A future-proof water system for Campbelltown and the Greater Sydney area

Evaluating the potentials and implications of Decentralised Wastewater Treatment in suburban developments

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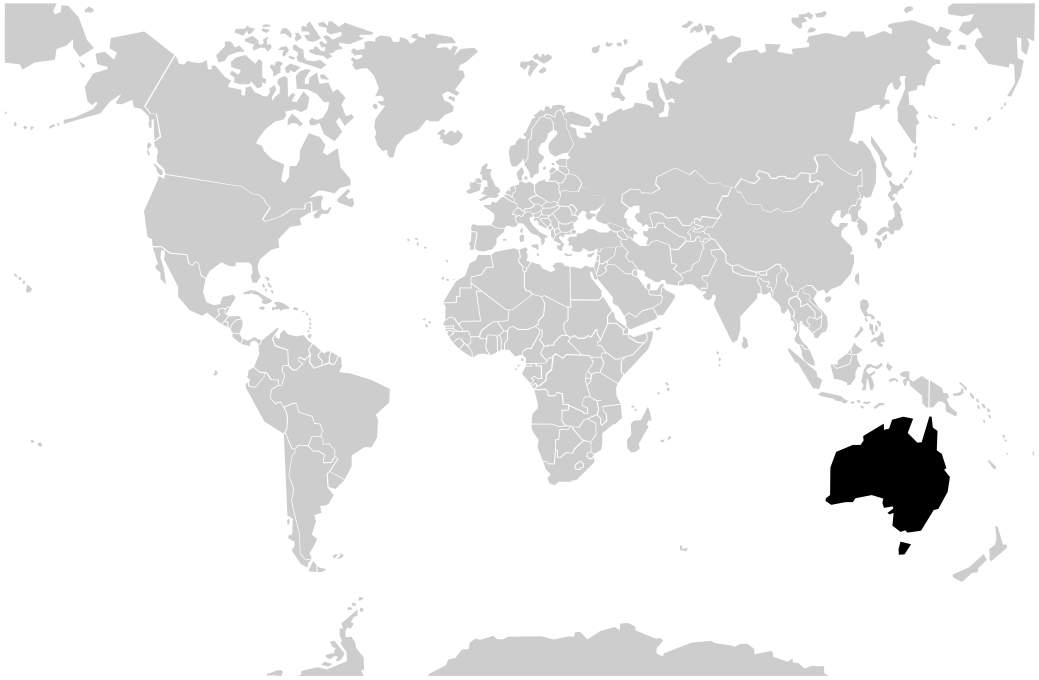
22 Jun 2023


ENNARDS
HIRE
OUTBACK
OUTBACK

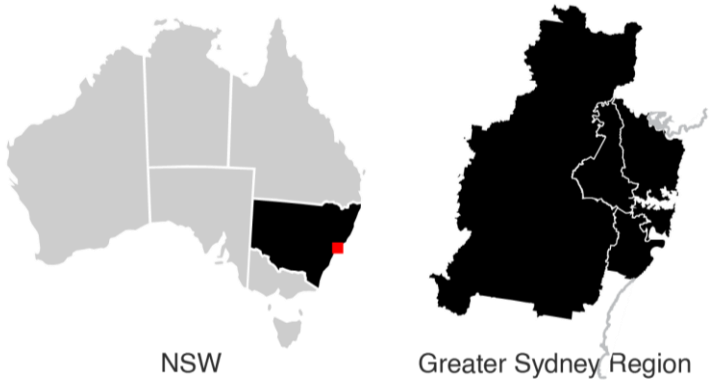
Introduction to the problem

- Location of Greater Sydney
- General perception
- Challenges today
- Methods to fight against drought in Sydney
- Reducing the dependence on stormwater supply

Location of Greater Sydney



Australia



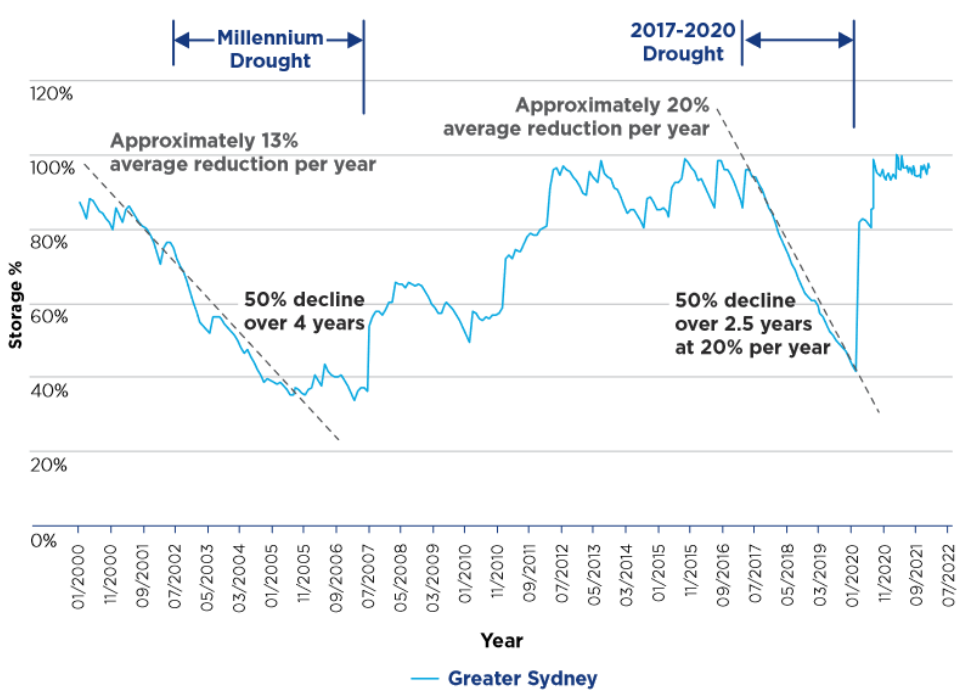
Location of Greater Sydney

Sydney's water crisis

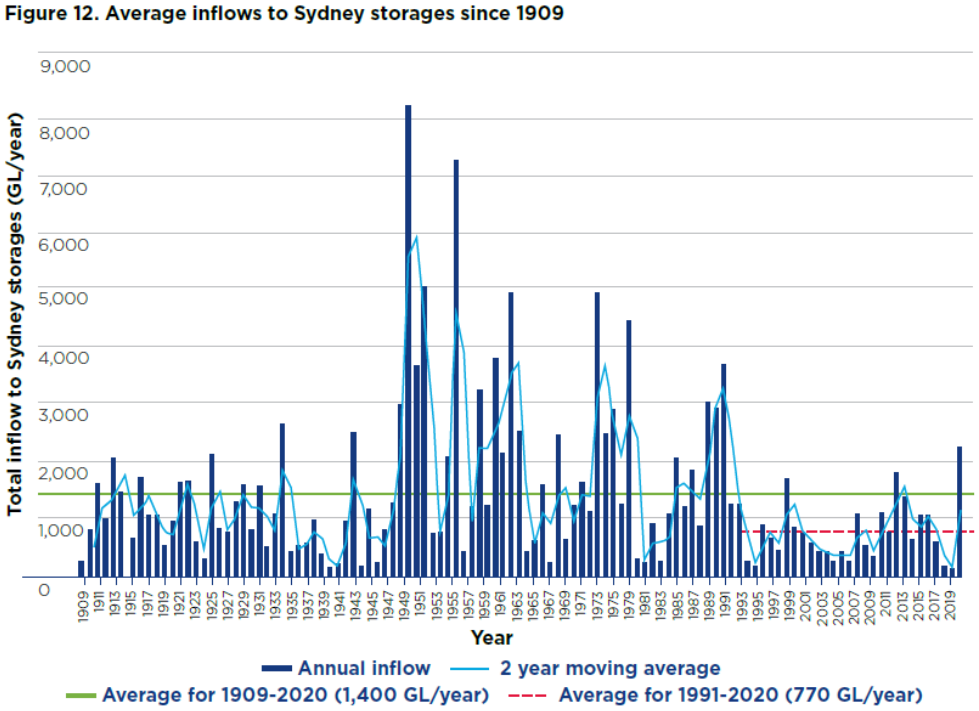
Warragamba dam storage is low in 2019 (Western Advocate, 2019)

Warragamba's water reserves was dry and contaminated (Coë, 2019)

Two significant drought in past 20 years

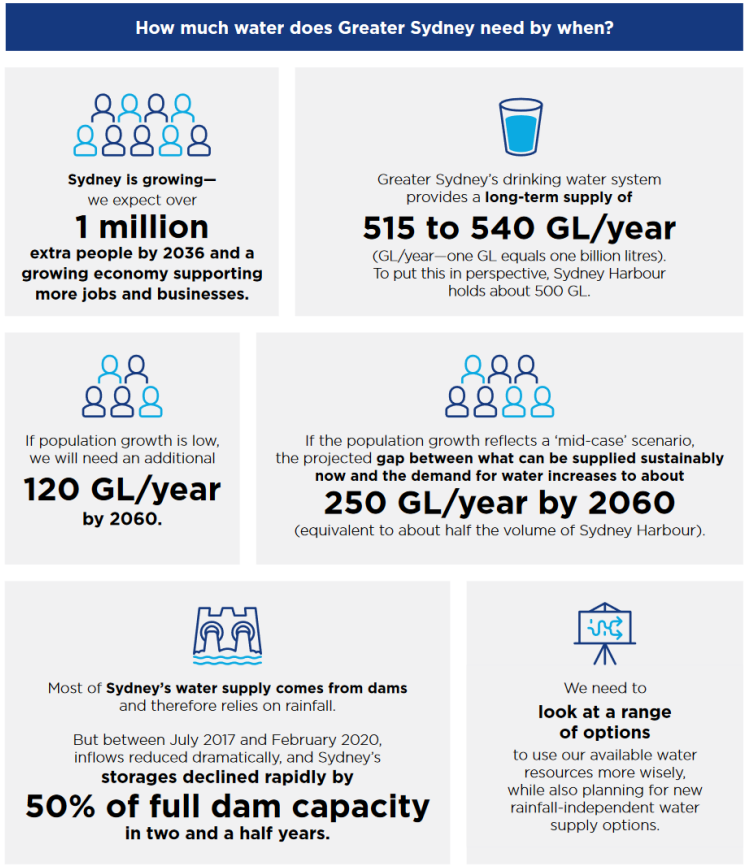


Greater Sydney storage level profile 2000-2020 (NSW Department of Planning and Environment, 2022)

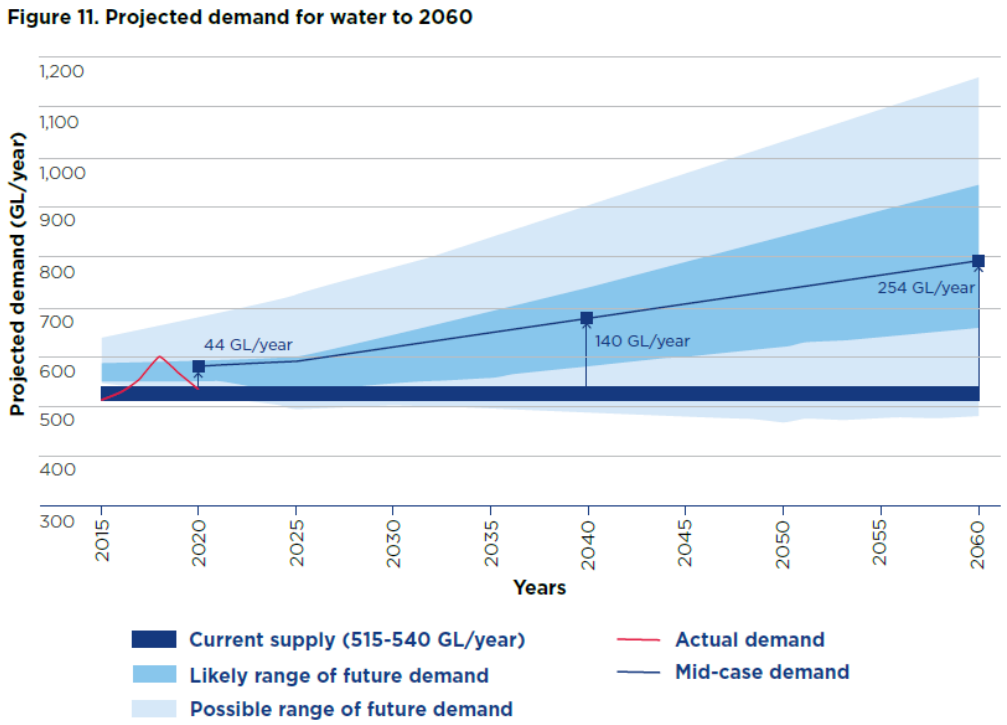


Average inflows to Sydney storages since 1909 (NSW Department of Planning and Environment, 2022)

Ongoing population growth increases the demand

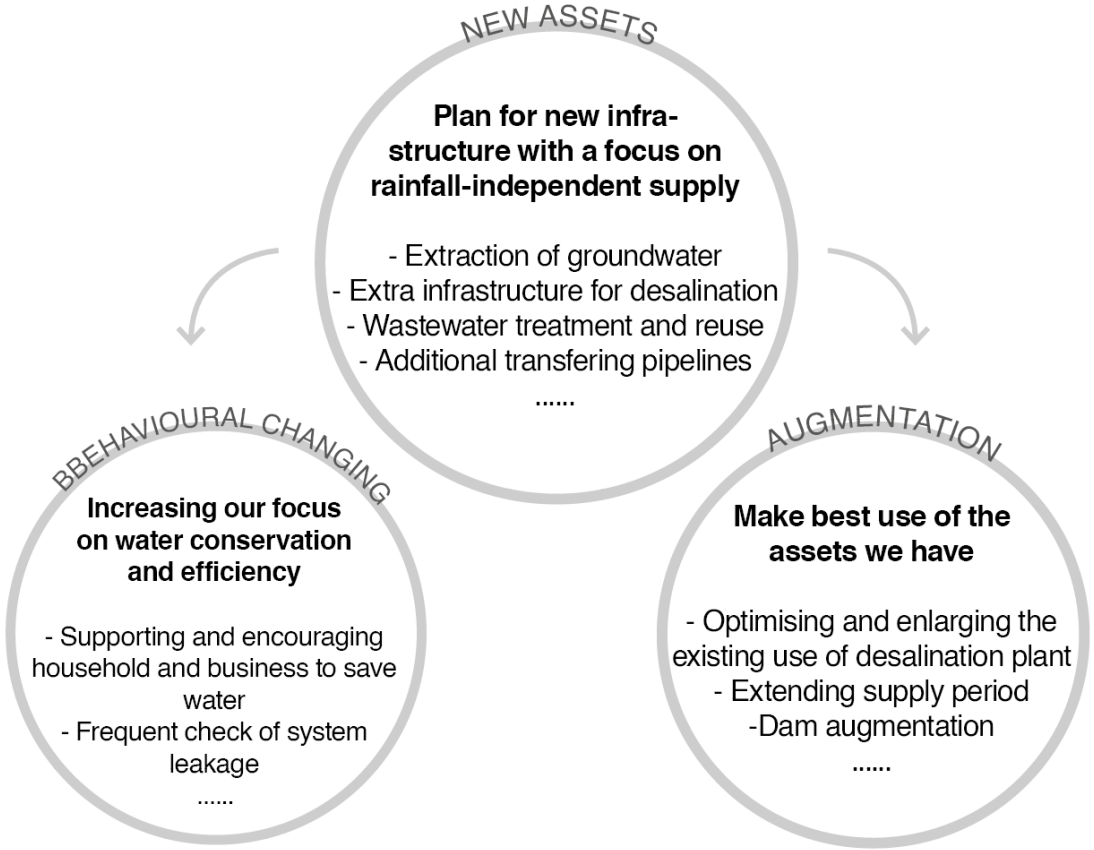


Forecast of water consumption with population growth (NSW Department of Planning and Environment, 2022)



