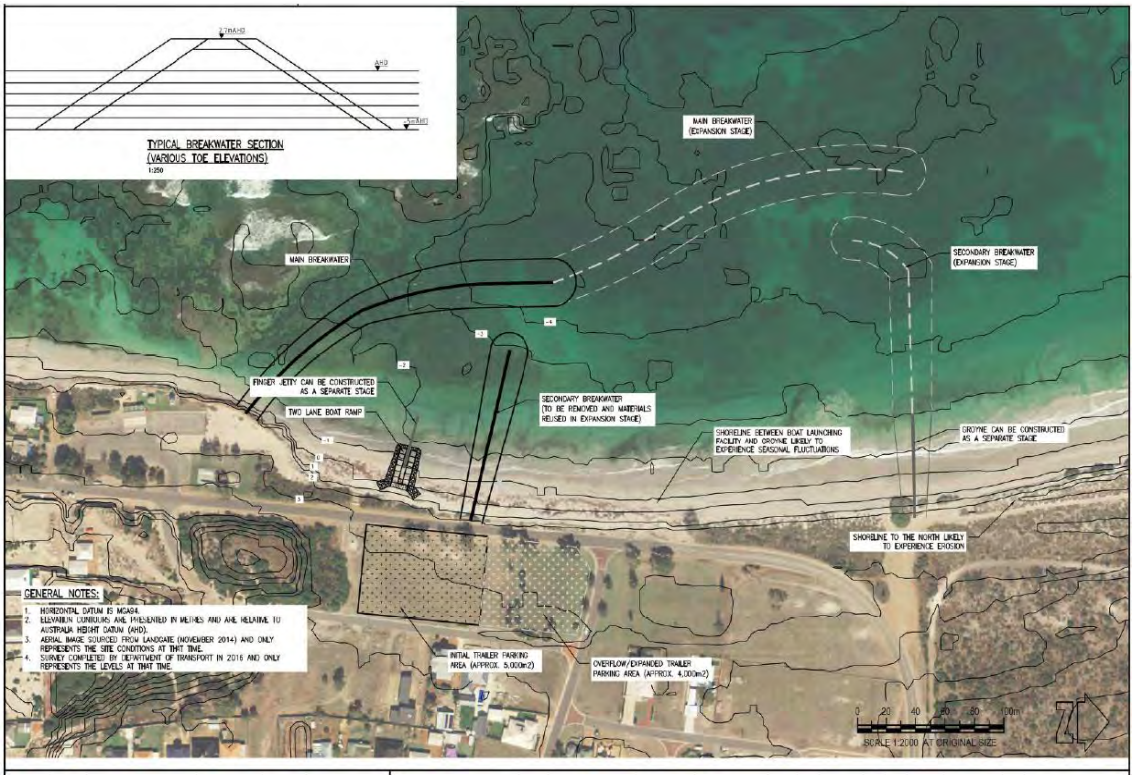

Figure 3-5 Location of Boat Launch in Drummond Cove

3.3.6 Geotextile Groyne Field with Sand Nourishment

The sixth option is a geotextile groyne field (four groynes) including sand nourishment in the Bluff Point study area **(Figure 3-6)**.

To install the four groynes, it would cost $480,000 in total with a cost of $120,000 for each. Maintenance cost for the groynes is estimated at $9,600 annually with an additional annual cost of $15,000 for sand nourishment.

The construction and maintenance costs for all adaptation options are provided in **Section 3.4.1**.

Figure 3-6 Location of the geotextile groyne field in Bluff Point

3.4 Benefits and Costs

The following sections explain benefits and costs that were incorporated in to the analysis for the options presented in **Table 3-1**. The key costs include direct expenditure for construction and maintenance. The project is likely to generate benefits to the local community and these were quantitatively evaluated for each scenario against the base case scenario. Benefits quantified include:

- Asset values
- Beach values
- Property values.

3.4.1 Costs

Capital Costs

A summary of the cost estimates for each option considered is provided in **Table 3-2**.

Table 3-2 Cost estimates for adaptation options

Study area	Option	Construction/installation cost	Design life (years)
Bluff Point	Sea wall	$3,150,000	50
	Geotextile Groyne Field	$480,000	15
Drummond Cove	Boat Launch (Stages 1 & 2)	$7,000,000	50
	Boat Launch (Stage 1 only)	$3,500,000	50
	Sea wall	$3,850,000	50
	Artificial Reef	$3,500,000	20
	Geotextile Groynes backed by sea wall	$3,160,000	15 (Groyne) 50 (Sea Wall)

Ongoing Maintenance costs

The annual maintenance costs for each adaptation option is based on 2% of construction cost, as advised by Baird. Ongoing maintenance costs for each scenario are shown in **Table 3-3**. The estimates include replacement costs of the groynes and the artificial reef at the end of their design life.

