WESTERN PORT
SEAGRASS PARTNERSHIP

BACKGROUND PAPER

The significant loss of seagrass in Western Port and the subsequent impact on the environmental values of the area have long been a concern of the Western Port community. The community's desire to restore the environmental values of the Western Port environment, in particular seagrasses has lead to the establishment of the Western Port Seagrass Partnership. Chaired by Professor John Swan, the Western Port Seagrass Partnership, has the key role of developing research, educational and on-ground restoration programs and projects that add value and integrate with other ongoing activities in Western Port.

The report Western Port Seagrass Restoration (Seddon and Cheshire 1999) synthesised current understanding of seagrass restoration programs and proposed a 4-phase framework for seagrass restoration in Western Port (Appendix 1).

The Western Port Seagrass Workshop and Seminar to be held 8–9 March 2001 aims to build upon the Seddon and Cheshire (1999) report by seeking further advice on seagrass restoration and factors affecting the ecological integrity of Western Port. The workshop (8th March 2001) convenes expert knowledge on seagrass and the Western Port environment. The seminar (9th March 2001) is a public forum with key presentations on Western Port, other seagrass revegetation efforts from around Australia, and the key findings from the Workshop.

The aim of the workshop is to develop a conceptual framework (model) for successful seagrass revegetation in Western Port. In doing so, we also wish to consider the following 4 questions:

- Is the revegetation strategy outlined in Seddon and Cheshire supported? What other information do we know of the state of restoration ecology that is applicable?
- What are the minimum habitat requirements for Heterozostera tasmanica and Zostera muelleri in Western Port? What further information do we need to collect to characterise habitat requirements? What information do we know already, or need to know about the physiology of these seagrass species and their response to propagation and transplantation?
- Is the current 'condition' of the Western Port marine environment sufficient to attempt revegetation? What areas would be most suitable for revegetation and are there other areas where revegetation should not be attempted?
- What information do we need to collect whilst progressing with other stages of the project? What areas of Research are recommended?

As background to this workshop, this document summarises current understanding of:

1. Western Port Catchment and its influence on Western Port;
2. Current condition of the Western Port marine environment;
3. Seagrass distribution, condition and relationship with environmental factors in Western Port, and
4. Past and current research on seagrass in Western Port.

1.0 The Western Port Evironment

1.1 The Western Port Catchment

The Western Port catchment area is defined by the watersheds of the Mornington Peninsula to the west, the Strezleki Ranges to the east and the southern fringes of the Yarra ranges to the north and covers an area of 3000 km^2 (Figure 1).

The catchment of Western Port has over the past 100 years been subject to enormous changes to its hydrology. The draining of the Koo-wee-rup swamp and its subsequent reclamation fro agricultural use have significantly altered the catchment hydrology and quality of water that flows into the upper north arm of the bay.

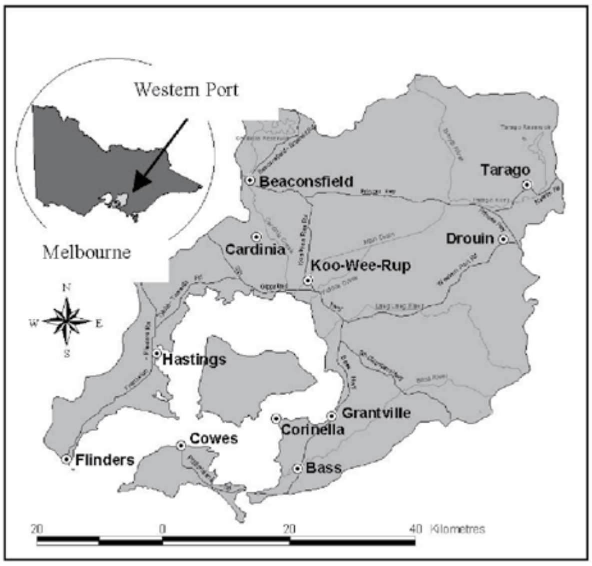

Figure 1. Western Port and Catchment

Today, the Western Port catchment is one of the most important and productive agricultural areas in the State ($430 M in 1994). There are an estimated 1840 farming enterprises, primarily devoted to dairy, cattle and sheep grazing, and smaller areas utilised for orchards, market gardens, viticulture, poultry and nurseries.