Projected demand for water to 2060 (NSW Department of Planning and Environment, 2022)

Methods to fight against drought in Sydney



Sydney could need new additional rainfall-independent water supply as early as 2026/27

Reducing the dependence on stormwater supply

General opinion about DEWATS

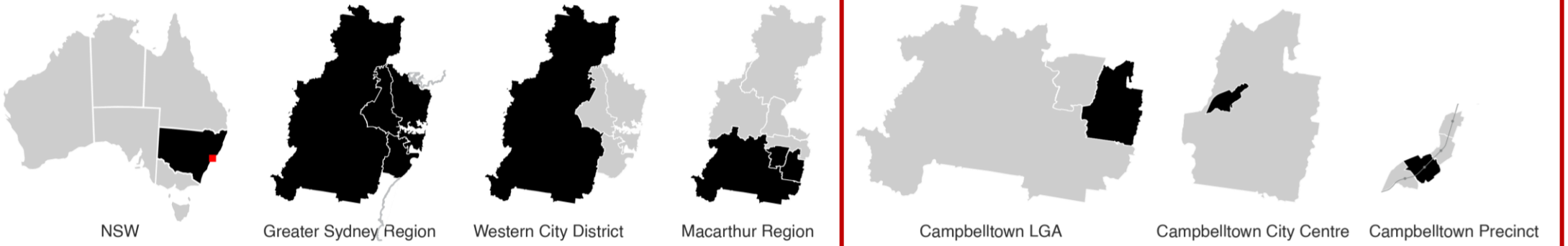
- Small scale
- Flexible
- Natural-based
- Low energy consumption
- High autonomy in management

- High requirement of the site condition
- Hard to monitor
- Unstable treated water quality

Project location - Campbelltown

- Campbelltown in administrative layers
- Strategic importance
- The largest city centre
- Campbelltown now

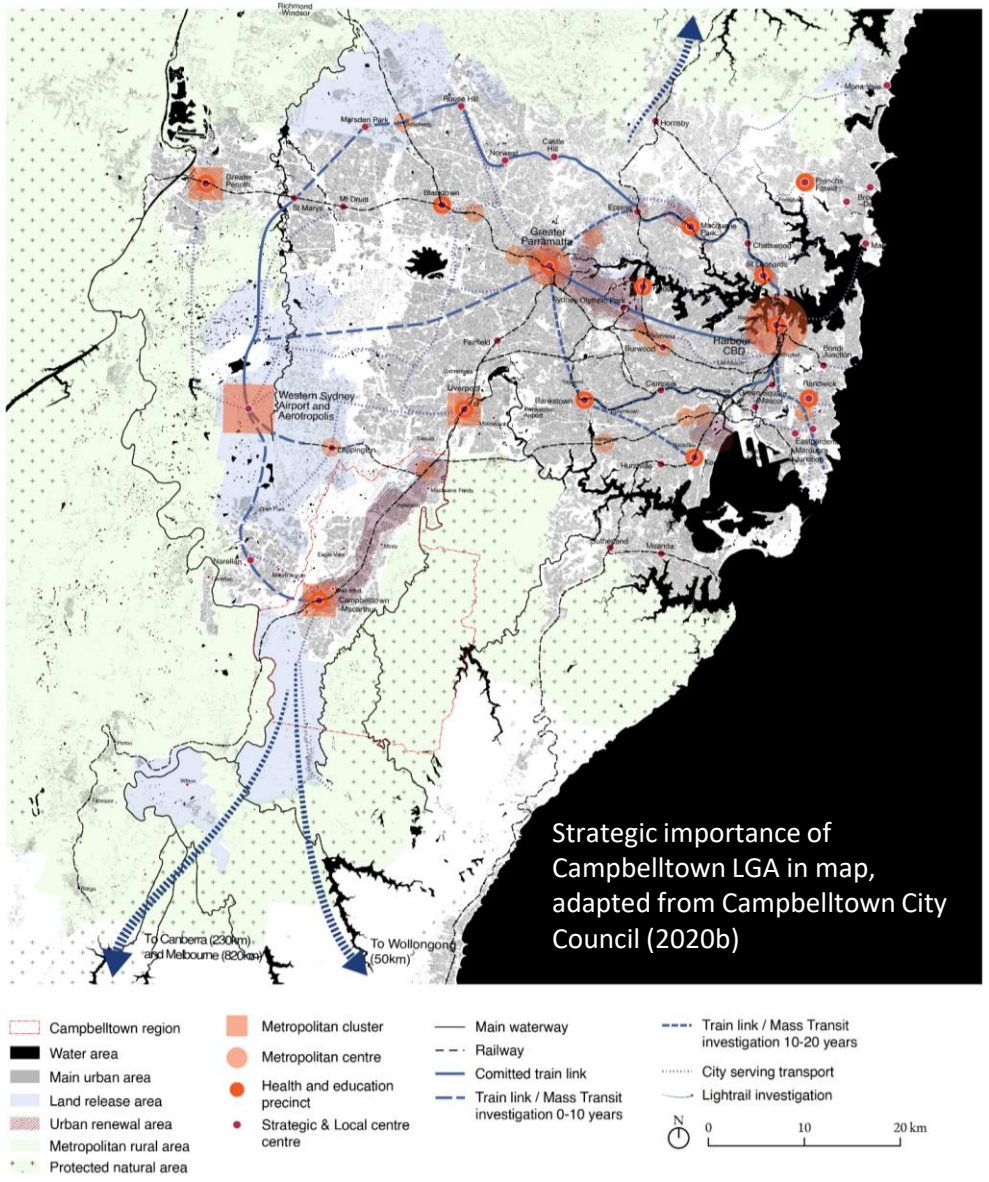
Campbelltown in administrative layers



The location of the sites in three administrative layers

Strategic importance of Campbelltown LGA in 2040

- Two metropolitan centres and a metropolitan cluster
- Largest urban renewal area
- Foundation for land release of the Greater Macarthur area
- Future transportation node



Campbelltown now

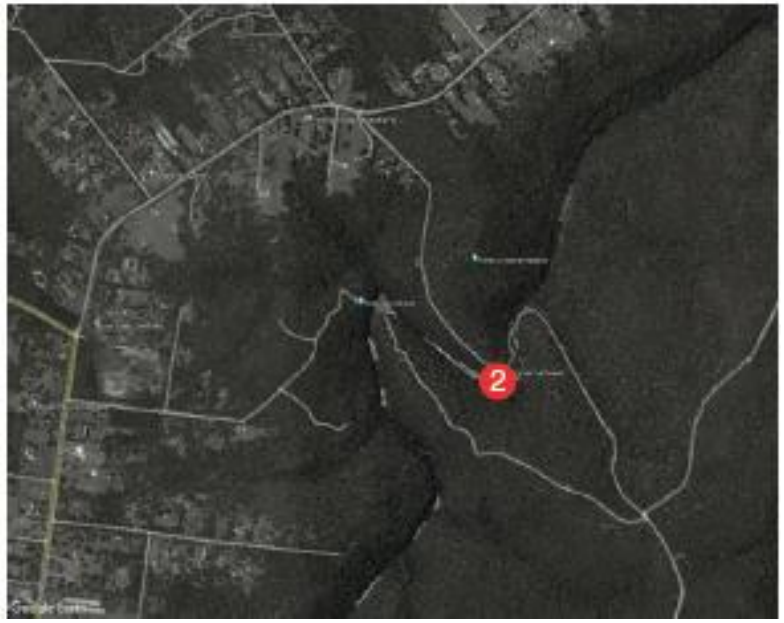
(Google, 2019)

(Google, 2019)

(Google, 2019)

Campbelltown now

(Google, 2019)

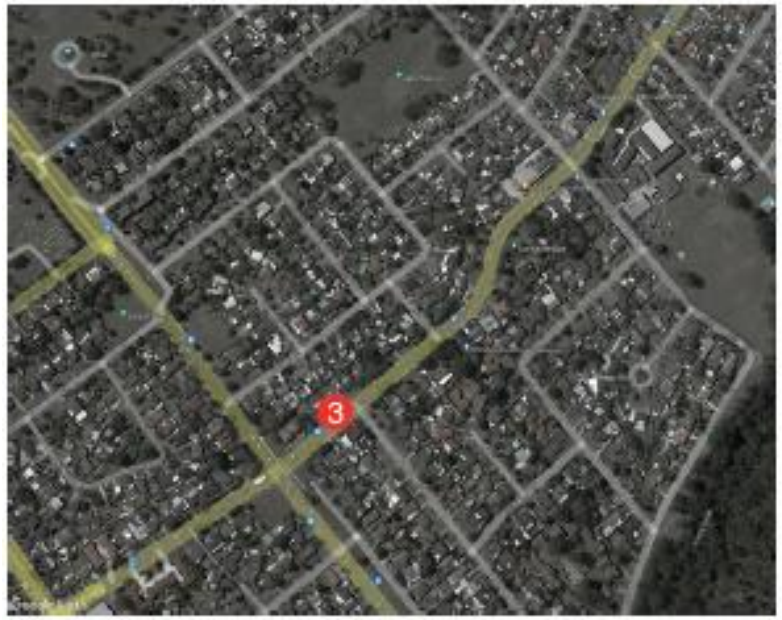


(Google, 2019)

(Google, 2019)

Campbelltown now

(Google, 2019)



(Google, 2019)

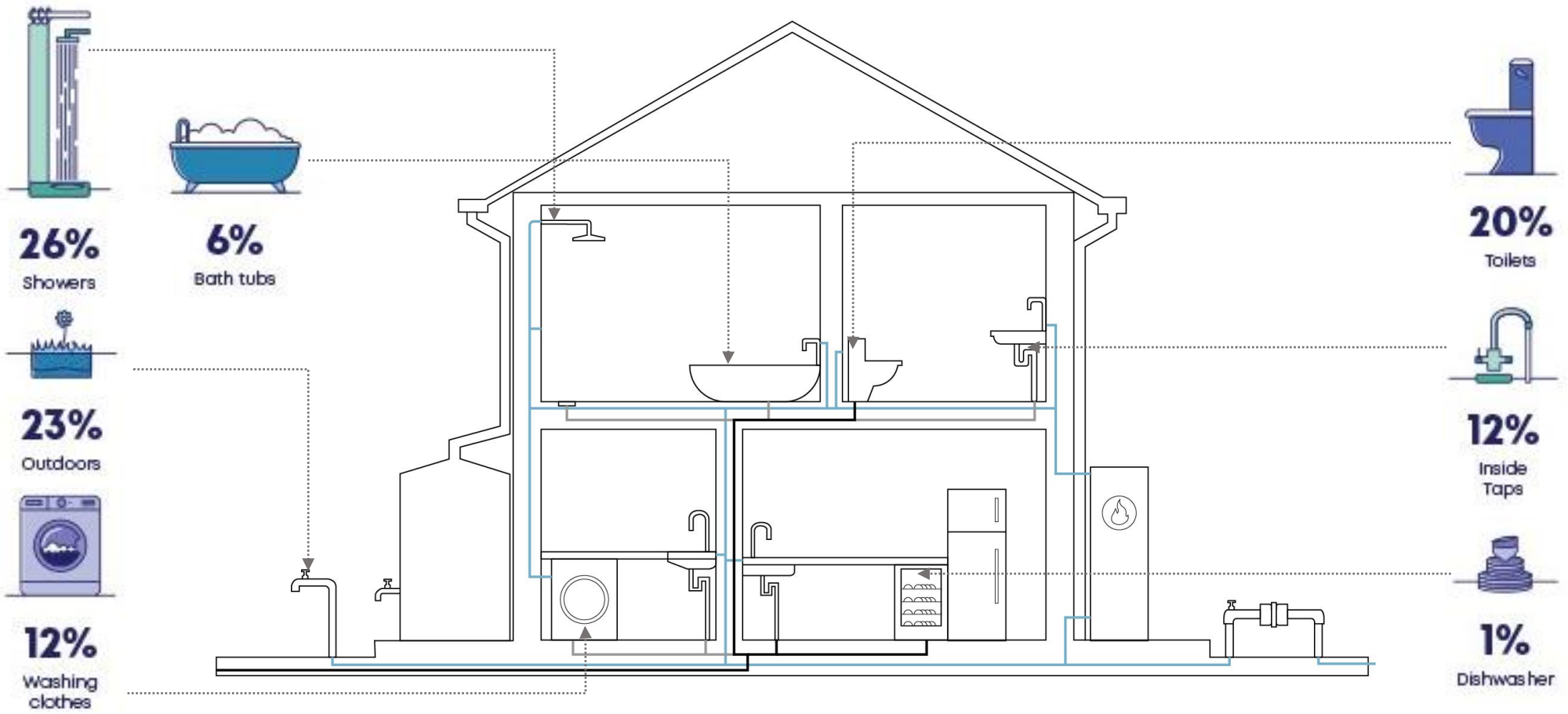
(Google, 2019)

Theory

- Introduction to domestic wastewater in Australia
- The constituents targeted for treatment
- Concept of Decentralised wastewater treatment system (DEWATS)

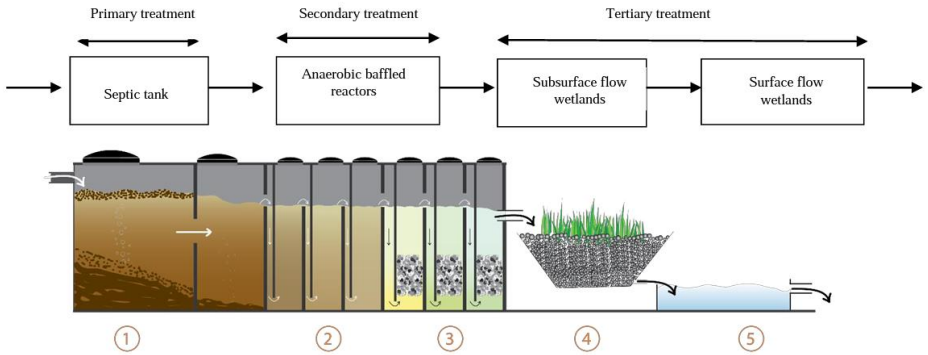
Introduction to domestic wastewater in Australia

How much water is used in your home?