Table 3-3 Maintenance costs

Project	Scenario	Present Value of Net Future Costs
Bluff Point	Sea Wall	$ 590,100
	Sea wall with sand nourishment	$ 894,000
	Geotextile groyne field with sand nourishment	$ 371,900
Drummond Cove	Boat launch with sand nourishment (Stages 1 & 2)	$ 1,412,600
	Boat launch with sand nourishment (Stage 1 only)	$ 757,000
	Sea wall with sand nourishment	$ 1,329,000
	Artificial reef with sand nourishment	$ 1,635,800
	Geotextile groynes backed by seawall	$ 750,600

3.4.2 Benefits

Beach/Parkland/Foreshore Values

It was assumed under the base case scenario that the beach would progress backwards with erosion, and therefore there would be no loss in beach area. The area of the parkland and foreshore would be progressively lost after 2018.

Pascoe et al (2017) provides non-market values for a number of coastal areas, but does not include estimates for parkland. While there are some similar studies on parkland values, most require some estimate of the usage of the parkland. Given the immediate proximity to the beach, the value of the parkland was assumed to be related to the value of the beach area.

For the purposes of this study, a non-use value per hectare of half the beach value was adopted for foreshore and parkland areas for Bluff Point. Within the Bluff Point area, the natural reserve area was not significant and therefore only the beach and parkland components were incorporated.

Within the Drummond Cove area, there is a higher proportion of natural reserve area. This was additionally incorporated in to the analysis using the non-market values for the foreshore area as given in Pascoe et al. (2017). The values for beach, park and foreshore areas are given in **Table 3-4**.

Socio economic data of Geraldton LGA were used where necessary to transform the above non-market values to reflect Geraldton characteristics. The non-use values provided in Pascoe et al. (2017) showed a linear relationship with the number of households in each suburb studied. Therefore, using data obtained from Australian Bureau of Statistics (ABS), the corresponding values for Geraldton LGA were estimated. Without information on usage of the park and beach, usage values at this stage were not incorporated within the analysis.

Table 3-4 Value of beachfront assets for Bluff Point and Drummond Cove

	Bluff Point	Drummond Cove
Beach value (m^2)	$200	$200
Park value (m^2)	$100	$100
Foreshore/reserve (m^2)	-	$141
Total	**$3.95M**	**$9.4M**

The adaptation options are observed to provide the present value saving for beach/parkland/foreshore areas as given in **Table 3-5**.

Table 3-5 Present value cost of loss of beach/park/foreshore areas

Project	Scenario	Base Case	Project Case	Difference	Comment
Bluff Point	Sea Wall	$ 1,324,100	$ 1,302,900	$ 21,200	Assumed to be complete loss of beach with erosion under the sea wall scenario
	All other scenarios	$ 1,324,100	$ 437,500	$ 886,600	
Drummond Cove	All scenarios	$ 2,478,000	$ 1,580,300	$ 897,700	

Residential Property Values

Under the base case scenario, properties in the study area will fall under a managed retreat scenario between 2030 and 2070, due to the projected rate of erosion of the shoreline. Under this assumption, a total of 16 properties in Bluff Point and 78 properties in Drummond Cove would be acquired and returned to foreshore reserve.

The value of the properties was estimated based on suburb averages for Geraldton. A property value of $297,500 per property for Bluff Point and $366,250 for Drummond Cove were estimated. It is noted that

property values may potentially be higher for beach front properties, but the suburb wide averages have conservatively been adopted.

Property value present value saving of approximately $0.6M for Bluff Point and $2.1M for Drummond Cove were estimated as given in **Table 3-6**.

It is noted that the Drummond Cove study area includes the entire study area, inclusive of Section 1. As the options only focus on protection for Section 1, some residual impacts results in the remaining portion of the study area over time.

Table 3-6 Present value of residential property impacts

Project	Base Case	Project Case	Saving
Bluff Point	$ 572,500	$ 0	$ 572,500
Drummond Cove	$ 3,436,000	$ 1,321,600	$ 2,114,500

Asset Values

Under the base case, the erosion will progressively result in the loss of assets within the park (e.g. playground equipment etc), as well as the carparks and surrounding roads. The replacement values of these assets have been estimated and included as an economic loss in the base case. Under the options this is assumed to be prevented after 2021 when the works are completed. The adaptation options are observed to provide a present value saving for asset values as given in **Table 3-7**.

Table 3-7 Present value of asset values

Project	Base Case	Project Case	Difference
Bluff Point	$ 504,100	$ 122,000	$ 382,100
Drummond Cove	$ 1,052,100	$ 393,700	$ 658,500

Unquantified benefits

There are a range of other intangible benefits and non-quantified benefits that were not assessed as part of the economic assessment. As such, the economic evaluation for this project should be seen as a conservative appraisal. Other benefits arising from the Project are likely to include:

- Usage values for the beach and parkland;
- Improved usage values for the boat ramp (for Drummond Cove only)
- Damage/ loss of utilities
- Environmental values

Should the development of the options progress further, then further analysis and work could be undertaken to quantify some of these values. For example, surveys of the park and beach areas could be undertaken to estimate visitor numbers for the usage values.

3.5 Inundation: Flood Damages Methodology

The assessment focussed on quantifying estimates of residential, commercial and industrial damages from inundation as detailed below. The analysis estimated Annual Average Damage (AAD) using flood damage curves to quantify the potential direct damages to urban properties within the Geraldton City Centre area.