The proximity of Western Port to Melbourne attracts many people to the region. Since the early 1970s, the population of the Western Port catchment has grown from 45 000 to 150 000 people in 1999, living primarily in some 25 towns and villages located around the coast. Residents, tourists, farmers, fishermen and commercial and industry workers all share the Western Port region and rely upon its resources for their livelihood.

Urban development in the Western Port catchment is expected to further increase the region's population, particularly in the 'south east growth corridor' from Cranbourne through to Pakenham. Although the majority of this growth corridor falls outside the Western Port catchment, indirect impacts of population growth, such as increased industrial, commercial and domestic activity may influence Western Port and its catchment.

1.2 Western Port Marine Environment

Western Port, a 680 km2 deepwater inlet is classified as a neutral oceanic embayment with tide-dominated circulation. French Island lies in the centre of Western Port and Phillip Island lies at its entrance. Western Port's coastline, including the islands, is approximately 263 km in length (Figure 2).

The total volume of water in Western Port at high tide is 2 900 000 ML. Under tidal influence circulation is clockwise around Phillip and French Island. (Figure 2, Shapiro 1975).

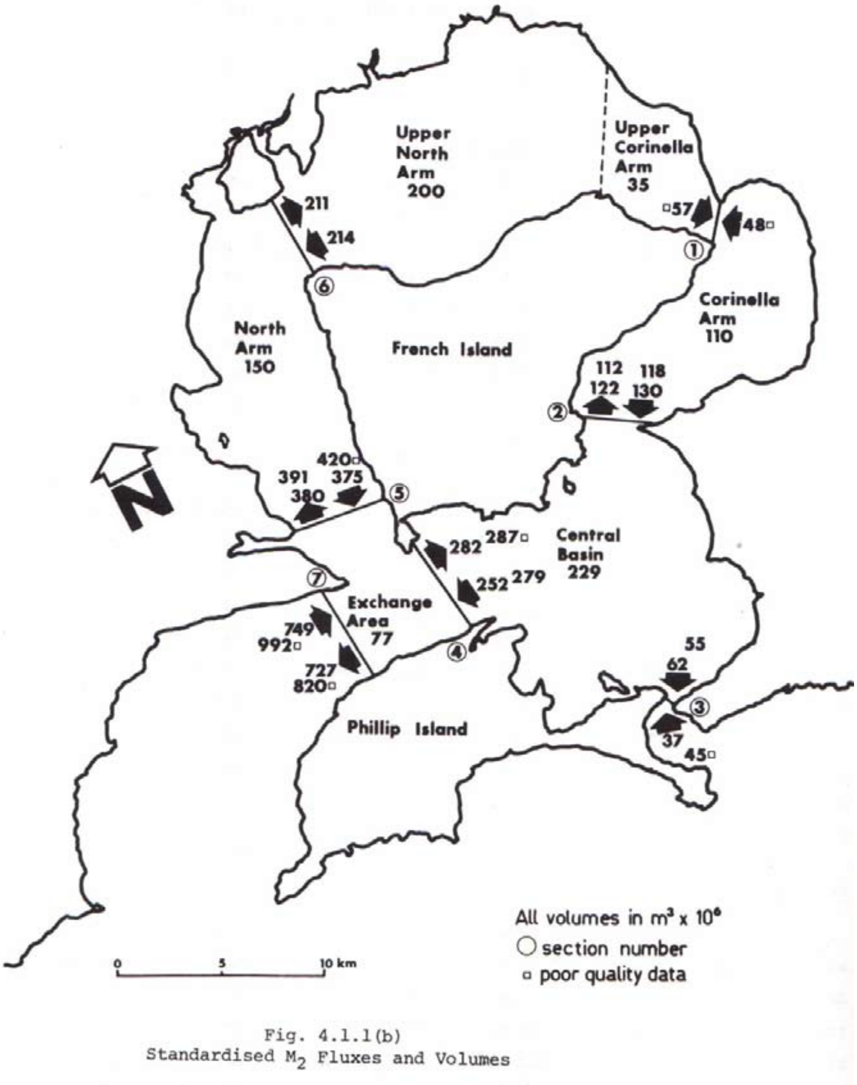

Figure 2. Pattern of ebb and flood volume fluxes across each section of Western Port (from Shapiro 1975).