Concept of Decentralised wastewater treatment system (DEWATS)

- Septic tank
- Anaerobic reactor (ABR)
- Subsurface flow wetlands
  a) Vertical flow (VF)
  b) Horizontal flow (HF)
  c) Vertical flow + Horizontal flow (VF + HF)
- Surface flow wetlands

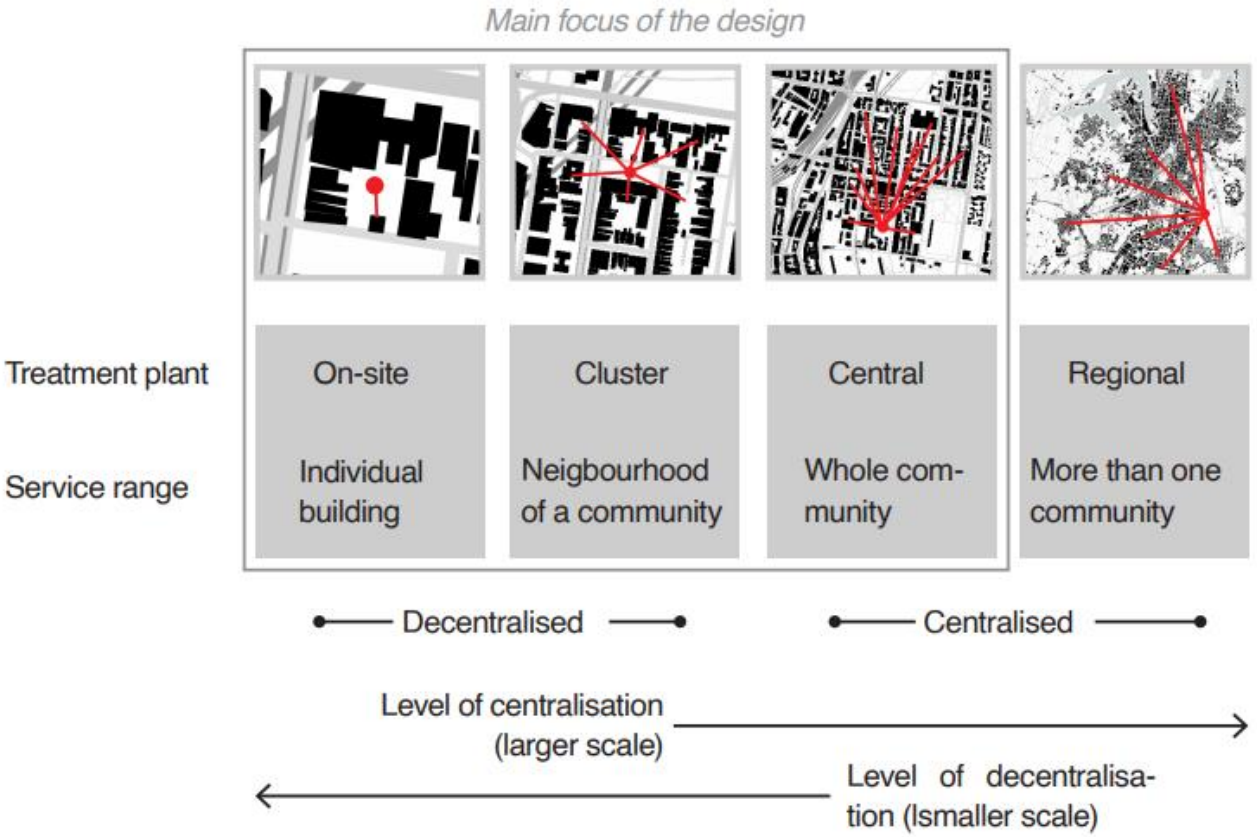


Section 1	Section 2	Section 3	Section 4	Section 5
Primary treatment	**Secondary treatment**		**Tertiary treatment**	**Post-treatment**
Septic tank	Baffled reactor	Anaerobic filter	Constructed wetland	Polishing pond/ Surface flow wetland
Sedimentation tank stabilising settled sludge by anaerobic digestion Dissolved and suspended matter leave tank untreated	Anaerobic degradation of suspended and dissolved solids 2–5 chambers depending of treatment required	Water passes through filter media Enhance digestion of organic matter	Open shallow basin filled with gravel/pebbles to support growth of plant/reeds with shallow roots Reduces organic contents and acts as filter mechanism	Open shallow basin for removal of stabilised or inactive suspended substances Exposure to UV rays
Removal of COD 20-25%, BOD 15-20%, TSS 50-55%	Removal of COD 25-30%, BOD 30-35%, TSS 10-15%	Removal of COD 20-25%, BOD 15-20%, TSS 15-20%	Removal of COD 15-20%, BOD 20-25%, TSS 5-10%	Removes odour and pathogens

COD: Chemical oxygen demand
BOD: Biochemical oxygen demand
TSS: Total suspended solids

Illustration of the typical modules in DEWATS and their performance (Harvey et al., 2017)

Concept of Decentralised wastewater treatment system (DEWATS)



The levels of decentalisation and centralisation treatment, adapted from Rocky Mountain Institute (2004)

General research aim

The general aim for this project is to explore and experiment how the implement of decentralised wastewater treatment system (DEWATS) for different population density contributes to water re-use in Campbelltown. Meanwhile, understanding the upper limit for urban sprawl based on the gap between water supply and consumption.

Research question

Main question: How to implement nature-based Decentralised Wastewater System (DEWATS) as a means to facilitate water re-use for future household in Campbelltown?

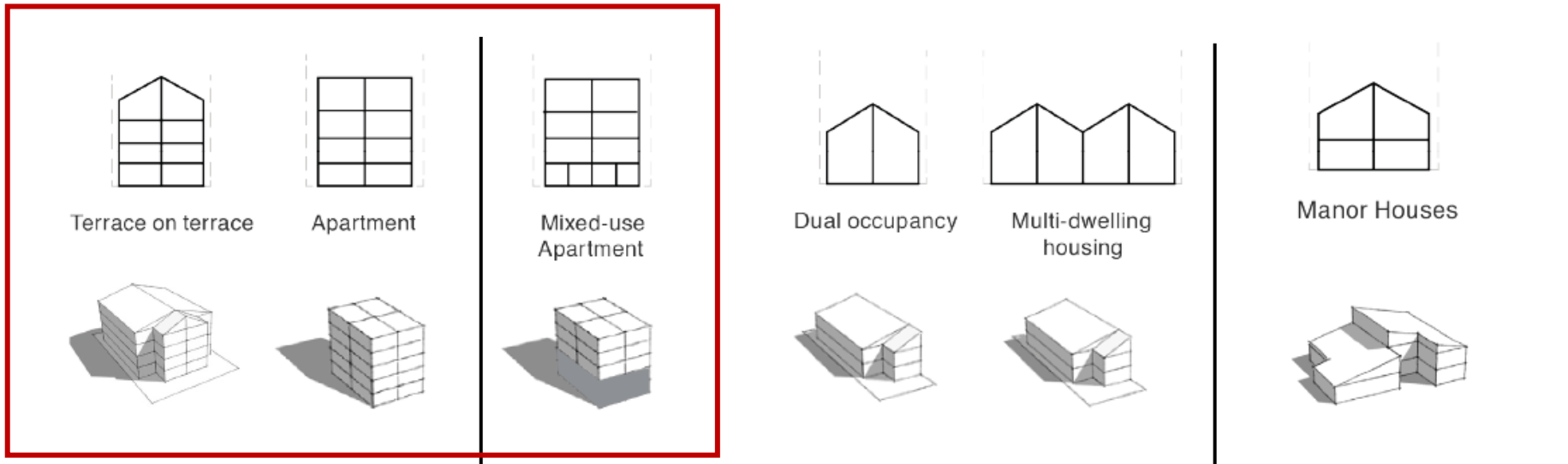
- Q1: Can the design be applied to different urban densities equally well?
- Q2: What are the treated water quality required for different purposes of reuse?
- Q3: What are the spatial requirements and synergies for the selected DEWATS system in the case study area?
- Q4: How can the existing infrastructure and landscape participate in the case study area?
- Q5: How can the interventions contribute to the resilience of the water system in other parts of the Greater Sydney region?

Analysis and site overview

- Densification scenarios
- Area requirement for DEWATS in Campbelltown
- Spatial analysis
- Conceptual framework
- Site overview
- Open green space and building situation in the target sites
- Vision and current residential development of the target sites

Densification scenarios

Dwelling types in Campbelltown



High density: Flats in a block of 4 or more storeys

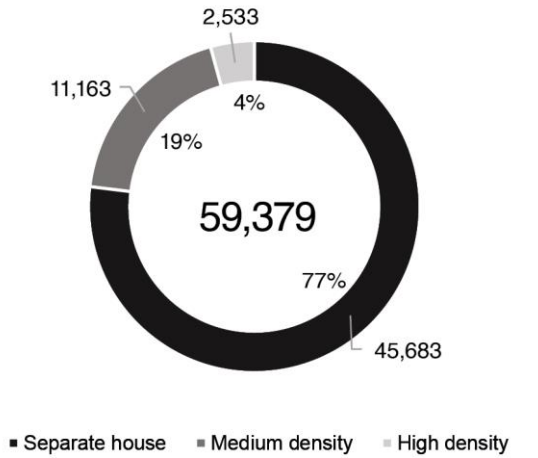
Medium density: Flats in a block of less than 4 storeys, Semi-detached dwelling

Separate house

Illustration of housing types, adapted from Campbelltown City Council (2020b)

Densification scenarios

Population growth



Numbers of different types of active dwellings in Campbelltown in 2021, data from idcommunity (n.d.)

Totals	2011	2016	2021	2026	2031	2036
Total Population	151,150	164,400	177,800	197,000	214,100	233,150
Total Households	51,300	56,950	62,250	69,350	75,550	82,550
Implied Dwellings	53,600	59,500	65,050	72,450	78,950	86,200

Low scenario (Implied figure based on 2016 forcast): 233,150 in 2036

Summary	2021	2026	2031	2036	2041
Total Population	176,151	195,130	229,665	256,041	272,303
Total Households	59,378	66,271	77,652	86,615	92,610
Implied Dwellings	62,760	69,893	81,983	91,564	97,918

Moderate (Implied figure based on 2021 forcast): 256,041 in 2036

Summary	2016	2021	2026	2031	2036
Total Population	161,408	180,957	212,002	244,088	275,778
Total Households	54,638	61,759	72,212	83,070	93,397
Implied Dwellings	55,986	63,558	74,507	85,718	96,394

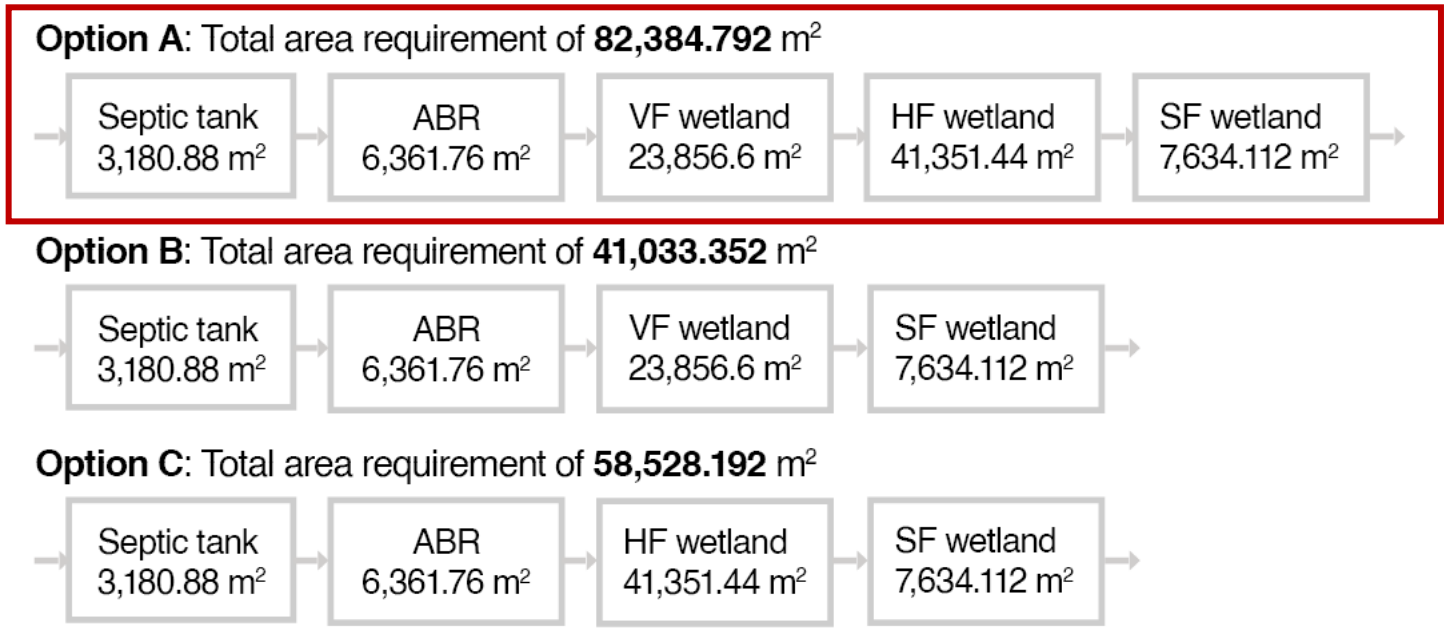
High (expected figure from the city council): 275,778 in 2036

Area requirement for DEWATS in Campbelltown

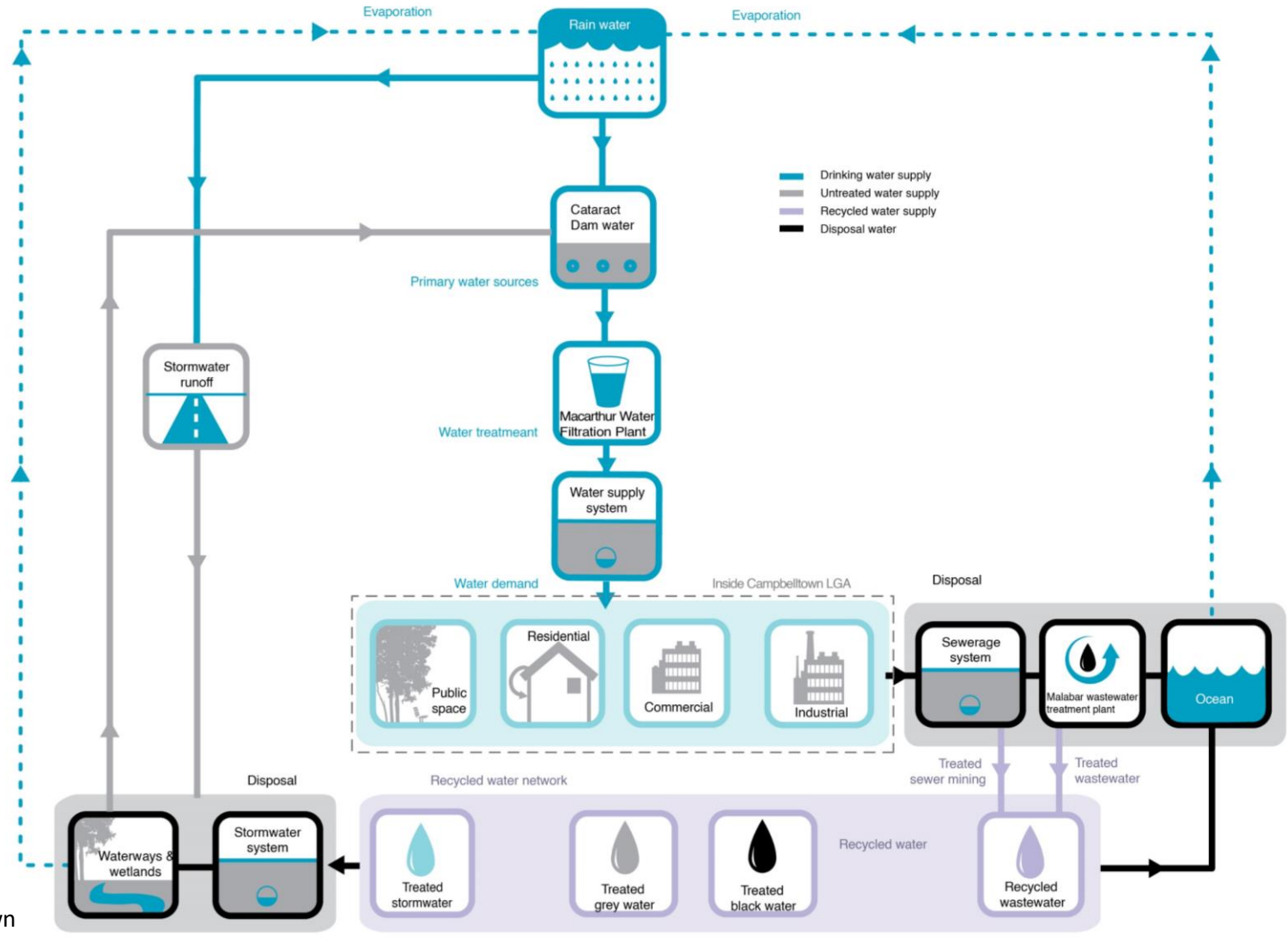
key modules

- Septic tank
- Anaerobic reactor (ABR)
- Subsurface flow wetlands
  a) Vertical flow (VF)
  b) Horizontal flow (HF)
  c) VF + HF
- Surface flow wetlands