This analysis was intended as a very board estimate of the damages for the Geraldton City Centre, suitable to understand the general magnitude of the potential impacts and to understand what options might be feasible.

The flood model results have been used to derive peak flood levels at each property in the dataset for a range of design flood events, including 20, 100 and 500-year ARI events. Data relevant 500-year ARI events have been excluded from the analysis due to the very low probability of occurrence in any given year. The flood levels have been used to estimate the depth of over ground flooding, with a rough assumption of a floor level of 0.3m above ground.

Due to data limitations the following assumptions have been made to facilitate the analysis:

- The depth of over floor flooding is based on a height above ground of 0.3m. This could be improved through floor level survey within the area
- Vacant lots within the area are undergoing development or only temporarily vacant (these were included in the analysis)
- Damage curves that have been adopted for the study are based on flooding conditions, rather than coastal inundation.
- No floor area information is available for commercial and industrial properties.

The results of the inundation assessment are provided in **Section 4.3**.

3.5.1 Flood Damage Curves

Residential Damage Curve

The Office of Environment and Heritage (OEH) Residential Flood Damage Calculation (NSW Government, 2005) was used in the creation of residential damage curve for Geraldton City Centre. These represent some of the most comprehensive estimates for residential damages in the country.

The curve is based on a number of input parameters including typical house size, bench heights, regional and scale cost factors, and awareness and warning times. The parameters adopted for this study are detailed in **Table 3-8**. The residential damage curve was derived using the most recent Average Weekly Earnings (AWE) data (November 2017) from the Australian Bureau of Statistics (ABS). The residential damage curve is derived for a property with a floor area of 190 m^2 which is approximately the average house size in the area based on an interrogation of Google Earth imagery.

The damage curve for slab on ground residential properties was adopted as an estimate in the absence of more information.

Table 3-8 Input Parameters for Residential Damage Curve

Input parameters	Adopted	Explanation
Regional Cost Variation Factor	1.00	From Rawlinsons
Post late 2001 adjustments	1.77	Based on changes to AWE since late 2001 based on data collected from ABS.

Post Flood Inflation Factor	1.00	
Typical Duration of Immersion	1 hour	This is assumed, based on a likely period of the coastal storm event and high tide
Building Damage Repair Limitation Factor	0.85	Default value
Typical House Size	190	Approximate figure based on average house size of Geraldton
Average Contents Relevant to Site	$125,000	Default value
Contents Damage Repair Limitation Factor	0.75	Default value
Level of Flood Awareness	Low	
Effective Warning Time	0 hours	
Typical Table/Bench Height (TTBH)	0.90	

The residential annual average damage (AAD) curve was estimated using the above parameters based on the 20 year and 100-year ARI events. Typically, AAD should be calculated over a range of inundation events ranging including frequent and less frequent events, in order to come up with an appropriate estimate. In this case, with only the 20 year and 100-year ARI events included, the AAD is a relatively coarse estimate.

Commercial and Industrial Damage Curves

The NSW guidance does not current include commercial and industrial flood damages. There are several alternative damage curves that could be adopted, such as FLDamage (Water Studies, 1992). Many of these curves require information on the type of commercial and industrial properties (such as the value of the goods held on the premises) as well as the floor area. In the absence of this information, only a broad estimate can be undertaken. Reflecting this uncertainty, curves for the industrial and commercial properties were roughly proportioned based on the residential damage curve and reviewing some recent studies undertaken. A floor area of 200m^2 and 500m^2 were assumed for commercial and industrial lots respectively. The residential damage curve derived were factored to account for the above floor areas in the estimation of commercial and industrial damage curves.

4 Results

The following sections outline the outcomes of the analysis for the three study sites considered.

Section 4-1 and **Section 4-2** summarise the results of the economic assessment undertaken for the various adaptation options proposed to protect Bluff Point and Drummond Cove areas against coastal erosion. The relative costs and benefits of each adaptation scenario in comparison to the Base Case, were compared through a CBA. **Section 4-3** outlines the results of the economic quantification of potential damages associated with inundation estimated for the Geraldton area.

4.1 Bluff Point

A negative NPV is observed for both sea wall options. The groyne field provides the best outcome with a benefit cost ratio (BCR) of 2.4, as it has a relatively low cost upfront, even when considering replacement every 15 years, and it has similar benefits to the sea wall with nourishment. This BCR means that for each $1 spent on the project, $2.40 is expected to be returned in economic benefits. The Groyne Field option is anticipated to generate over $1 million in net benefit to society. The preliminary results of the analysis at a 7% discount rate are provided in **Table 4-1**.

Table 4-1 Economic Appraisal results for Bluff Point

	Sea Wall	*Sea Wall with Sand Nourishment*	*Groyne Field*
PV COST	$3,161,400	$3,465,300	$763,800
PV BENEFIT	$1,111,000	$1,841,300	$1,841,300
NPV	-$2,050,500	-$1,624,000	$1,077,500
BCR	**0.4**	**0.5**	**2.4**
NPVI	-0.8	-0.6	2.8
FYRR	1%	6%	42%
IRR	0%	-2%	39%

A chart showing the composition of the benefits is provided below for the groyne field **(Figure 4-1)**. Note that as the property benefits do not commence until after 2030, these are relatively low in present value terms compared to the park and beach value.