The volume of water entering the Bay from Bass Strait is equivalent to the volume of the Bay An average of 1 100 ML flows into Western Port per day via 17 waterways, representing less then 1% of the total volume of water in Western Port. Water residence times range from about 3 months in the north and east to days in the south-west. Sea surface temperatures range from ~10-22oC and salinity's range annually from 22–38 (EPA 1996).

Contemporary surface sediment deposits in Western Port reflect both the hydrodynamics and terrigenous inputs of sediment. To the west and north of French Island (the Lower Northern Arm) there are significant deposits of sand consistent with marine deposition. In the Upper Northern Arm there is a large component of > 250 m material of terrestrial origin, while the Corinella segment is dominated by fine muds (< 63 m). The accumulation of clay rich sediments in southern areas result from a winnowing of coarser grain sediments deposited in the northern areas under energetic conditions (Wallbrink pers. comm.).

Western Port supports a unique seagrass-mangrove-saltmarsh habitat. Approximately 130 km^2 (2000 estimate) of seagrass, 37 km^2 of mangrove and 310 km^2 of saltmarsh exist in and around Western Port. Seagrass (Heterozostera tasmanica and Zostera muelleri) meadows occur inter-and sub-tidally providing habitat for a diverse array of invertebrates and is a nursery for a range of commercial and recreational fish species including flathead, whiting and calamari. Large intertidal mudflats, common on the northern end of the Bay occupy over 40% of the area of Western Port. These intertidal mudflats are covered by seagrass and seasonally dominant macroalgae, and are intersected by a network of channels, some more than 15 m deep.

Activities in Western Port include shipping, boating, fishing and aquaculture, various recreational activities and tourism. Western Port provides recreational amenity for fishing, boating and other activities, supports commercial fisheries ($0.5 M in 19996/97) and aquaculture and is an important port linking industry with Australian and overseas markets.

The viability of recreational and commercial fisheries and nature based tourism activities, and the protection of biodiversity and internationally significant bird habitats are directly dependent on Western Port's highly productive vegetation, particularly seagrass communities. The loss of about 170 km2 of intertidal seagrass during the late 1970s is linked to a subsequent reduction in commercial and recreational fish catches.

2.0 Seagrass distribution and condition in Western Port

This section summarises data on seagrasses in Western Port including current knowledge of seagrass physiology and ecology, current distribution and condition of seagrass in Western Port. Figure 3 displays sampling sites used in seagrass studies undertaken in thew 1970s by Bulthuis and co-workers and seagrass studies undertaken in 1998/99 by EPA and co-studies. Also shown are sites used in EPA marine fixed site monitoring network monitoring program and sites sampled by Longmore et al. (1998) in a pilot benthic flux study.

Seagrass species in Western Port

Heterozostera tasmanica and Zostera muelleri are the dominant seagrass species in Western Port and are the focus for this section. Halophila ovalis occurs sparsely intermingled with subtidal H. tasmanica. Amphibilus antarctica is found in Western Port growing in coarse sediments.

Table 1 summarise known life cycle and growth characteristics of H. tasmanica and Zostera spp. Heterozostera tasmanica is the most abundant species occurring sub-tidally and inter-tidally throughout Western Port. It is a small seagrass with fast growing rhizomes fast rates of short shoot proliferation and rapid turnover (~5.8 y-1) of vertical stems (Marba and Walker 1999). Zostera muelleri is a colonising species and is found to extend to the upper regions of the intertidal and is able to tolerate long periods of exposure.