Best treatment quality

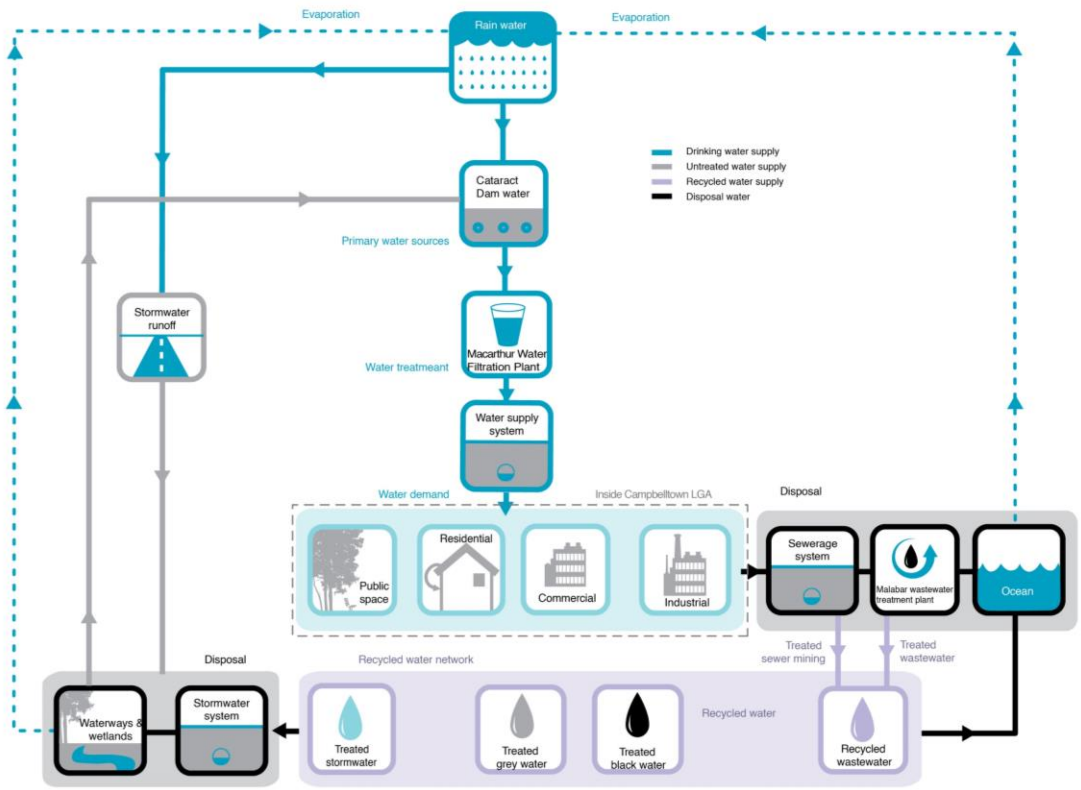


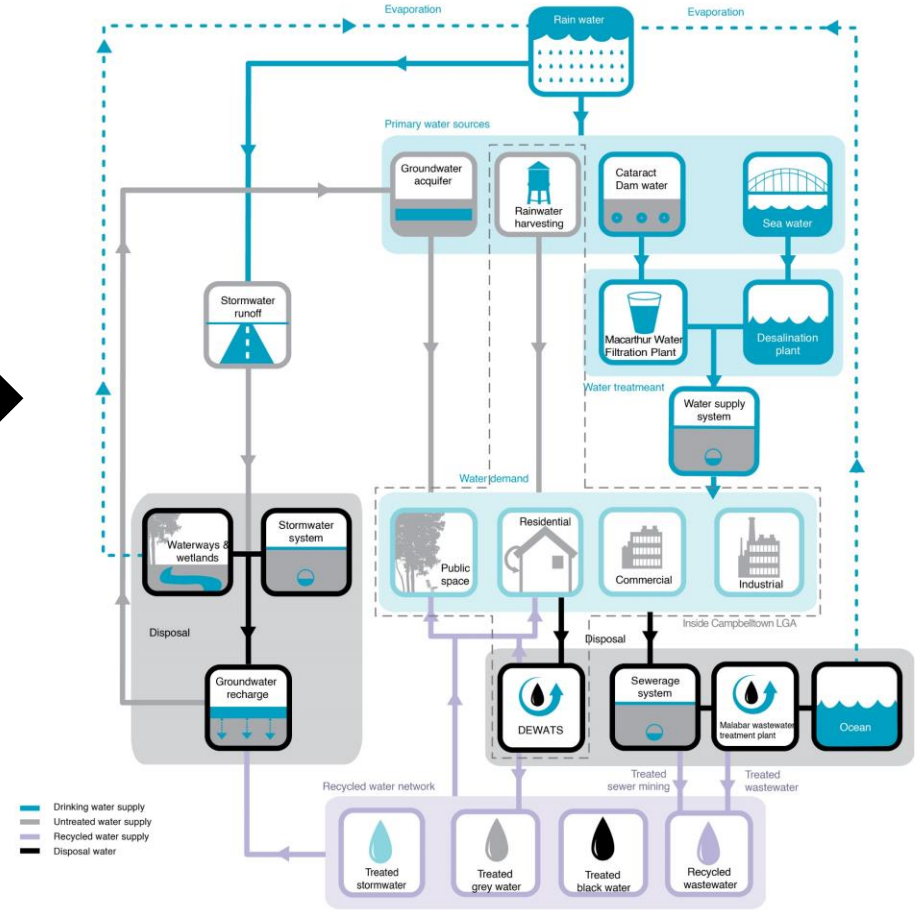
Overview of the water system in Campbelltown



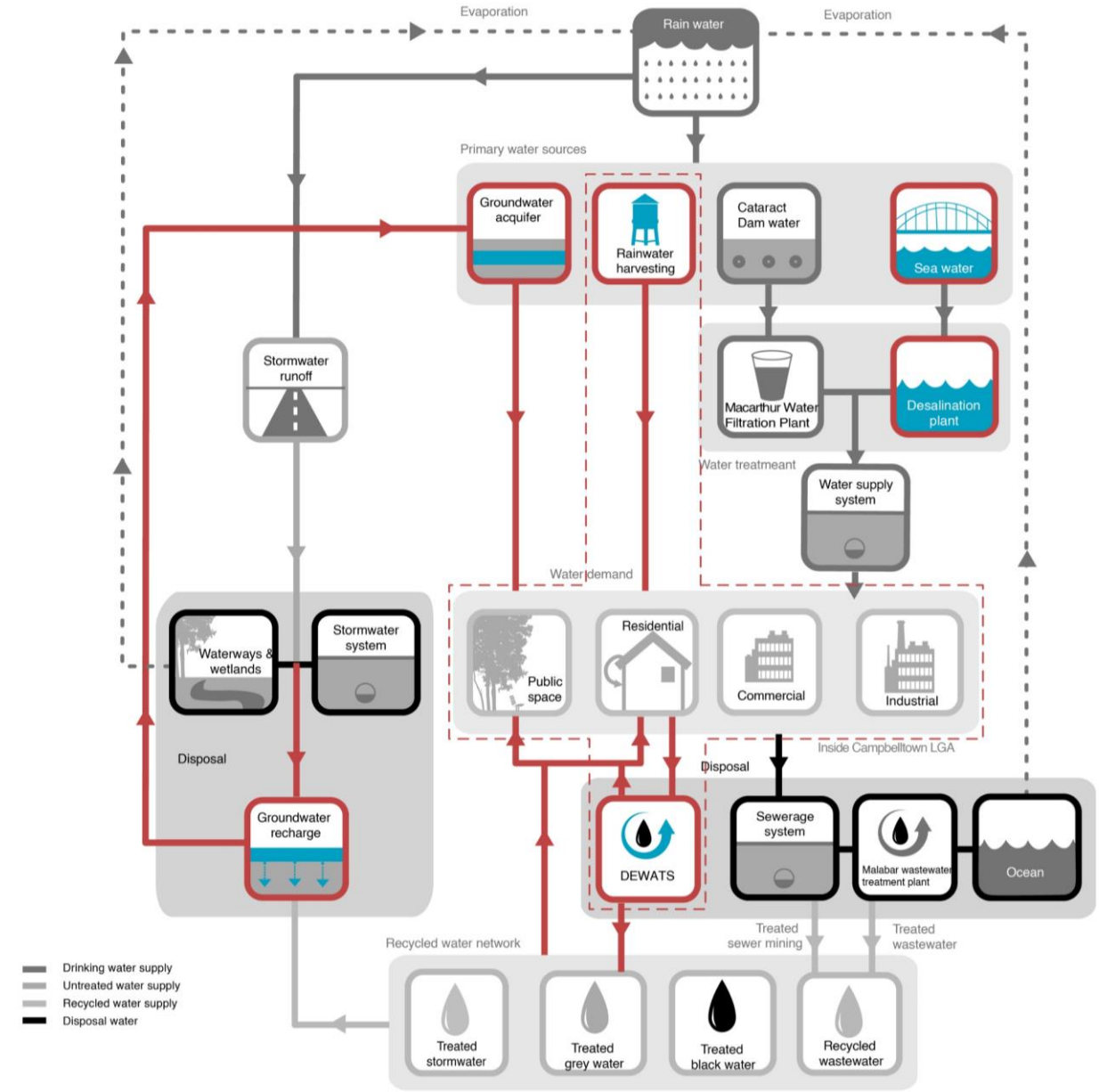
Overview of existing water network in Campbelltown

Conceptual framework





Conceptual framework



Highlight of design elements

Site overview

City centre corridor with three sites

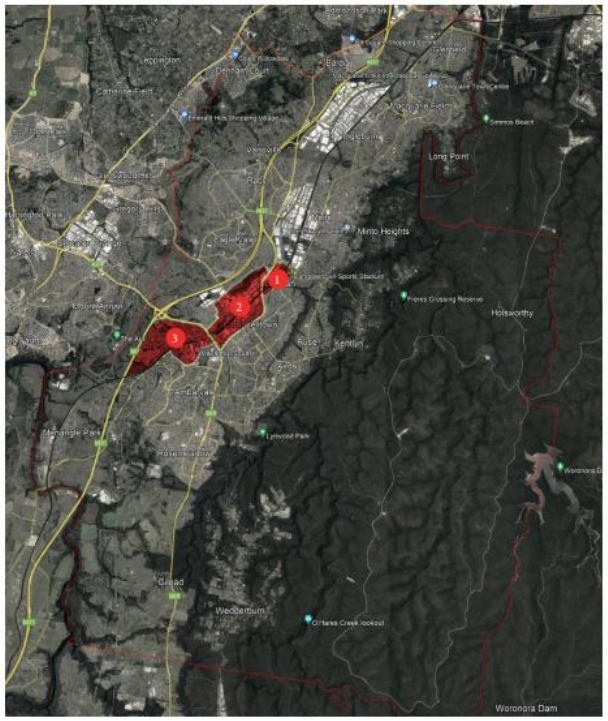


Fig 6.9 Map showing the three sites for detailed design, adapted from Google Earth (2023)

Map showing the three sites for detailed design, adapted from Google Earth (2023)

Open green space in Leumeah Centre

Fig 6.16 Map and photos showing the open space in Leumeah centre, adapted from Google Earth (2023)

Buildings in Leumeah Centre

Fig 6.17 Map and photos showing the buildings in Leumeah centre, adapted from Google Earth (2023)

Open green space in Campbelltown Centre

Fig 6.18 Map and photos showing the open space in Campbelltown centre, adapted from Google Earth (2023)

Buildings in Campbelltown Centre

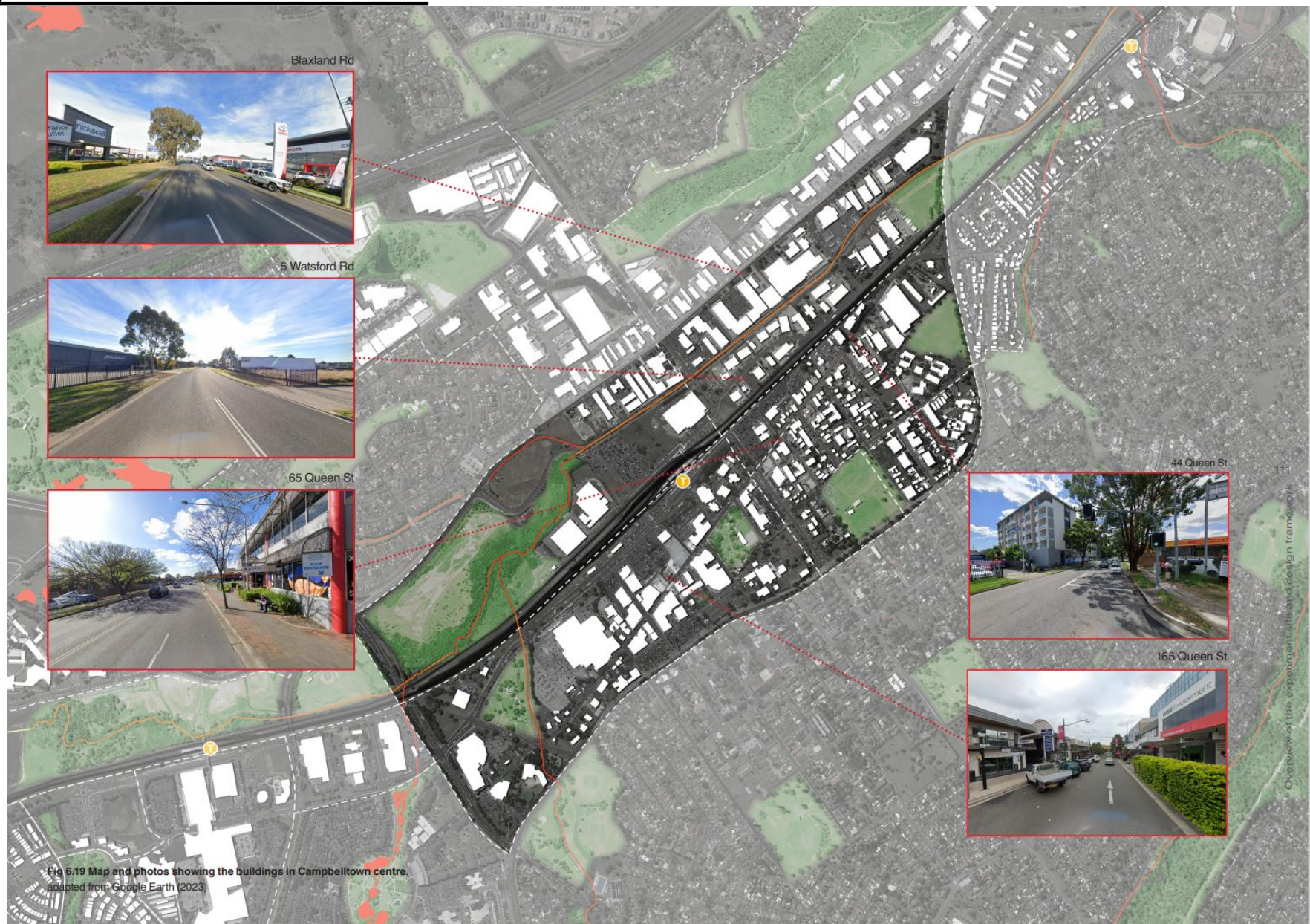


Fig 6.19 Map and photos showing the buildings in Campbelltown centre, adapted from Google Earth (2023)

Design concept

- Functional design of the integrated wetland system
- Main direction of SF development for each target site and for the overall area

Functional design of the integrated wetland system

- Septic tank → Primary treatment
- Anaerobic reactor (ABR) → Secondary treatment
- Subsurface flow wetlands → Tertiary treatment
  a) Vertical flow (VF)
  b) Horizontal flow (HF)
  c) Vertical flow + Horizontal flow (VF + HF)
- Surface flow wetlands → Post treatment