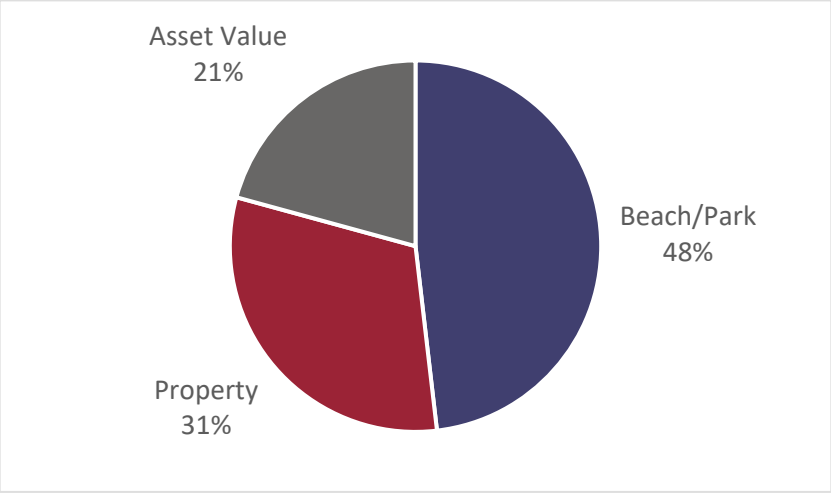

Figure 4-1 Composition of benefits for the Groyne Field

4.1.1 Sensitivity Analysis: Bluff Point

It is recognised that the results of the assessment presented in **Table 4-1** are dependent upon a range of assumptions made as part of the economic analysis. Both in terms of financial parameters (i.e. discount rates) as well as cost and benefit assessments. Consequently, to assess the robustness of the observed results, a sensitivity analysis of the CBA was undertaken.

The sensitivity analyses for the sea wall, sea wall with sand nourishment and groyne field options are given in **Table 4-2**, **Table 4-3** and **Table 4-4** respectively. The sensitivity analysis supports the economic viability of the groyne field option, showing a BCR greater than 1 under the different sensitivity scenarios.

Table 4-2 Sensitivity Analysis for Sea Wall

	BCR	NPV	IRR	NPVI
Cost Estimate +40%	0.3	-$3,315,000	-2.5%	-0.9
Cost Estimate +20%	0.3	-$2,682,800	-1.4%	-0.9
Cost Estimate – 20%	0.4	-$1,418,200	1.2%	-0.7
PV Benefits +20%	0.4	-$1,828,300	1.0%	-0.7
PV Benefits – 20%	0.3	-$2,272,700	-1.7%	-0.9
PV Benefits –40%	0.2	-$2,494,900	-3.6%	-1.0

Table 4-3 Sensitivity Analysis for Sea Wall with Sand Nourishment

	BCR	NPV	IRR	NPVI
Cost Estimate +40%	0.4	-$3,010,200	-9.4%	-0.8
Cost Estimate +20%	0.4	-$2,317,100	-5.5%	-0.8
Cost Estimate – 20%	0.7	-$931,000	0.9%	-0.5
PV Benefits +20%	0.6	-$1,255,800	0.3%	-0.5
PV Benefits – 20%	0.4	-$1,992,300	-6.4%	-0.8
PV Benefits –40%	0.3	-$2,360,500	N/A[1]	-0.9

Table 4-4 Sensitivity Analysis for Groyne Field

	BCR	NPV	IRR	NPVI
Cost Estimate +40%	1.7	$772,000	25.0%	1.4
Cost Estimate +20%	2.0	$924,800	30.9%	2.0
Cost Estimate – 20%	3.0	$1,230,300	50.6%	3.9
PV Benefits +20%	2.9	$1,445,800	48.3%	3.7
PV Benefits – 20%	1.9	$709,300	29.3%	1.8
PV Benefits –40%	1.4	$341,000	18.9%	0.9

4.2 Drummond Cove

Among the adaptation options considered for Drummond Cove, boat launch (stages 1 and 2), sea wall and artificial reef options have negative NPVs. A positive NPV was observed for the groyne field and boat launch (stage 1 only) with the groyne field the former provides the best economic outcome. Under a seven per cent

[1] There is no discount rate at which the present value of benefits equals the present value of costs.

discount rate, the groyne field option has a BCR of 1.1. This BCR means that for each $1 spent on the project, $1.10 is expected to be returned in economic benefits. This option is anticipated to generate over $0.3 million in net benefit to society. The results of the preliminary analysis are provided in **Table 4-5**.

There is a little difference between the sea wall and artificial reef options with the former performing marginally better, but within the uncertainty limits they are quite similar. It is noted that the artificial reef incorporates ongoing large payments in the maintenance for the replacement of the reef every 20 years. This is a consideration depending on the funding sources, as it may be difficult to secure this funding on a regular basis.