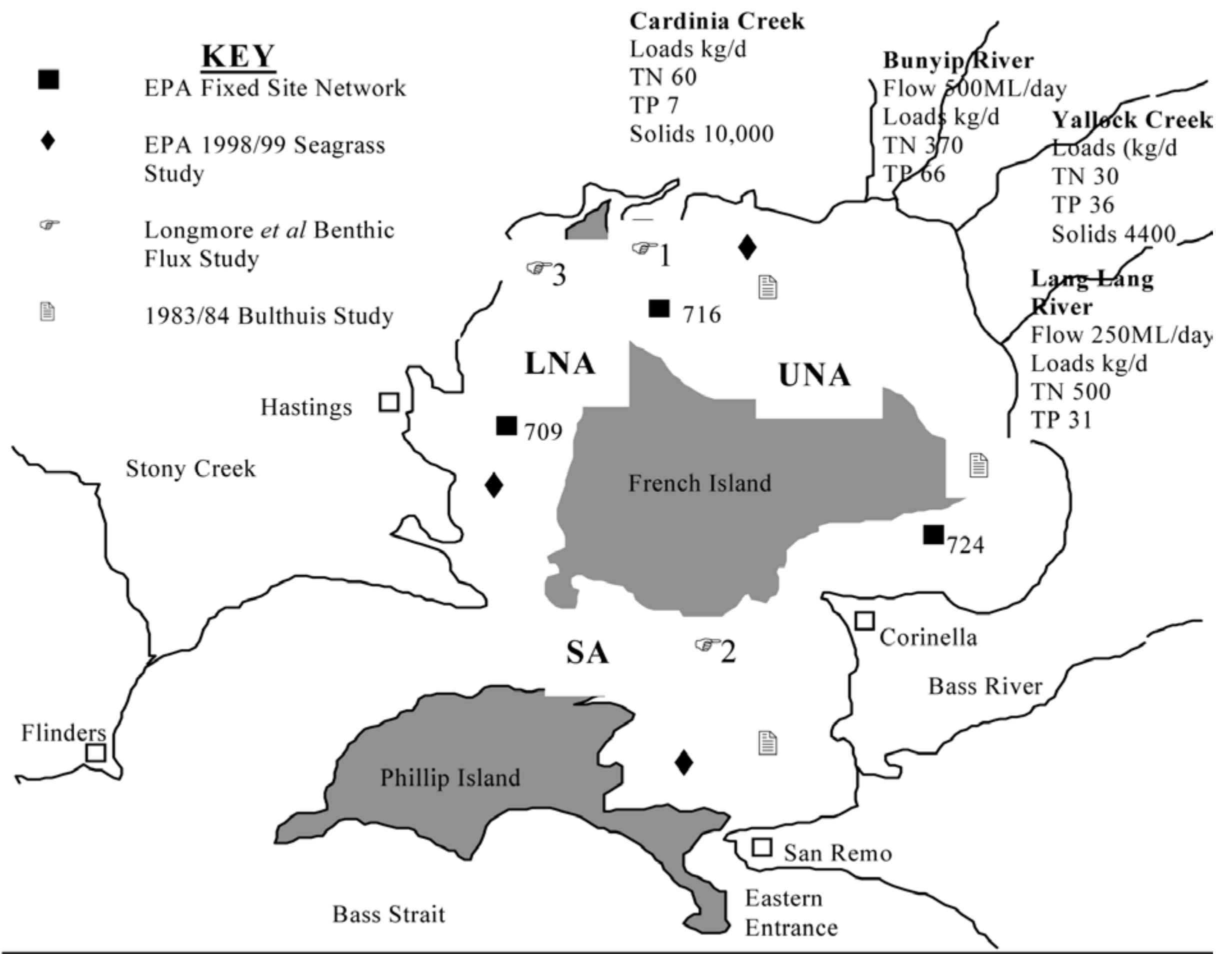

Figure 3. Sampling locations of Western Port research and monitoring studies of water quality and seagrass. The EPA fixed site network has measured water physico-chemical and water quality parameters at 3 sites monthly since 1986. A pilot study of benthic remineralisation near seagrass beds by Longmore et al. (1998) used 4 benthic chambers at 3 sites in March 1998. The seagrass studies of Bulthuis characterised seagrass dynamics, morphology and photo-physiology at 3 sites during 1983-84. The EPA 1998 seagrass study further chraracterised contemporary differences in seagrass dynamics, morphology and photo-sphysiology related to putative differences in water quality at 3 locations during 1998-1999. Four sites were sampled within each of these locations. All sites are defined within three geographic segments: Lower North Arm (NA) Upper North Arm, and Southern Arm (SA).

Table 1. Lifecycle and growth characteristics and habitat requirements of H. tasmanica and Zostera spp.

	H. tasmanica	*Z. muelleri*
Life cycle		
Reproductive mode	Seed, Vegetative Shoots	Seed
[b] Dormancy	Distinct	Distinct
[b] Seed bank	Unknown	Transient
[b] Length of Dormancy	Unknown	Up to 12 months
[b] Fruit/Seed Covering	Hard	Hard
Growth		
[c] Leaf PI (d)	22.6	
[c] Horizontal rhizome PI (d)	12.8	
[c] Vertical rhizome elongation (cm yr^{-1})	8.9	
[c] Horizontal rhizome elongation (cm yr^{-1})	55.7	
[c] Vertical shoot PI (d)	487	
[c] Horizontal shoot PI (d)	17	
Light Requirements		
[a] Max Depth Limit (m)	3.8-9.8	
[a] Min light requirement (%)	5.0 ± 0.6	

[a]Dennison et al (1996)
[b] Kuo and Kirkman (1996)
[c] Marba and Walker (1999).