Functional design of the integrated wetland system

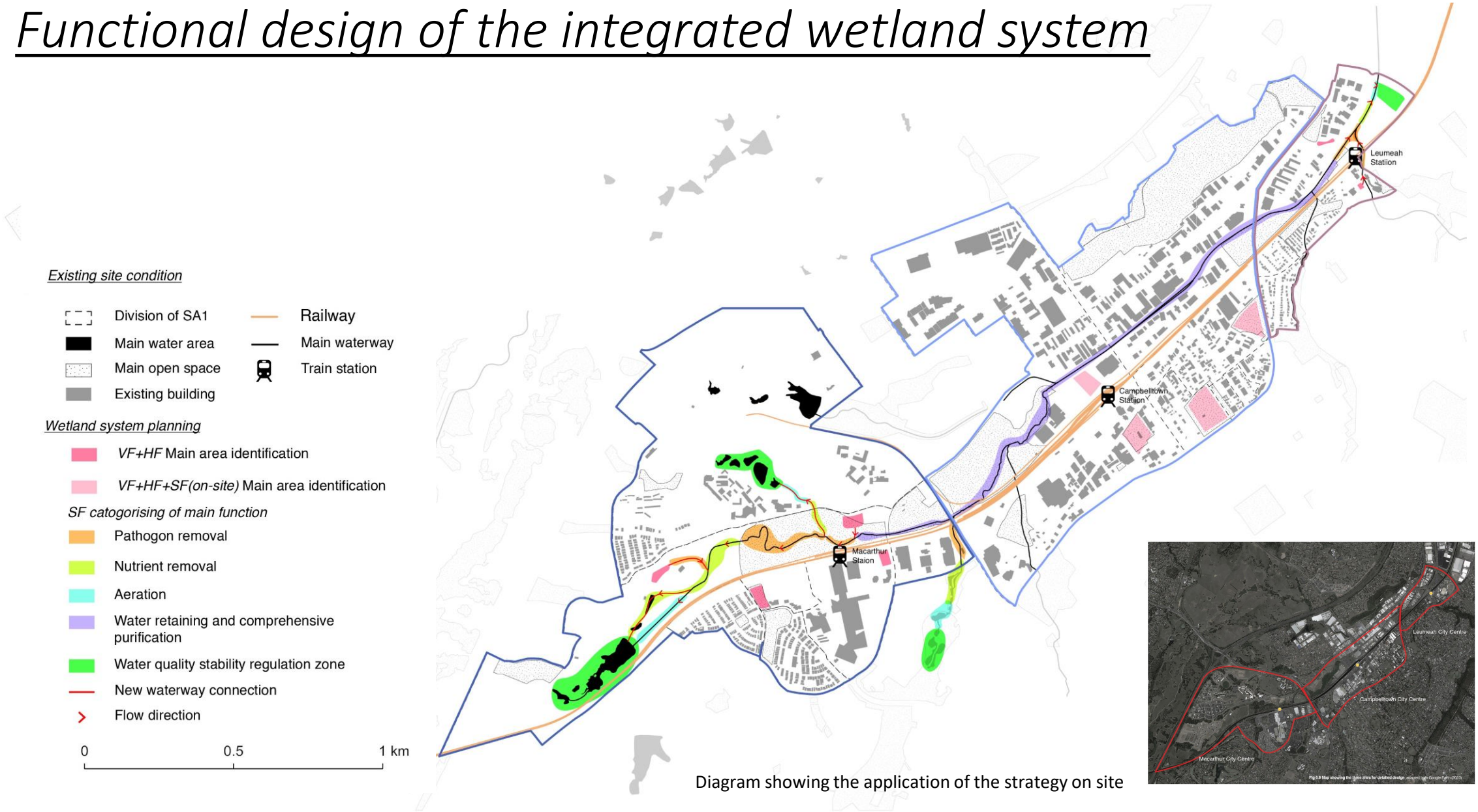


Diagram showing the application of the strategy on site

Functional design of the integrated wetland system

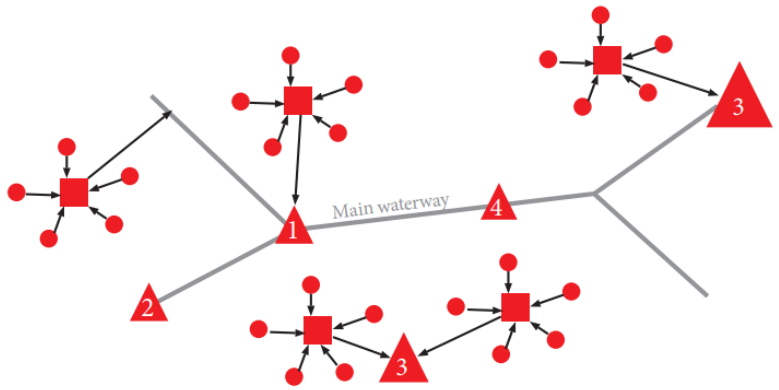


Fig 6.10 Diagram showing the basic design logic of the three sites as a whole

Lowest spatial impact

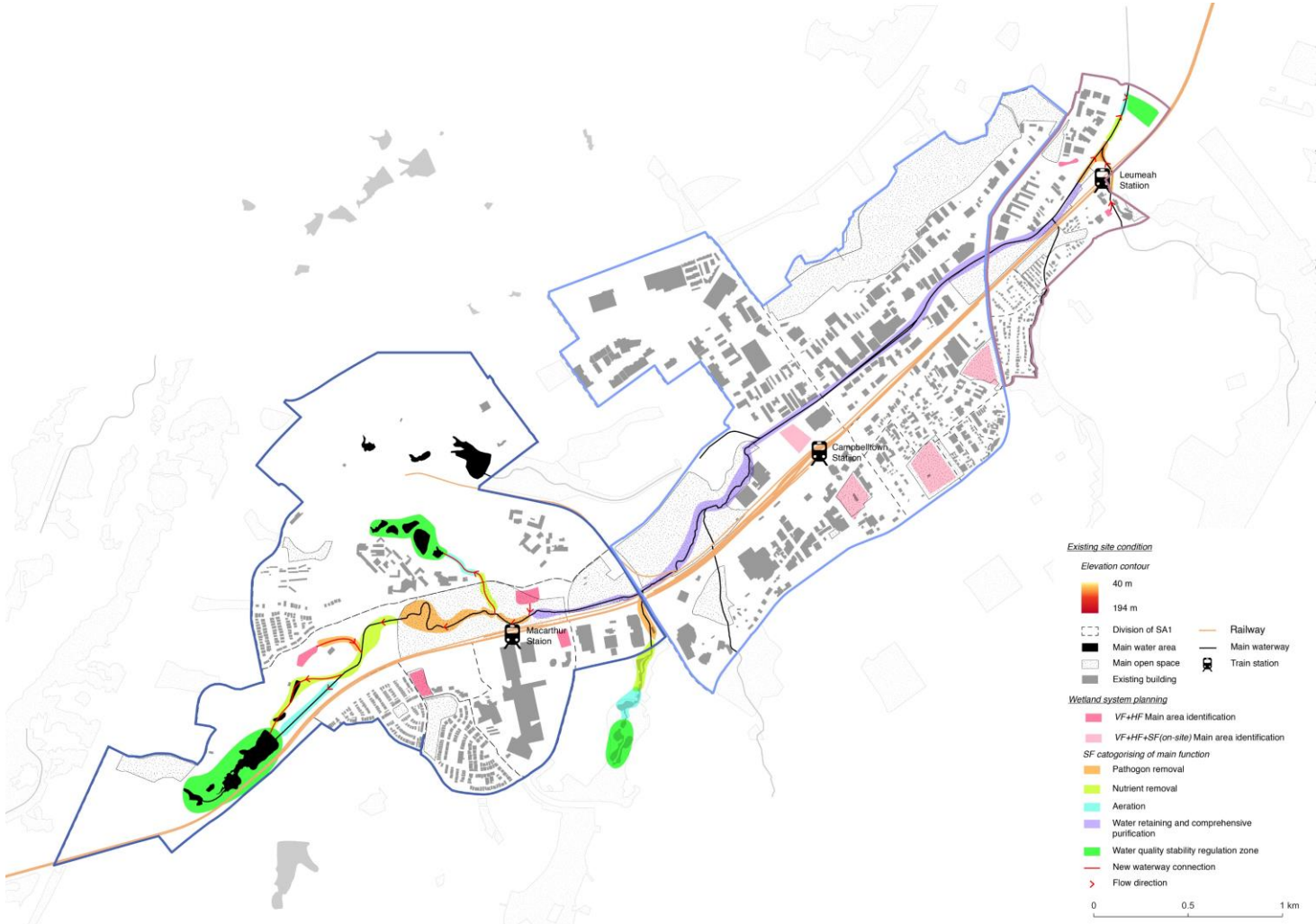
Highest spatial impact

Stage 1: Primary + Secondary + Tertiary treatment

- Septic tank (underground) + ABR (underground)
- Pipeline or direct outlet
- Potential pipeline or direct outlet (more research required)
- Vertical flow wetlands + Horizontal flow wetlands with different levels of centralisation

Stage 2: Post treatment

1. Joints / Key points of the existing surface water network
2. Adding value to the existing ponds
3. New constructed surface flow wetland on-site
4. Revival and redesign of the surface water stream



Main direction of SF development for each target site and for the overall area

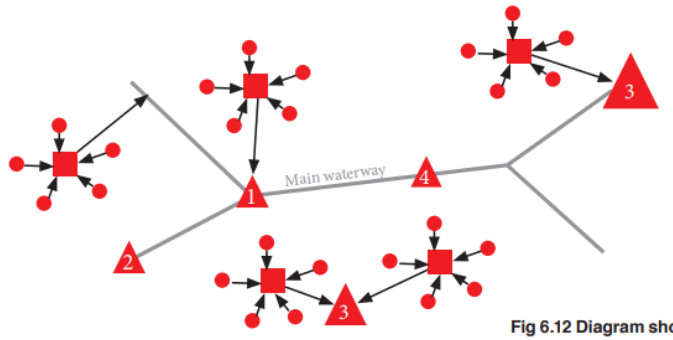


Fig 6.12 Diagram showing the basic design logic of the three sites as a whole

1 Joints / Key points of the existing surface water network

2 Adding value to the existing ponds

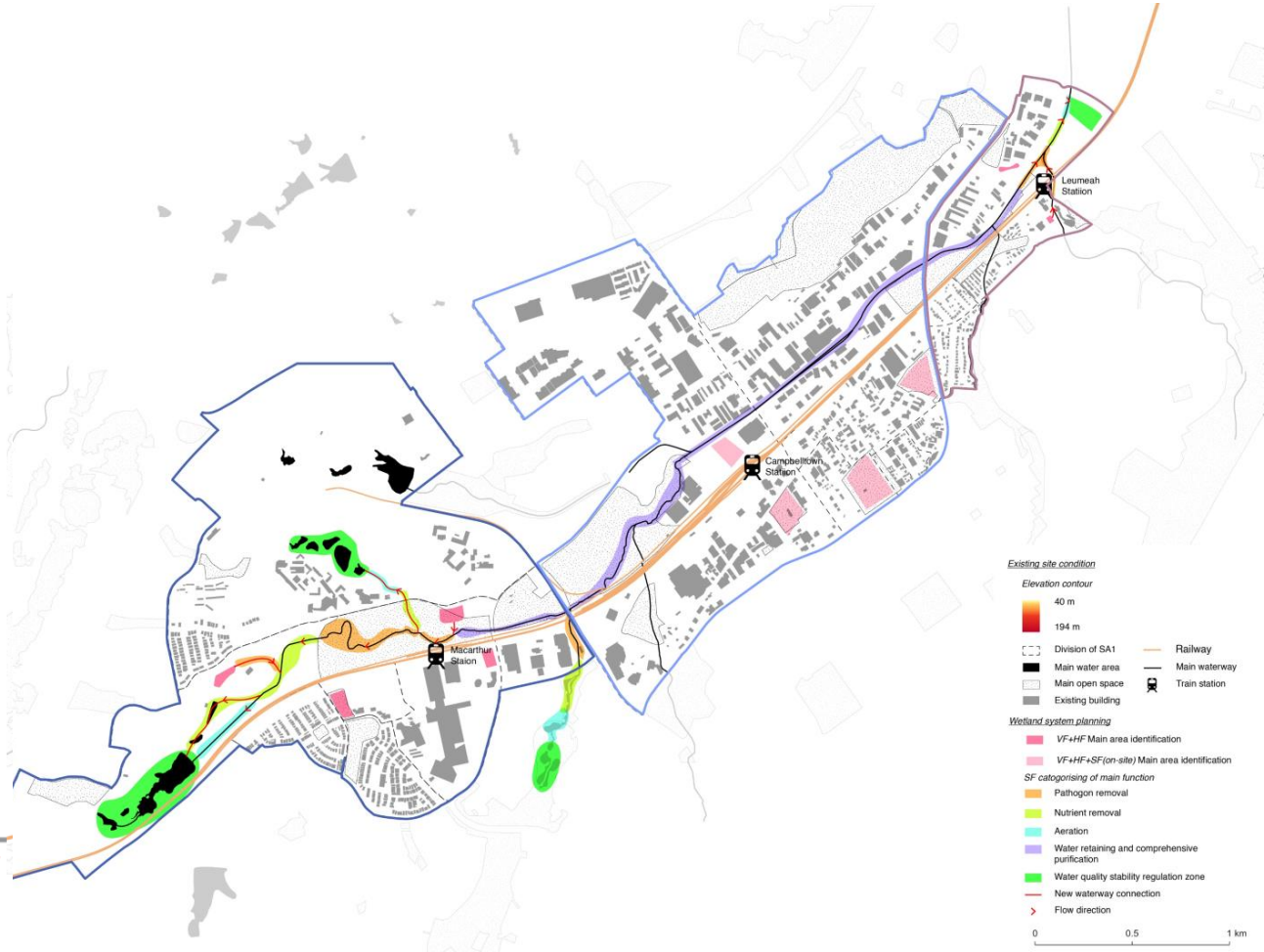
3 New constructed surface flow wetlands on-site