The boat launch options have stage 1 performing better than stages 1 and 2. However, as noted in **Section 3-2**, there are likely to be other benefits associated with this option that are not currently incorporated within this analysis (such as the usage value of a safe boat harbour). For the purposes of this analysis, there is only limited differences between the Stage 1 and 2, and Stage 1 only boat launch. (such as the usage value of a safe boat harbour).

Table 4-5 Economic Appraisal results for Drummond Cove

	Boat Launch + sand nourishment (Stages 1 & 2)	*Boat Launch + sand nourishment (Stage 1 only)*	*Sea Wall with Sand Nourishment*	*Artificial Reef*	*Geotextile Groynes backed by Seawall*
PV COST	$7,126,700	$3,614,000	$4,471,800	$4,492,800	$3,330,000
PV BENEFIT	$3,970,900	$3,670,600	$3,670,600	$3,670,600	$3,670,600
NPV	-$3,155,800	$56,600	-$801,100	-$822,200	$340,500
BCR	**0.6**	**1.0**	**0.8**	**0.8**	**1.1**
NPVI	-0.6	0.0	-0.3	-0.3	0.1
FYRR	3%	5%	5%	5%	6%
IRR	2%	7%	5%	4%	8%

A chart showing the composition of the benefits is provided in **Figure 4-2** for the artificial reef (although they are all similar with the exception of the residual values for the boat ramps and sea walls). Note that as the property benefits do not commence until after 2030, these are relatively low compared to the park and beach values.

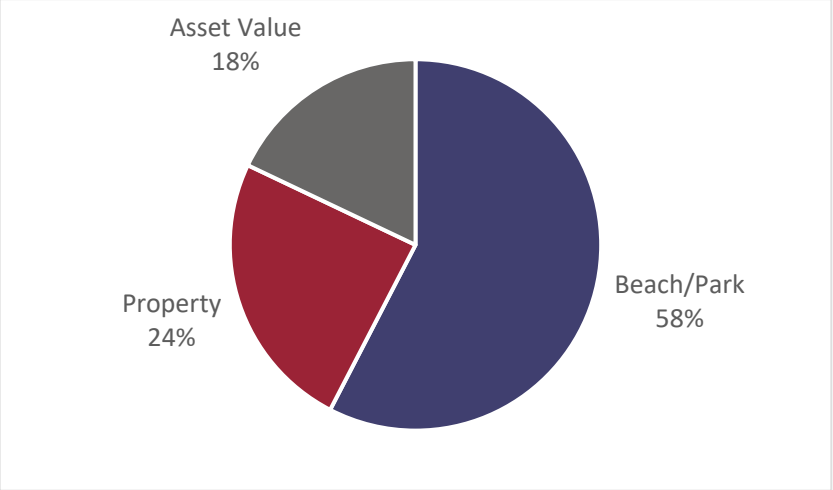

Figure 4-2 Composition of benefits for the Artificial Reef

4.2.1 Sensitivity Analysis: Drummond Cove

The sensitivity analysis for the five adaptation options considered for Drummond Cove are given in **Tables 4-6 to 4-11**.

Table 4-6 Sensitivity Analysis for the Boat Launch option (Stages 1 & 2)

	BCR	NPV	IRR	NPVI
Cost Estimate +40%	0.4	-$6,006,500	0.0%	-0.8
Cost Estimate +20%	0.5	-$4,581,200	1.1%	-0.7
Cost Estimate – 20%	0.7	-$1,730,500	4.1%	-0.4
PV Benefits +20%	0.7	-$2,361,700	3.8%	-0.4
PV Benefits – 20%	0.4	-$3,950,000	0.8%	-0.7
PV Benefits –40%	0.3	-$4,744,200	-1.2%	-0.8

Table 4-7 Sensitivity Analysis for the Boat Launch option (Stage 1 only)

	BCR	NPV	IRR	NPVI
Cost Estimate +40%	0.7	-$1,389,000	4.1%	-0.3
Cost Estimate +20%	0.8	-$666,200	5.5%	-0.2
Cost Estimate – 20%	1.3	$779,400	9.3%	0.3
PV Benefits +20%	1.2	$790,700	8.9%	0.3
PV Benefits – 20%	0.8	-$677,500	5.1%	-0.2
PV Benefits –40%	0.6	-$1,411,600	2.6%	-0.5

Table 4-8 Sensitivity Analysis for the Sea Wall option

	BCR	NPV	IRR	NPVI
Cost Estimate +40%	0.6	-$2,589,800	1.8%	-0.6
Cost Estimate +20%	0.7	-$1,695,500	3.3%	-0.4
Cost Estimate – 20%	1.0	$93,200	7.3%	0.0
PV Benefits +20%	1.0	-$67,000	6.8%	0.0
PV Benefits – 20%	0.7	-$1,535,300	2.9%	-0.5
PV Benefits –40%	0.5	-$2,269,400	0.0%	-0.7

Table 4-9 Sensitivity Analysis for the Artificial Reef Option

	BCR	NPV	IRR	NPVI
Cost Estimate +40%	0.6	-$2,619,300	-0.8%	-0.7
Cost Estimate +20%	0.7	-$1,720,800	1.7%	-0.5
Cost Estimate – 20%	1.0	$76,400	7.3%	0.0
PV Benefits +20%	1.0	-$88,100	6.7%	0.0
PV Benefits – 20%	0.7	-$1,556,300	1.1%	-0.5
PV Benefits –40%	0.5	-$2,290,400	-4.4%	-0.8