2.2 Seagrasses Distribution in Western Port

Table 2 summarises changes in the distribution of seagrass in Western Port from 1973-2000. Key findings are:

- Research by Bulthuis (1984) showed 70% loss of seagrass from 1973 to 1984. This loss occurred predominantly in the East Arm and loss was greatest in inter-tidal areas and was predominantly H. tasmanica.
- Examination of 1994 aerial photography (EPA 1995) showed limited recovery of seagrass had occurred; generally this was in the Entrance and Northern Arm where water quality conditions are more favourable to growth.
- Recent mapping in 1999 by MAFRI (2000) has shown further limited recovery of seagrass (14 km2). This recent estimate is still however ~ 2-fold less than that estimated in 1973 by Bulthuis (1981) and the report notes that in the Upper North Arm seagrass cover has further declined and there has been an increase in macroalgae.

Table 2. Areas (km2) of seagrass recorded in Western Port (modified from MAFRI 2000)

Year Mapped	Report	Total seagrass Area	Area in the Western Entrance	Total seagrass area minus Western Entrance
1973/74	Bulthuis, 1981	250	20	230
1983/84	Bulthuis, 1984	72	13	59
1994	EPA 1995	113	20	93
1999	MAFRI, 2000	130	22	107*

The total seagrass area for 1999 does not include areas of undefined algae which covered an additional 24 km2.

The possible cited causes of the loss of seagrass in Western Port have been many and include:

- Increased turbidity and sedimentation resulting from catchment erosion and harbour dredging.
- Increased epiphytic growth from nutrient stimulation
- Contaminants and pollution from nearby industry
- Dessication resulting from either a gradual change in intertidal bank morphology or from an acute extreme event such as a low tide during warm summer weather
- Natural events including disease.

2.3 Seagrass Condition in Western Port

Table 3 summarises parameters of seagrass growth and morphology from a variety of studies in Western Port over the last 30 years. Sites are broadly divided into 3 segments previously defined and have quantitatively different water quality and light environments; Waters are highly turbid and subject to high nutrient inputs from catchment sources in the UNA, while in the south (SA) waters are primarily influenced by oceanic conditions. The LNA represents an intermediate region in water quality (see 3.0 for details). The key points from Table 3 are:

- In 1998 seagrass cover, density and above ground biomass was least at UNA sites and greatest at SA sites. At the UNA site macroalgae cover was greater than 30% whereas it was less than 10% at the other two sites. These patterns persisted over an annual cycle.
- These current estimates of shoot density and standing crop at UNA were 65% and 95% lower respectively than estimates previously reported in 1978 (Bulthuis and Woelkerling, 1983).
- The number of leaves and short shoots, and mean shoot length and growth is generally least at UNA and greatest at SA.
- Maximal fluorescence (Fm) and yield (Y) are least at UNA and suggest a reduced photosynthetic capacity. The low leaf area of shoots at this location also denote a reduction in photosynthetic capacity. Data not shown here, for Z. muelleri show a similar pattern in photo-physiology, but photosynthetic activity is greater than .H tasmanica.
- Photosynthetically active radiation is least at UNA (see Table 5). The short duration of saturated photosynthesis at UNA would appear to inhibit growth and survival of H. tasmanica at this site. PAR values are 2–3 fold higher values at SA site where seagrass growth is optimal.

In summary, these observations suggest that seagrass condition and morphology at UNA is quantitatively different from the other two locations and that these differences are related to poorer water quality and/or the attenuated light environment. The growth and photo-physiology of H. tasmanica at SA appears similar to studies at unpolluted sites in other geographic locations.