4 Revival and redesign of the surface water stream

Macarthur: 1 + 2 + 4

Campbelltown: 3 + 4

Leumeah: 1 + 3 + 4



Scenarios for Leumeah centre

Low densification: additional 1,171 population

Low centralisation | Moderate centralisation | High centralisation

High densification: additional 5,142 population

Low centralisation | Moderate centralisation | High centralisation

Scenarios for Campbelltown centre

Low densification: additional 6,322 population

Low centralisation | Moderate centralisation | High centralisation

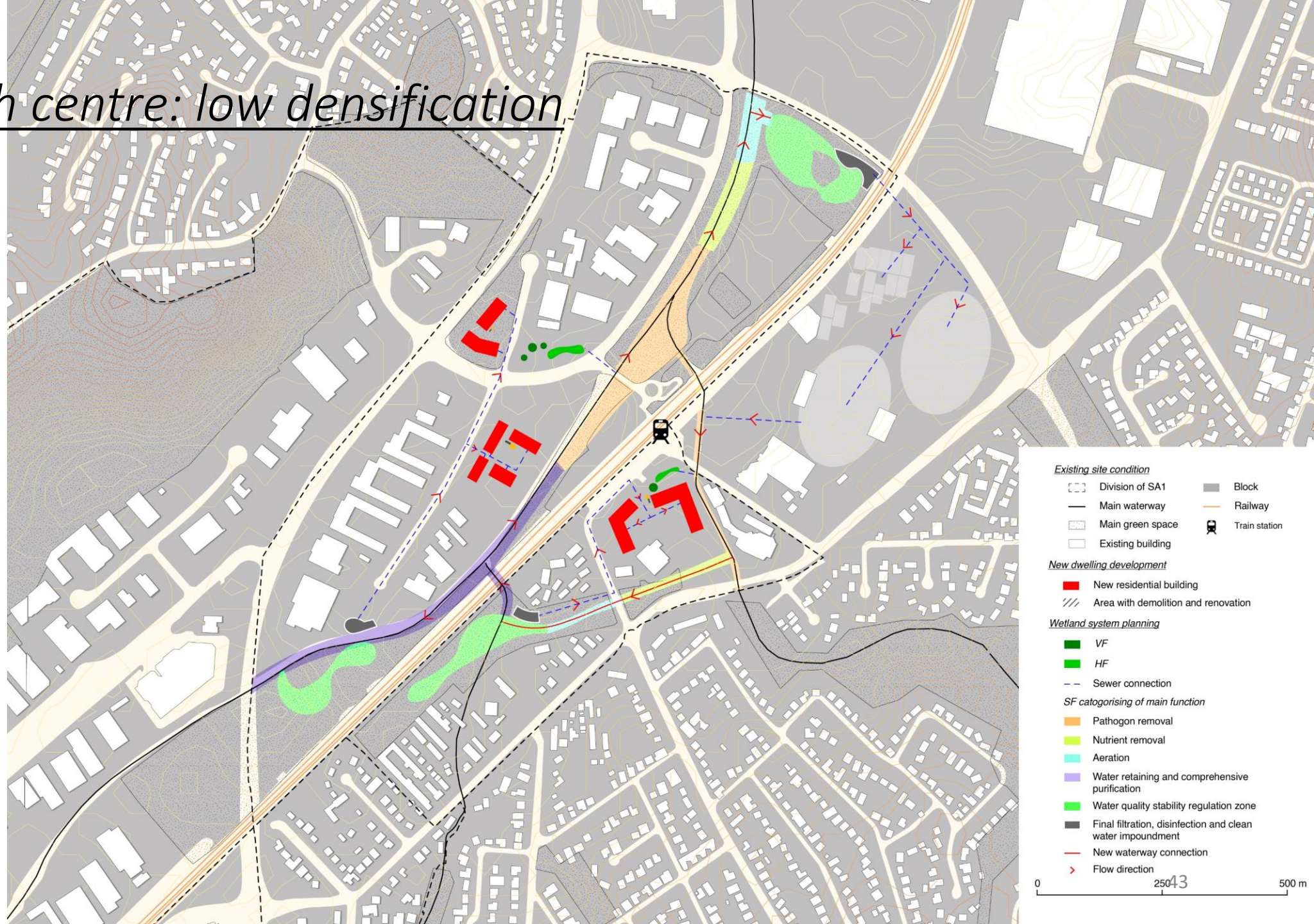
High densification: additional 11,429 population

Low centralisation | Moderate centralisation | High centralisation

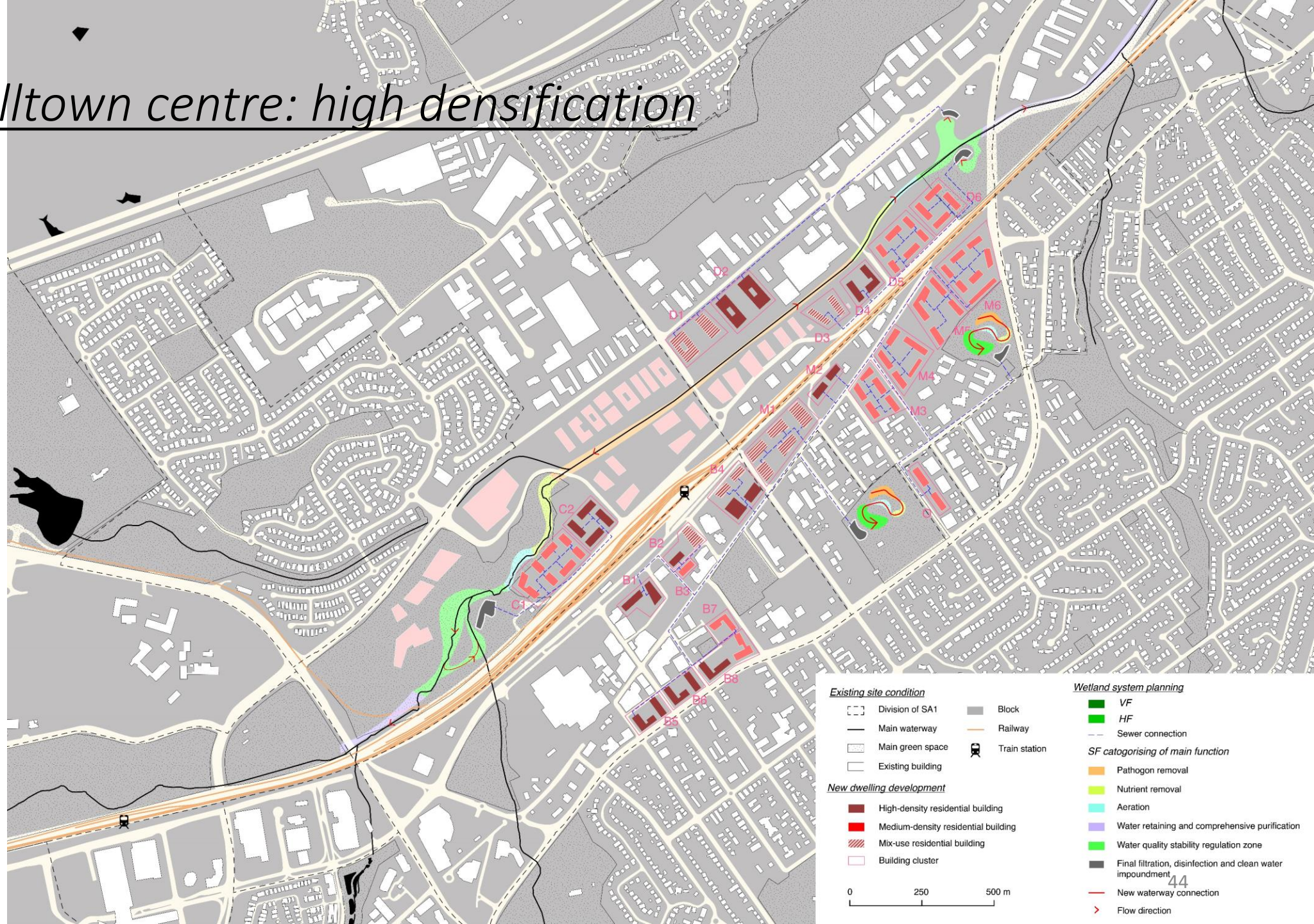
Connection for treated water re-use

- Leumeah centre: low densification
- Leumeah centre: high densification
- Campbelltown centre: high densification

Leumeah centre: low densification



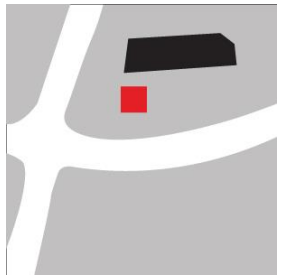
Campbelltown centre: high densification



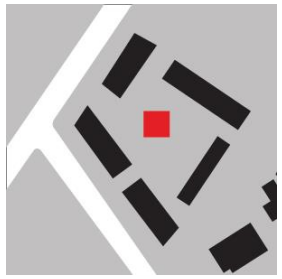
Spatial design

- Categorisation of the wetlands
- Leumeah Centre
- Campbelltown Centre

Categorisation of the wetlands

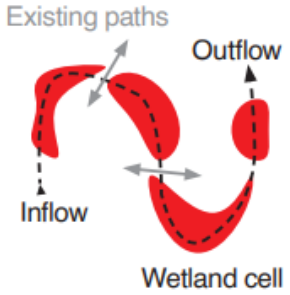


Street-side garden



On-site community garden

Functional pond and water routes



Cells in the park

Living machine showroom

Integrating the wetlands in public space

Mawson park

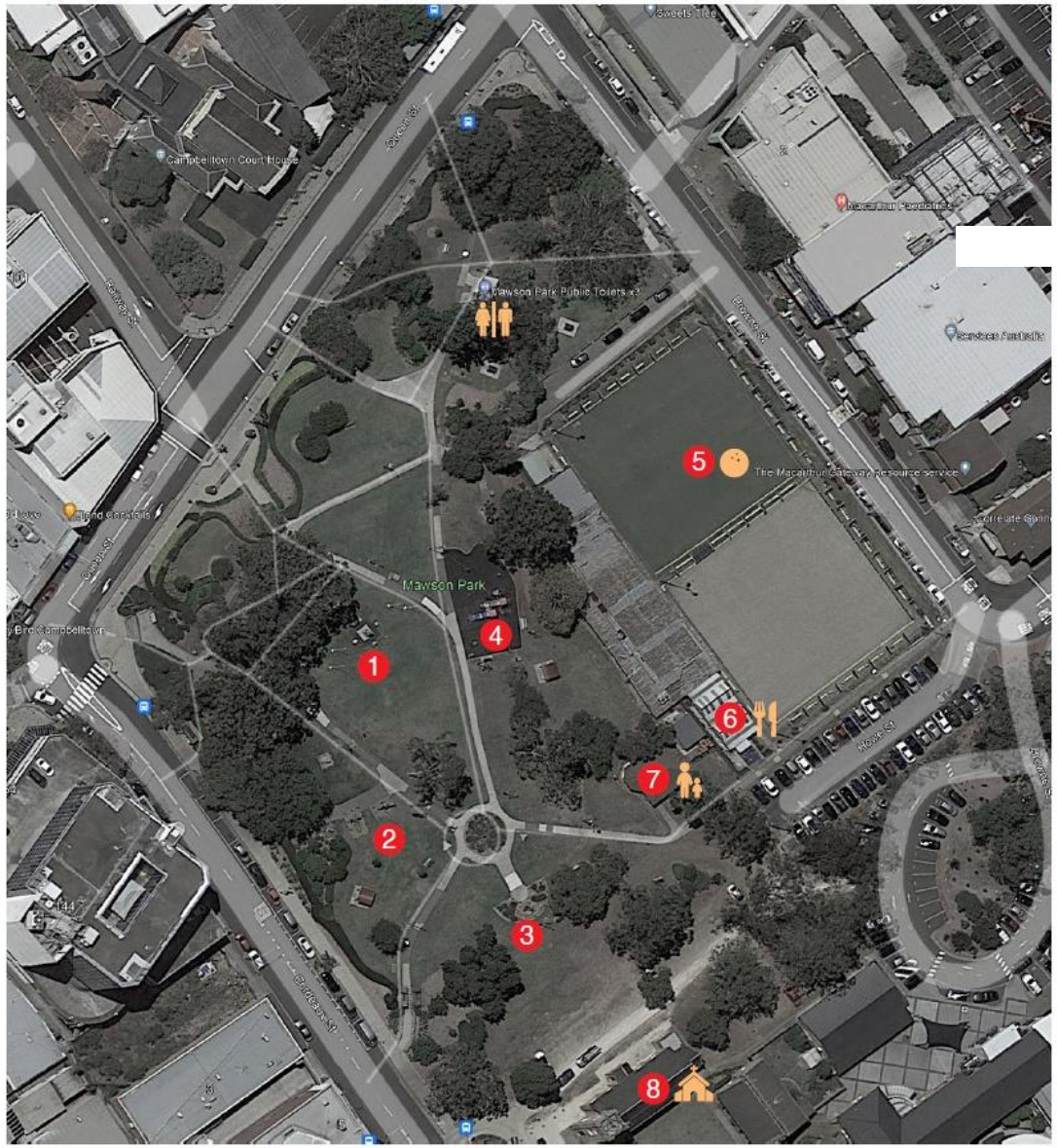
presenting the history of Campbelltown and Anzac (Australian and New Zealand Army Corps) spirits

Fig 10.12 The War Memorial sandstone obelisk (Kontos, 2021)

Fig 10.13 A Naval memorial, Air Force Memorial and Army Memorial (Campbelltown City Council, n.d.-b)

Fig 10.14 A sculpture / fountain that commemorates Mrs Elizabeth Macquarie, whose maiden name was Campbell (Campbelltown City Council, n.d.-b)

Fig 10.15 A small children's playground (Campbelltown City Council, n.d.-b)



City Bowling Club

Fig 10.17 Chilli Joe Thai Cuisine Restaurant (Google, 2023)

Fig 10.18 Mawson Park Early Childhood Health Service (Monument Australia, 2019)

Fig 10.19 Campbelltown Anglican Church (Design, 2021)

Integrating the wetlands in public space

Mawson park

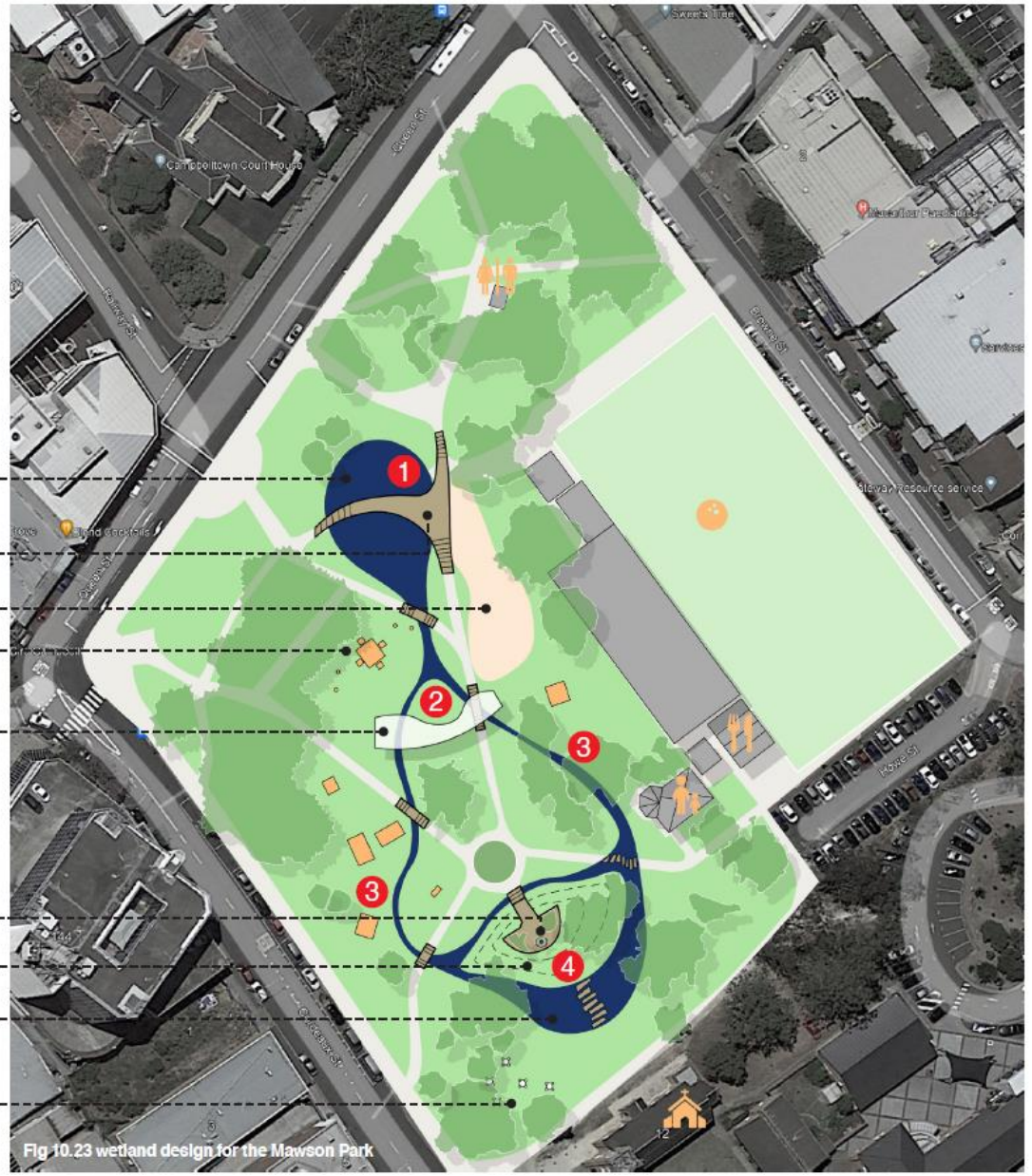


Fig 10.23 wetland design for the Mawson Park

Fig 10.21 Example of the observation deck (The Wild Deck Company, 2018)

Fig 10.22 Example of the pavilion (Landscape China, 2018)

Integrating the wetlands in public space

Campbelltown Showground

Fig 10.26 Campbelltown's Bicycle Education Centre
(Campbelltown City Council, n.d.-b)

Fig 10.30 Satellite map of the Campbelltown showground (Google map, 2021)

Fig 10.27 Campbelltown Community Preschool
(Campbelltown Community Preschool, n.d.)