Table 4-10 Sensitivity Analysis for the Geotextile Groyne Option

	BCR	NPV	IRR	NPVI
Cost Estimate +40%	0.8	-$991,500	4.8%	-0.3
Cost Estimate +20%	0.9	-$325,500	6.2%	-0.1
Cost Estimate – 20%	1.4	$1,006,600	10.2%	0.5
PV Benefits +20%	1.3	$1,074,700	9.8%	0.4
PV Benefits – 20%	0.9	-$393,600	5.8%	-0.2
PV Benefits –40%	0.7	-$1,127,700	3.3%	-0.4

4.3 Geraldton Town Centre

The AAD calculated for residential, commercial and industrial lots for each given year is presented in **Table 4-11**.

Table 4-11 Annual Average Damage from Inundation

	2015	2030	2070	2110
Residential	$ 59,000	$ 80,500	$ 160,700	$ 451,000
Commercial	$ 26,300	$ 38,200	$ 167,900	$ 425,200
Industrial	$ 91,000	$ 103,100	$ 148,100	$ 191,600

The present value calculations of AAD for residential, commercial and industrial properties at 4%,7% and 10% discount rates are summarised in **Table 4-12**. Present value calculations based on a 50-year lifespan (2018-2068) provides a **$3.5M** worth of damages at a 7% discount rate.

As noted above, this is very much a broad approximation of the potential damages from coastal inundation intended to provide an indication of the likely magnitude of the impacts.

Table 4-12 Net Present value of AAD

Type	Discount factor		
	4%	7%	10%
Residential	$ 2,074,300	$ 1,244,800	$ 858,500
Commercial	$ 1,390,500	$ 746,200	$ 471,400
Industrial	$ 2,466,000	$ 1,555,500	$ 1,113,700
Total	**$ 5,930,800**	**$ 3,546,600**	**$ 2,443,600**

4.3.1 Delayed Commencement Scenario

Climate change results in impacts are not stationary. For the City Centre, climate change will result in an increased frequency of major inundation events, resulting in greater impacts over time. An assessment was undertaken on the impact if the analysis were delayed by 10 years. The sensitivity analysis for a 10-year delay scenario (2028-2078) is given in **Table 4-13**. If the assessment is undertaken in 2028, over a 50-year period at a discount rate of 7%, a PV of $4.3M is obtained.

This assessment shows that the PV will continue to worsen over time. Therefore, some options that are not viable at present, may become viable in the future as climate change continues to have more significant impacts.

Table 4-13 Sensitivity Analysis for Geraldton: 10-year delay

Type	Discount factor		
	4%	7%	10%
Residential	$ 2,516,900	$ 1,515,100	$ 1,048,300
Commercial	$ 1,978,000	$ 1,086,100	$ 694,000
Industrial	$ 2,698,200	$ 1,703,300	$ 1,219,300
Total	**$ 7,193,100**	**$ 4,304,500**	**$ 2,961,600**

5 Conclusion

The CBA conducted for Bluff Point and Drummond Cove herein assessed various adaptation options for dealing with coastal erosion and recession. The analyses rely heavily upon the intangible non-use benefits of the beach/foreshore and park areas in addition to the value of beachfront residential properties. It appears that the Geraldton community benefits to a larger degree upon the numerous intangible values of beach.

Among the various adaptation options considered for Bluff Point, installation of a groyne field is found to be the preferred alternative. With a relatively lower cost for installation and maintenance, the groyne field would permit retaining the beach amenity for the Bluff Point community.

The economic assessment for Drummond Cove found that boat launch (stage 1 only) and geotextile groyne options economically feasible with a positive NPV and a BCR above 1. It is noted that other recreational benefits associated with the boat launch option were not incorporated within the current analysis and therefore the estimated value represents an underestimation of the true value.

The economic quantification of coastal inundation impacts undertaken for the Geraldton area showed a relatively higher annual average damage for industrial properties. The present value of damages at a 7% discount rate over a 50-year period was coarsely estimated at a total of $3.5M for residential, commercial and industrial properties. It is important to note that this is very much an approximation, intended to provide an indication of the relative magnitude of these impacts.

6 References

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Appendix A

Asset values summary: Bluff Point

Asset Type	$ per unit	unit	Assets Impacted by Setback
Road / Carpark	63	m^2	9500
Footpath / Cycle Pathway	150	m^2	1450
Fencing	125	m^2	600
Barbeque	11000	each	3
Toilets	250000	each	1
Picnic Tables	3320	each	3
Beach Shelter	13400	each	5
Small Storage Shed	15000	each	1
Park / Reserve Lighting	7000	avg / each	7
Street Lighting	14000	avg / each	9
Signs laege (e.g. car park)	1000	avg / each	19
Street Furniture (seating)	2500	avg / each	8
Minor I/S e.g. Water Tap, Bins, Bike Rack	100	avg / each	16
Water tank Above Ground	8000	avg / each	1
Groynes (e.g. Town Beach)	7000	m	20
Play System	50000	each	1