Table 3. Morphological and physiological characteristics of H. tasmanica from research undertaken in Western Port 1973– 1999. Values are mean + 1 standard error

	Parameter	Units	Year	Location Southern Arm	Lower North Arm	Upper North Arm
	Population indices					
b	% algae cover	%	1998	7.6 ± 1.7	32.2±3.7	8.5±1.6
b	% seagrass cover	%	1998	99.9±0.1	40.3±4.1	92.8±2.5
b	Seagrass density	no. m^{-2}	1998	1652 ± 158	491 ± 100	1109 ± 201
b	Leaf biomass	g dry wt. m^{-2}		43.0 ± 6.5	6.2±1.6	7.8 ± 1.3
b	Stem biomass	g dry wt. m^{-2}		28.9 ± 4.3	2.3 ± 0.9	4.13 ± 1.1
b	Above–ground biomass	g dry wt. m^{-2}	1998	71.9 ± 10.5	8.4 ± 2.4	11.9 ± 1.9
a			1973	854 ± 19	355 ± 19	128 ± 35
	Module morphology					
b	Leaves	no. $shoot^{-1}$	1998	8.2 ± 0.4	4.0 ± 0.2	4.7 ± 0.3
b	Short shoots	no. $shoot^{-1}$	1998	1.5 ± 0.1	1.1 ± 0.04	1.1 ± 0.03
b	Shoot length	cm $shoot^{-1}$	1998	29.4 ± 1.2	2.2 ± 0.6	7.3 ± 1.25
b	Mean Shoot growth PI	d	1998	224	82	27
	Nutrient Content		1998			
c c	Seagrass N	%	1998	1.17	1.92	1.85
c	Seagrass P	%	1998	0.05	0.08	0.09
c	N:P		1998			
c	Epiphyte N		1998	-	0.87	1.11
c	Epiphyte P		1998	0.06	0.03	0.09
b	Seagrass Chl *a*		1998	1.97 ± 9.16 se	1.94 ± 0.12 se	1.73 ± 0.12 se
b	Seagrass Chl b		1998	2.27 ± 0.03	2.14 ± 0.03	0.80 ± 0.05
	Photosynthetic parameters					
b	Fm		1998	672 ± 67	701 ± 148	539 ± 60
b	Y		1998	0.75 ± 0.005	0.76 ± 0.003	0.62 ± 0.008

[a]Bulthuis seagrass studies
[b]EPA Seagrass studies [c]Saunders (1999)

2.4 Seagrass Restoration

Western Port Seagrass Restoration Project

The Western Port Seagrass Partnership has obtained expert advice on a Seagrass Restoration Project in Western Port from Dr Anthony Cheshire and Dr Stephanie Seddon. Natural Heritage Trust Coasts and Clean Seas funding together with corporate sponsorship has been sought for this project. The objective is to re-establish Heterozostera tasmanica and Zostera muelleri at selected pilot sites trialing different planting techniques and monitoring for future wide scale propagation and planting. The Western Port Seagrass Restoration Project comprises 4 phases and implementation over 10 years is recommended:

Phase 1 Select suitable planting sites (3 months)
Phase 2 Develop optimal planting methodologies (12-18 months)

Phase 3 Assess the success of methodologies at different sites (3 years)
Phase 4 Large-scale planting trials (5 years +)

Western Port Seagrass Management Team

The Western Port Seagrass Management Team, headed by Dr Peter Attiwill has been recently established to oversee the implementation of the Western Port Seagrass Restoration Project and other community and scientific research in Western Port. Current Projects include:

- Community Seagrass Care
- Monash University Seagrass Genetics Study
- Seagrass Propagation Research at Kilcunda Abalone Farm
- Community Monitoring and Research at Coronet Bay.
- Coasts and Clean Seas funding has been requested for Phase 1 and 2 of the Western Port Seagrass Restoration Project. Corporate sponsorship has also been obtained.
- Fisheries Research Development Corporation (FRDC) funding has also been requested for a project involving Monash University and Kilcunda Abalone Farm to develop seagrass propagation techniques.

3.0 Environmental condition of Western Port

The quality of water in Western Port is influenced by both catchment inputs and in-bay processes. This section provides background to the factors potentially affecting the condition of seagrass in Western Port.

The major sources of inputs into Western Port include industrial and agricultural practices, roads, and sewage treatment plants. Seventeen rivers and drains discharge to the Bay, delivering an estimated 1963 tonnes of nitrogen, 2353 tonnes of phosphorus and 40 205 tonnes of sediment per annum (Figure 1).