Fig 10.28 Campbelltown Harlequins Rugby Club
(Campbelltown Harlequin Rugby Club - Juniors, 2020)

Fig 10.29 New properties in 38/48-52 warby Street
(Totten, 2023)

Integrating the wetlands in public space

Campbelltown Showground

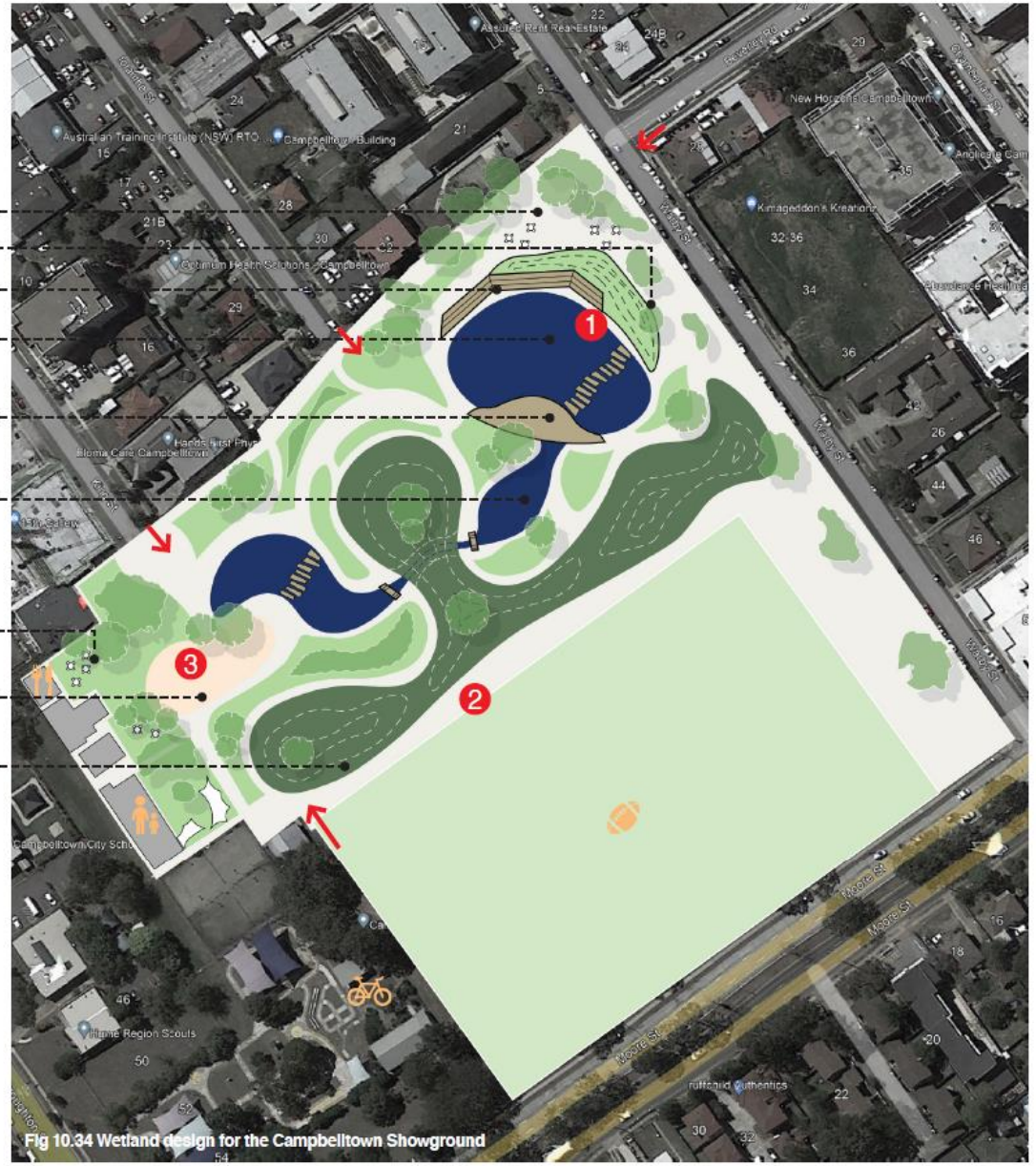


Fig 10.34 Wetland design for the Campbelltown Showground

Fig 10.31 Example of the theatre (WWT, 2023)

Fig 10.32 Example of the bike park (BERN, n.d.)

Fig 10.33 Example of the playground (Arcady, 2011)

Integrating the wetlands in public space

Community garden

Fig 10.37 Location of the site for community garden design

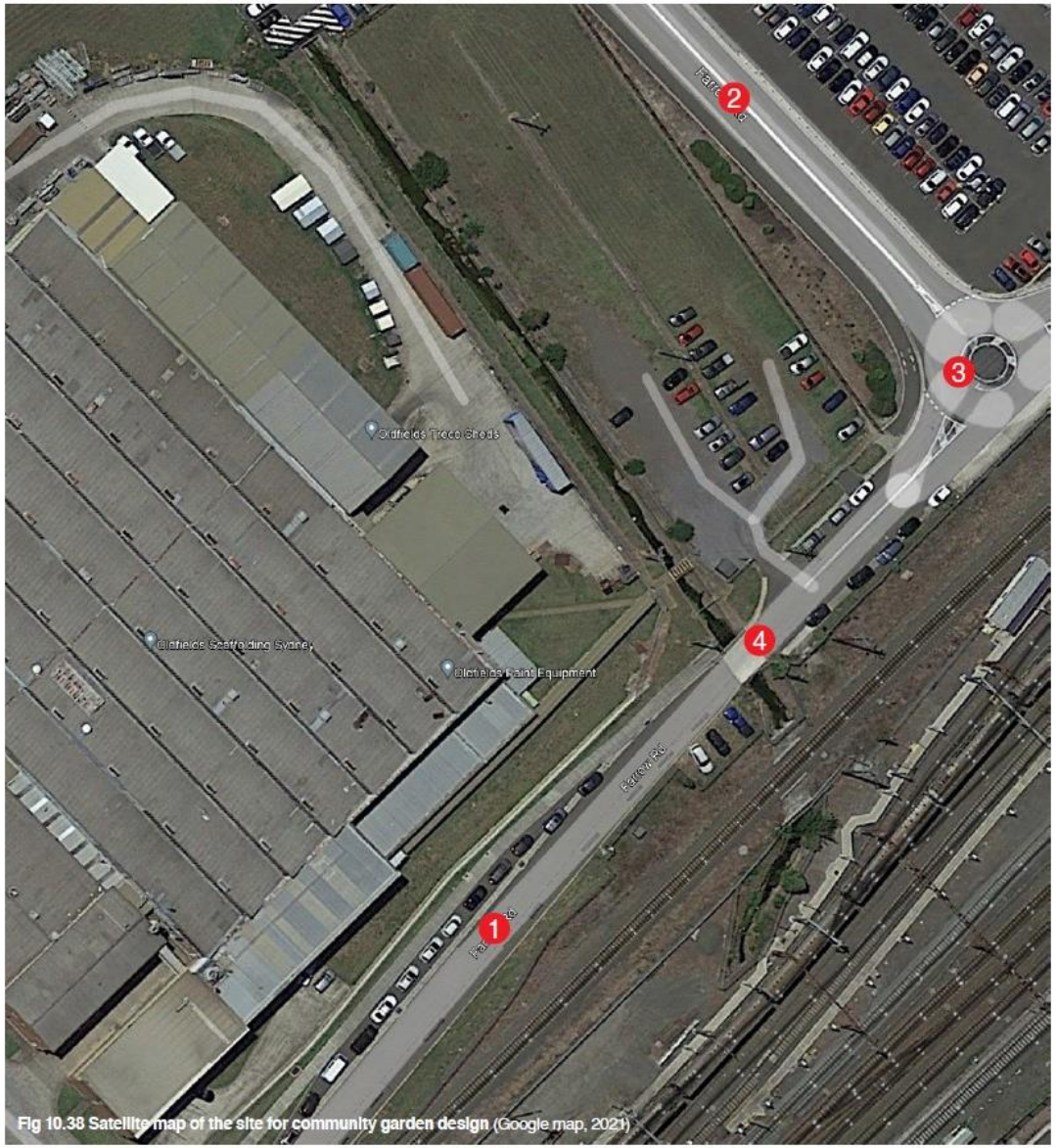


Fig 10.38 Satellite map of the site for community garden design (Google map, 2021)

Fig 10.40 View on Farrow Rd (Google streetview, 2021)

Fig 10.41 View on Farrow Rd (Google streetview, 2021)

Fig 10.39 View on Farrow Rd (Google streetview, 2021)

Fig 10.42 View on Farrow Rd (Google streetview, 2021)

Integrating the wetlands in public space

Community garden

Fig 10.43 Example of the community garden (Waterscapes Australia, n.d.)

Evaluation

- Parameters
- Evaluation for Leumeah Centre
- Evaluation for Campbelltown Centre
- Contribution to spatial use
- Impact on the other area in Greater Sydney

Parameters

- Cost
- Treatment quality
- Public accessibility and visibility of the wetlands
- Adaptation to population increase
- Performance for water reuse

Cost

planning and site supervision cost				investment cost						total annual cost			
salaries for planning and supervision	transport and allowance for visiting or staying at site	cost for waste-water analysis	total planning cost incl. overheads and acquisition	cost of plot incl. site preparation	main structures of 50 years' durability (sewer)	main structures of 20 years' durability	secondary structures of 10 years' durability	equipment and parts of 6 years' durability	total investment cost (incl. land and planning)	total an-nual cost (including land)	total annual cost (excluding land)		
l.c.	l.c.	l.c.	l.c.	l.c.	l.c.	l.c.	l.c.	l.c.	l.c.	l.c.	l.c.		
1,200	650	500	2,350	150,000	133,602 222,670	300,514 453,293			586,466 828,313	61,875 97,195	56,100 91,420		
wastewater data				annual capital costs									
daily waste-water flow	strength of waste-water inflow	COD/BOD ratio of inflow	strength of waste-water outflow	rate of interest in % p.a. (bank rate minus inflation)	interest factor q=1+i	on investment for land	on main structures of 50 years' durability	on main structures of 20 years' lifetime (incl. plan-ning fees)	on secondary structures of 10 years' lifetime	on equipment of 6 years' lifetime	total capital costs		
m³/d	mg/l COD	mg/l	mg/l COD	%		l.c./year	l.c. /year	l.c./year	l.c./year	l.c./year	l.c./year		
94	534	1.6	3	3.85%	1.04	5,775	9,871 16,338	21,990 33,083	0	0	30,938	48,597	
operational cost						income from biogas and other sources					explanation		
cost of personal for operation, maintenance and repair	cost of material for operation, maintenance and repair	cost of power (e.g. cost for pumping)	cost of treatment additives (e.g. chlorine)	total operational cost		daily biogas production (70% CH 4 , 50% dissolved)	price 1 litre of kerosene (1m³ CH 4 =0.85 l kerosene)	annual income from biogas per annum	other annual income or savings (e.g. fertili-ser, fees))	total income per annum	l.c. = local currency; mg/l = g/m³		
l.c./year	l.c./year	l.c./year	l.c./year	l.c./year			l.c./litre	l.c./year	l.c./year	l.c./year			
155 210	260 305	50	0	465 565		12	2.69	7,164	0	7,164			

Treatment quality

Table 3: Typical raw greywater composition

Parameter	Greywater range from greywater fixtures	Greywater typical	Blackwater typical
BOD_5 (g/m^3)	250 to 550	360	267
COD (g/m^3)	400 to 700	535	533
TSS (g/m^3)	30 to 180	40	200
TN (g/m^3)	10 to 17	13	67
TP (g/m^3)	3 to 8	5.4	15
Total coliform (CFU/100 mL)	10^2 to 10^6	10^5	10^4 to 10^7
E.coli (CFU/100 mL)	10^2 to 10^6	10^4	10^4 to 10^7

Treatment quality

Parameter	After primary treat-ment (septic tank)	After secondary treatment (ABR)	After tertiary treatment (subsurface wetlands)
BOD_5 (g/m^3)	168-253	25-51	1-15
COD (g/m^3)	267-401	53-187	3-56
TSS (g/m^3)	36-40	23-30	19-27
TN (g/m^3)	19-24	6-15	2-9
TP (g/m^3)	3-7	2-7	1-4
Total coliform (CFU/100 mL)	32,500-195,000	6,500-117,000	65-23,400
E.coli (CFU/100 mL)	25,750-128,750	2,575-64,375	26-12,875

Fig 11.2 General treatment results of the project

Treatment	BOD mg/l	Total Suspended Solids mg/l	Total Nitrogen mg/l	Total Phosphorus mg/l	*E coli* org/100 ml	Anionic Surfactants mg/l	Oil and Grease mg/l
Raw Wastewater	150-500	150-450	35-60	6-16	10^7-10^8	5-10	50-100
A	140-350	140-350					
B	120-250	80-200	30-55	6-14	10^6-10^7		30-70
C	20-30	25-40	20-50	6-12	10^5-10^6	< 5	< 10
D	5-20	5-20	10-20	< 2			< 5
E					< 10^3		
F	2-5	2-5	< 10	< 1	< 10^2		< 5

Table 7: Typical effluent quality for various levels of treatment

NOTES: PLANT TYPE - TYPICAL TREATMENT PROCESSES

	Treatment Process Category	Parameters to be removed	Examples of Treatment Processes
A	Pre Treatment	Gross solids, some of the readily settleable solids	Screening
B	Primary Treatment	Gross solids plus readily settleable solids	Primary sedimentation
C	Secondary Treatment	Most solids and BOD	Biological treatment, chemically assisted treatment, lagoons
D	Nutrient removal	Nutrients after removal of solids	Biological, chemical precipitation.
E	Disinfection	Bacteria and viruses	Lagooning, ultraviolet, chlorination.
F	Advanced wastewater treatment	Treatment to further reduce selected parameters	Sand filtration, microfiltration.

ABBREVIATIONS BOD = Biochemical Oxygen Demand

Fig 11.3 Typical effluent quality after each treatment stage (Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand, 1997)

Public accessibility and visibility of the wetlands

1	2	3	4	5
Most (more than half of) wetlands are accessible and visible only within the building cluster (all sides occupied).	Most wetlands are accessible and visible to one minor street surrounding.	Most wetlands are accessible and visible at least to one minor street surrounding, some of which are faced to a main street or junction.	Most wetlands are accessible and visible to main streets or junction surrounding.	Most wetlands are accessible and visible to junctions and is located in a public open area.

Fig 10.4 Evaluation scale of public accessibility and visibility

Adaptation to population increase

1	2	3	4	5
All the wetlands have to be re-located to a large degree (to a different block etc.) in order to fit a higher densification level.	Most wetlands have to be re-located to a large degree (to a different block etc.) in order to fit a higher densification level.	Most wetlands are adaptable to a higher densification level by adjustments of position within the block.	Most wetlands are highly adaptable by simply changing the area, while small proportion of the remaining wetlands require adjustments of position within the block.	All wetlands are highly adaptable by simply enlarging the area.