Asset values summary: Drummond Cove

Asset Type	$ per unit	unit	Area impacted by setback
Road / Carpark Section 1	$63.00	m^2	5420
Road / Carpark Section 2	$63.00	m^2	4560
Footpath / Cycle Pathway Section 1	$150.00	m^2	120
Footpath / Cycle Pathway Section 2	$150.00	m^2	530
Fencing	$125.00	m	1180
Barbeque	$11,000.00	each	3
Toilets	$250,000.00	each	1
Picnic Tables	$3,320.00	each	4
Beach Shelter	$13,400.00	each	3
Park / Reserve Lighting	$7,000.00	avg / each	1
Street Lighting	$14,000.00	avg / each	13
Signs small (e.g. beach access)	$500.00	avg / each	5
Signs laege (e.g. car park)	$1,000.00	avg / each	2
Street Furniture (seating)	$2,500.00	avg / each	1
Minor I/S e.g. Water Tap, Bins, Bike Rack	$100.00	avg / each	2
Stormwater Drainage Pipes	$2,000.00	m	300
Drainage Pits	$4,500.00	m	19
Play System	$50,000.00	each	1
Drummond Hall	$300,000.00	each	1
Skate Ramp	$60,000.00	each	1
Tennis Court	$20.00	m^2	12900

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Drummond Cove

MCA Summary Nb. Scores are all 0 - 5, the higher the better

Effectiveness

	Effect of Erosion on Asset Types										Effect of Innundation on Asset Types												
Management Option	Foreshore Reserve and beach	Road Infrastructure	Utilities	Ecological areas (onshore)	Ecological areas (offshore)	Residential properties	Commercial properties	Parks and Public Space	Council owned buildings	**TOTAL**	Foreshore Reserve and beach	Road Infrastructure	Utilities	Ecological areas (onshore)	Ecological areas (offshore)	Residential properties	Commercial properties	Parks and Public Space	Council owned buildings	**Total**	Option Flexibility (Score 0-5)	**WEIGHTED SCORE**	**Rank**
Base Case	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0**	2	**2**	NA
Beach Nourishment	4.71	2.00	1.00	3.00	3.10	1.88	1.88	0.20	1.88	**19.6**	1.46	1.65	5.88	1.00	1.00	1.50	1.50	1.00	1.50	**16.5**	2	**38.1**	3
SeaWall	0.10	4.26	2.00	0.41	0.41	5.00	5.00	1.40	5.00	**23.6**	1.25	0.35	0.48	3.00	3.00	5.00	5.00	0.41	5.00	**23.5**	0	**47.1**	1
Groyne Structures	1.08	2.25	2.00	1.41	1.41	4.75	4.75	1.41	4.75	**23.8**	1.25	0.35	1.66	1.41	1.41	2.35	2.35	1.41	2.35	**14.6**	0	**38.4**	2
Boat Launch Facility	0.51	0.75	2.00	1.41	1.41	4.75	4.75	1.41	4.75	**21.8**	1.25	0.35	1.66	1.41	1.41	2.35	2.35	1.41	2.35	**14.6**	0	**36.3**	5
Artifical Reef	0.62	0.75	1.66	1.41	1.41	5.00	3.00	1.41	5.00	**20.3**	1.25	2.50	1.66	1.41	1.41	2.35	2.35	1.41	2.35	**16.7**	0	**37.0**	4
Coastal Revegetation	0.51	0.50	1.00	1.00	1.00	1.00	1.00	0.33	4.60	**10.9**	1.25	0.00	1.18	1.00	1.00	4.85	4.85	1.00	4.85	**20.0**	2	**32.9**	6

Bluff Point CMU

MCA Summary Nb. Scores are all 0 - 5, the higher the better

Effectiveness

	Effect of Erosion on Asset Types									Effect of Innundation on Asset Types											
Management Option	Foreshore Reserve and beach	Road Infrastructure	Utilities	Ecological areas (onshore)	Ecological areas (offshore)	Residential properties	Commercial properties	Parks and Public Space	**TOTAL**	Foreshore Reserve and beach	Road Infrastructure	Utilities	Ecological areas (onshore)	Ecological areas (offshore)	Residential properties	Commercial properties	Parks and Public Space	**Total**	Option Flexibility (Score 0-5)	**WEIGHTED SCORE**	**Rank**
Base Case	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	**0.1**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.0**	2	**1.7**	NA
Beach Nourishment	1.9	0.8	2.4	2.0	0.0	2.2	0.0	1.0	**10.2**	1.00	0.00	2.35	0.00	0.00	0.00	0.00	0.00	**3.4**	2	**15.1**	5
SeaWall	2.7	2.5	4.7	0.6	1.0	5.0	0.0	3.3	**19.7**	1.00	0.00	2.84	0.00	1.00	0.00	0.00	0.00	**4.8**	0	**24.6**	2
Groyne Structures	2.4	2.5	4.7	0.6	2.0	5.0	0.0	3.0	**20.2**	1.00	0.00	2.35	0.00	1.00	0.00	0.00	0.00	**4.4**	1	**25.3**	1
Artifical Reef	2.9	1.1	2.4	0.6	5.0	2.2	0.0	2.5	**16.6**	2.00	0.00	2.35	0.00	3.00	0.00	0.00	0.00	**7.4**	0	**24.0**	3
Coastal Revegetation	1.2	0.8	2.4	4.0	5.0	2.2	0.0	2.0	**17.5**	0.00	0.00	1.18	0.00	1.00	0.00	0.00	0.00	**2.2**	2	**21.3**	4
																		Flexibility weighting	***0.8***		

A.6 Projected Timeline and Budget for Monitoring and Additional Studies

Task	Description (Frequency/Location)	Start	Cost
Year 1	**2019 (Baseline)**		**$102,500**
1.1	Analysis of Shoreline Movements (5 Yearly)	07-Jan-19	$1,500
1.2	Beach Transect Survey (Summer)	04-Mar-19	$3,500
1.3	Beach Transect Survey (Winter)	02-Sep-19	$3,500
1.4	UAV Survey (2 Yearly)	25-Mar-19	$4,000
1.5	Storm Bite Analysis (post storm)	01-Jan-19	$1,500
1.6	Photo Monitoring (Summer and post storm)	01-Apr-19	$2,500
1.7	Photo Monitoring (Winter and post storm)	02-Sep-19	$2,500
1.8	Minor Structure Inspection (Summer and post storm)	01-Apr-19	$2,500
1.9	Minor Structure Inspection (Winter and post storm)	30-Sep-19	$2,500
1.10	Coastal Protection Structure Inspection (Yearly and post storm)	04-Nov-19	$3,500
1.11	Geophysical Assessment (D, BP, SB)	11-Feb-19	$75,000
Year 2	**2020**		**$82,000**
2.1	Beach Transect Survey (Summer)	02-Mar-20	$3,500
2.2	Beach Transect Survey (Winter)	31-Aug-20	$3,500
2.3	Storm Bite Analysis (post storm)	01-Jan-20	$1,500
2.4	Photo Monitoring (Summer and post storm)	02-Mar-20	$2,500
2.5	Photo Monitoring (Winter and post storm)	31-Aug-20	$2,500
2.6	Minor Structure Inspection (Summer and post storm)	06-Apr-20	$2,500
2.7	Minor Structure Inspection (Winter and post storm)	31-Aug-20	$2,500
2.8	Coastal Protection Structure Inspection (Yearly and post storm)	02-Nov-20	$3,500
2.9	Detailed Flood Study (GTC)	10-Feb-20	$60,000
Year 3	**2021**		**$26,000**
3.1	Beach Transect Survey (Summer)	01-Mar-21	$3,500
3.2	Beach Transect Survey (Winter)	30-Aug-21	$3,500
3.3	UAV Survey (2 Yearly)	29-Mar-21	$4,000
3.4	Storm Bite Analysis (post storm)	01-Jan-21	$1,500
3.5	Photo Monitoring (Summer and post storm)	01-Mar-21	$2,500
3.6	Photo Monitoring (Winter and post storm)	30-Aug-21	$2,500
3.7	Minor Structure Inspection (Summer and post storm)	05-Apr-21	$2,500
3.8	Minor Structure Inspection (Winter and post storm)	30-Aug-21	$2,500
3.9	Coastal Protection Structure Inspection (Yearly and post storm)	01-Nov-21	$3,500
Year 4	**2022**		**$22,000**
4.1	Beach Transect Survey (Summer)	28-Feb-22	$3,500
4.2	Beach Transect Survey (Winter)	01-Aug-22	$3,500
4.3	Storm Bite Analysis (post storm)	03-Jan-22	$1,500
4.4	Photo Monitoring (Summer and post storm)	28-Feb-22	$2,500
4.5	Photo Monitoring (Winter and post storm)	05-Sep-22	$2,500
4.6	Minor Structure Inspection (Summer and post storm)	04-Apr-22	$2,500
4.7	Minor Structure Inspection (Winter and post storm)	05-Sep-22	$2,500
4.8	Coastal Protection Structure Inspection (Yearly and post storm)	31-Oct-22	$3,500
Year 5	**2023**		**$41,000**
5.1	Beach Transect Survey (Summer)	06-Mar-23	$3,500
5.2	Beach Transect Survey (Winter)	31-Jul-23	$3,500
5.3	UAV Survey (2 Yearly)	27-Mar-23	$4,000
5.4	Storm Bite Analysis (post storm)	02-Jan-23	$1,500
5.5	Photo Monitoring (Summer and post storm)	06-Mar-23	$2,500
5.6	Photo Monitoring (Winter and post storm)	31-Jul-23	$2,500
5.7	Minor Structure Inspection (Summer and post storm)	03-Apr-23	$2,500
5.8	Minor Structure Inspection (Winter and post storm)	04-Sep-23	$2,500
5.9	Coastal Protection Structure Inspection (Yearly and post storm)	30-Oct-23	$3,500
5.10	CHRMAP Review	07-Aug-23	$15,000
TOTAL	**Cost for All Activities over 5 Years (2019-2023)**		**$273,500**