Fig 10.5 Evaluation scale of adaptation to population increase

Performance for water reuse

INPUT (+)

- Wastewater production
- Stormwater harvesting

OUTPUT (-)

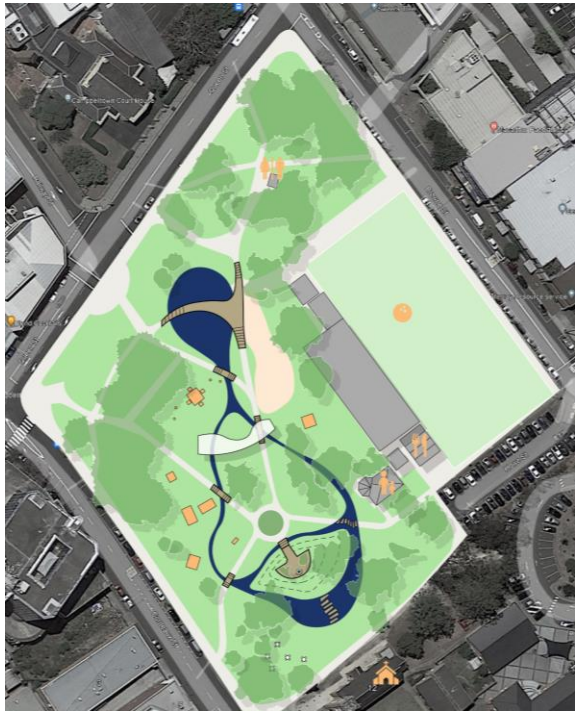
- Evaporation
- Irrigation for open sports field
- Consumption in household

Re-used water

Contribution to spatial use

Community garden –
Low centralization

Mawson park –
Moderate centralization



Campbelltown Showground–
High centralization

Leumeah Centre

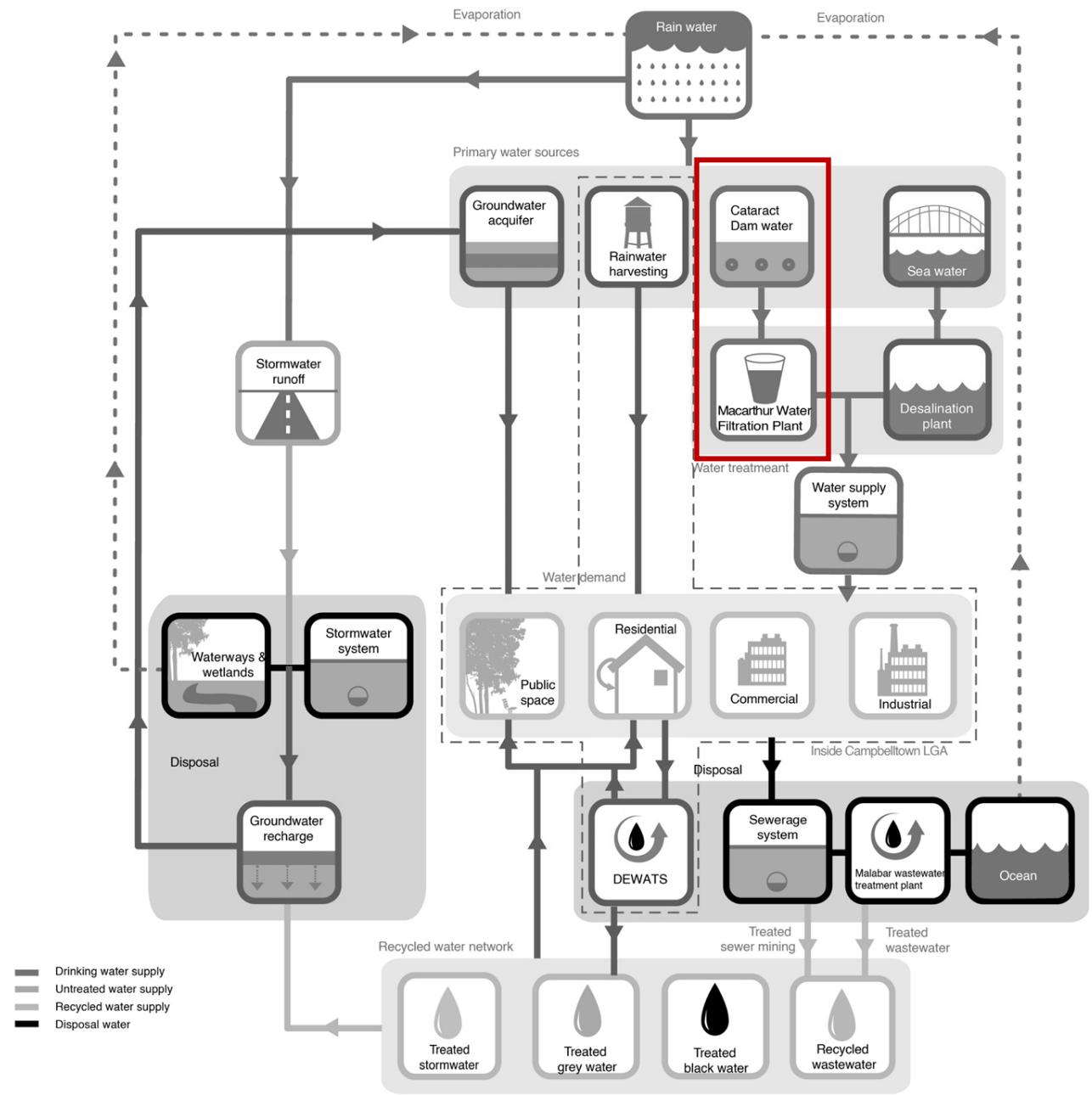
Level of densification		Low densification: additional 1,171 population			High densification: additional 5,142 population			
Level of treatment centralisation		 Low centralisation	 Moderate centralisation	 High centralisation	 Low centralisation	 Moderate centralisation	 High centralisation	
Annual cost (A$)		133,602 - 222,670	133,146 - 221,910	157,794 - 262,990	180,416 - 305,439	173,243 - 295,082	171,872 - 293,404	
Treatment quality		Capable to meet the standard of tertiary treatment and hopefully post treatment as well.			Capable to meet the standard of tertiary treatment and hopefully post treatment as well.			
Public accessibility and visibility of the wetlands		3	4	4	1	3	4	
Adaptation to population increase		2	1	1	4	1	5	
Performance for water reuse	Wastewater generation (m^3/year)	34,185			150,138			
	Stormwater harvesting by wetlands (m^3/year)	756	760	758	3,575	3,383	3,311	
	Stormwater harvesting by sportsfields (m^3/year)	5,591			5,591			
	Evaporation (m^3/year)	1,449	1,455	1,453	6,848	6,481	6,342	
	Irrigation for sports field (m^3/year)	2,400			2,400			
	Household consumption (m^3/year)	11,520			50,594			
	Reuse efficiency (input / treated water that is re-used)	96.3%	96.5%	96.4%	95.7%	95.9%	96.0%	

Campbelltown Centre

Level of densification	Low densification: additional 6,322 population			High densification: additional 11,429 population		
Level of treatment centralisation	 Low centralisation	 Moderate centralisation	 High centralisation	 Low centralisation	 Moderate centralisation	 High centralisation
Annual cost (A$)	168,327 - 289,955	164,587 - 284,283	164,142 - 283,608	395,961 - 680,624	401,881 - 691,218	421,800 - 724,542
Treatment quality	Capable to meet the standard of tertiary treatment and hopefully post treatment as well.			Capable to meet the standard of tertiary treatment and hopefully post treatment as well.		
Public accessibility and visibility of the wetlands	3	5	5	2	5	5
Adaptation to population increase	5			3	4	4
Performance for water reuse – Wastewater generation (m^3/year)	184,602			333,724		
Performance for water reuse – Stormwater harvesting (m^3/year)	4,144	4,077	4,069	7,459	7,371	7,356
Performance for water reuse – Evaporation (m^3/year)	7,938	7,809	7,794	14,287	14,120	14,091
Performance for water reuse – Household consumption (m^3/year)	62,209			112,460		
Performance for water reuse – Reuse efficiency (input / treated water that is re-used)	95.8%	95.9%	95.9%	95.8%	95.9%	95.9 %

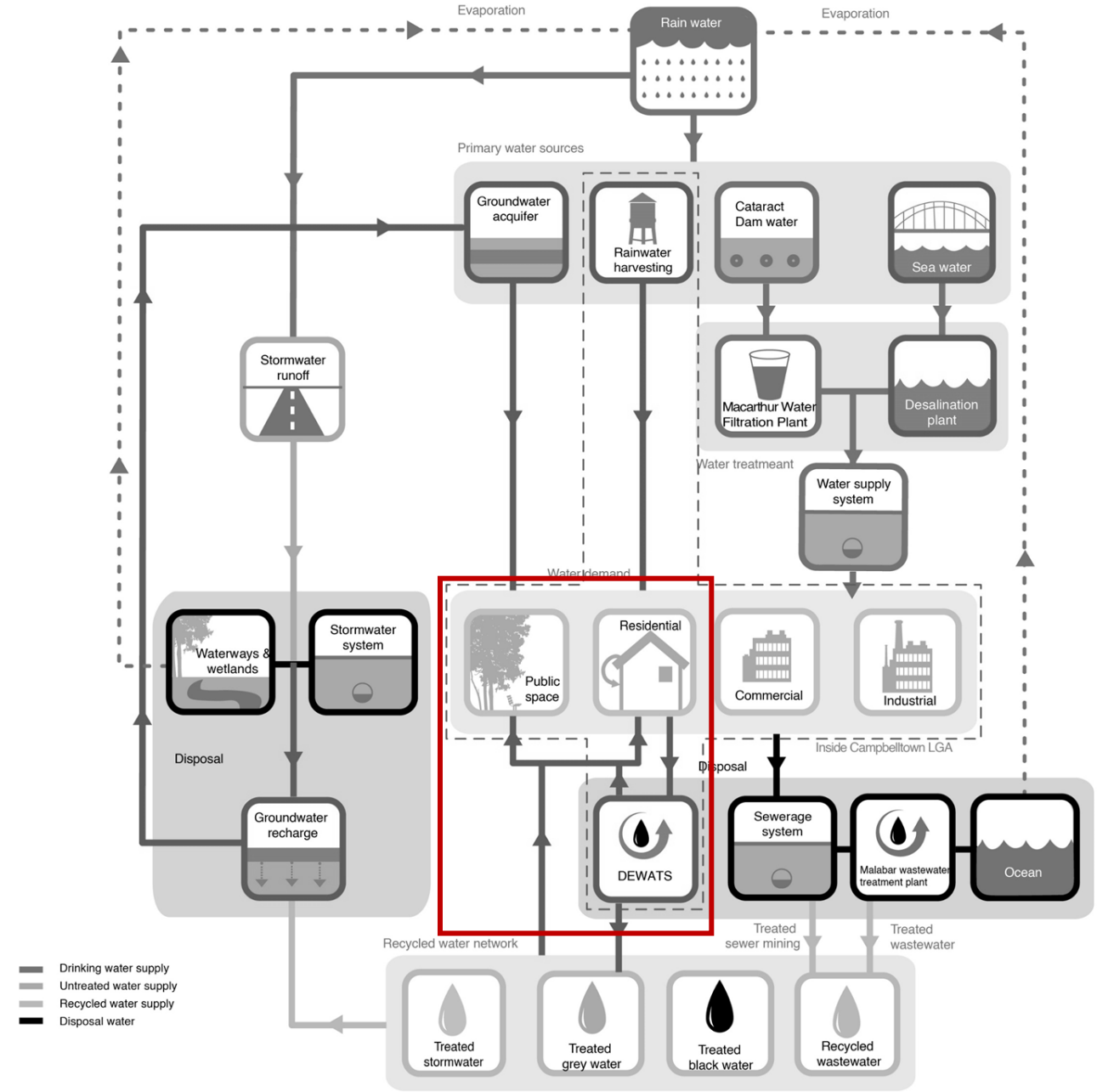
Impact on the other area in Greater Sydney

Reducing the pressure of Macarthur Filtration Plant and Cataract Dam by 42%.



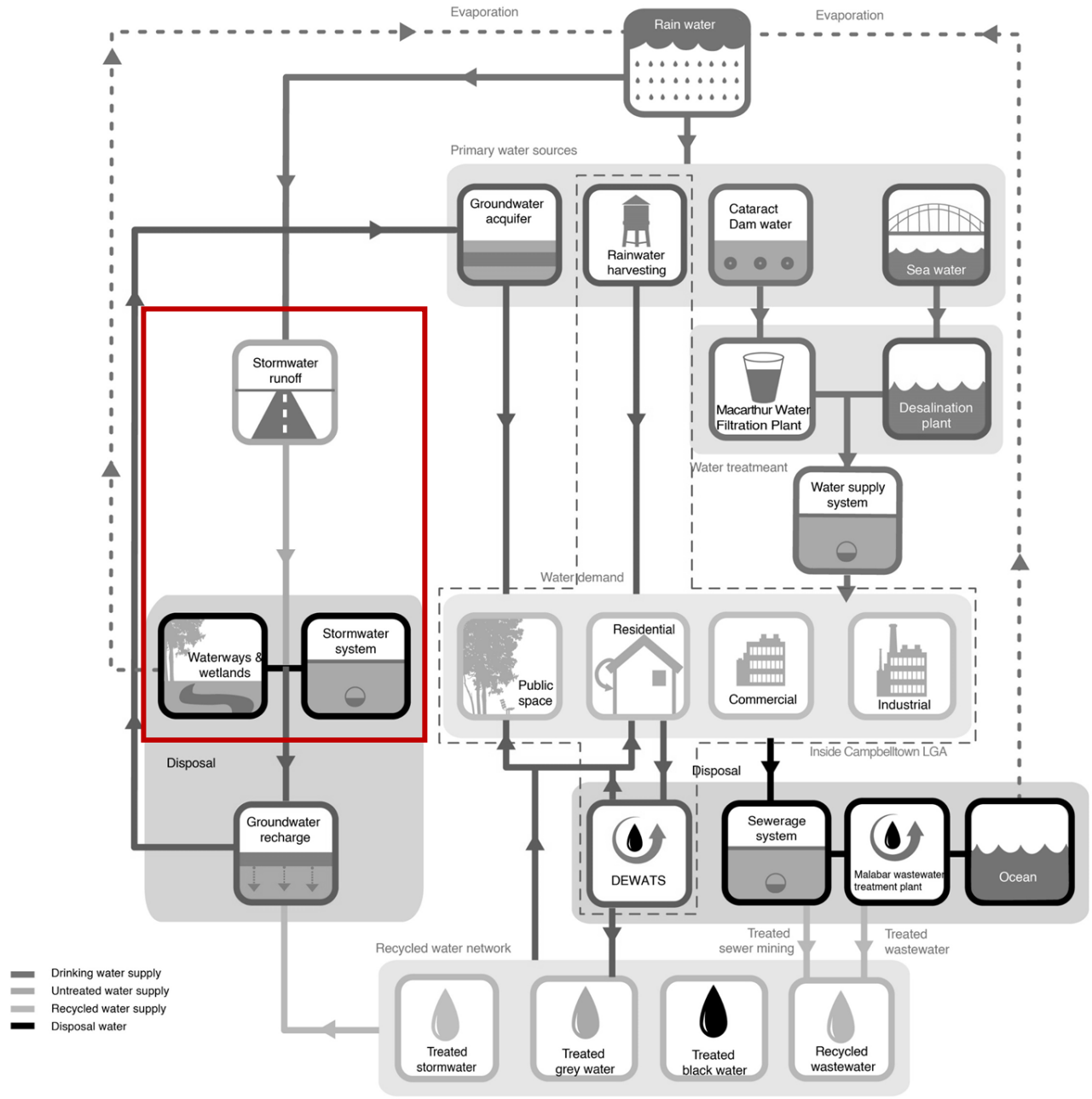
Impact on the other area in Greater Sydney

Rewriting the traditional pattern of consumption-treatment-discharge



Impact on the other area in Greater Sydney

Contributing to a better surface water quality overall.



For further development of the project…… 

♥ Thank you ♥

And acknowledgement to aboriginal and torres strait islanders as Australia’s first people, the Traditional Owners and Custodians of the lands and waters.