Annual sediment loads to the northern end of the Bay are 6–7 times those in other parts of the Bay (Figure 3). Rates of deposition estimated from a ^{210}Pb and ^{137}Cs show annual deposition rates of 0.6–1.5 cm $^{y-1}$in UNA and EA. Preliminary evidence suggests relatively recent (40-50 y) changes in deposition rates and sediment sources to Western Port (Wallbrink pers. comm.). Sediment-bound phosphorus increases 2-fold above ~ 30 cm sediment depth.

Tables 4, 5, and 6 respectively summarise the nutrient, light, and toxicant concentrations in surface waters and sediments in Western Port. This data is drawn from EPAs marine monitoring program and studies of benthic remineralisation (Longmore et al. 1998) and toxicant concentrations (Fabris et al 1999). Although the sites used in these studies are sometimes spatially disparate from seagrass sites (Figure 1), for the purpose of drawing some general conclusions on the relationships between seagrass and water quality condition they have been used to characterise water quality condition in the 3 segments, SA, LNA and

UNA. Although EPA site 724 is located in the East Arm, for the purposes of this comparison it is considered representative of the UNA. Similarly, site 716 is considered representative of the LNA and site 709 of SA.

Table 4. Concentrations of nutrient water column stocks and estimated sediment fluxes. Water column nutrients (µg 1^{-1}) are the median and range of data from monthly sampling in 1998 and 1999 at EPAs fixed site network. Benthic fluxes (mg m^{-2} d^{-1}) are mean ± 1 S.D) from Longmore et al. (1998).

Parameter	**Southern Arm**	**Lower North Arm**	**Upper North Arm**
Water Column stocks (µg l^{-1}) From EPA Fixed Site Network.			
	Site 709	**Site 716**	**Site 724**
NH_4	6.1	6.4	7.0
	0-13.5	0-15.0	2.2-21.3
NO_X	1.83	1.5	6.4
	0-3.2	0-11.6	0-25.4
DIN	8.6	8.3	15.9
	0.3-26.2	0.6-26.0	5.6-40.5
Total N	140.4	152.5	297.5
	98.3-220.6	100.7-313	138.6-860.4
DIP	6.4	4.9	7.0
	1.9-11.0	1.1-9.4	3.2-15.5
Total P (µg 1^{-1}	13.8	10.9	32.31
	7.9-23.0	5.3-28.2	9.7-151.3
SiOH4	92.8	187.6	465.5
	41.9-201.5	55.7-351.7	173.8-902.2
Benthic Fluxes. Mean ± S.D mg m^{-2} d^{-1} (from Longmore et al 1998)			
	Site 2	Site 3	Site 1
NH_4	3.08 ± 0.84	18.06 ± 4.2	5.46 ± 1.4
NO_2	0.28 ± 0.14	0.28 ± 0.28	0.56 ± 0.14
NO_3	6.02 ± 1.68	1.68 ± 1.12	8.54 ± 2.8
DIN	9.24 ± 3.5	19.88 ± 8.4	13.86 ± 5.6
PO_4	0.62 ± 0.31	1.24 ± 0.93	2.48 ± 0.93
SiO_4	33.04 ± 11.2	43.96 ± 15.4	81.2 ± 25.2
DO	-553.6 ± 96	-812.8 ± 480	-1318.4 ± 192
CO_2	598.4 ± 176	968 ± 440	453.2 ± 132

Table 5. Water column particulate matter and light environment at sites in the Southern Arm, Northern Arm and Upper North Arm Light data based on deployments of loggers from November 1998 until June 1999. Data are median and range.

Parameter		Southern Arm	Lower North Arm	Upper North Arm
Chlorophyll a	µg 1^{-1}	1.3 0.51-2.84	1.3 0.07-5.2	2.46 0.2-1.4
Suspended particulate matter	mg 1^{-1}	7.9 0.65-18.9	5.5 0.37-31	25 2.9-166
Secchi depth	m	3 1-7.5	2.5 0.5-6.5	0.7 0.00-3.5

Table 6. Mean (S.D.) heavy metal concentrations (µg 1^{-1}) measured in the water column and sediment. Water column concentrations were the mean of the 3 EPA fixed sites over the years 1998-99 (n = 48). Metals measured in sediments are from a study by Fabris et al (1999) of toxicants in Western Port Bay (n = 28).

	Sediment	Water Column
Arsenic	8.9 ± 4.49	2.00 ± 0.88
Cadmium	0.06 ±0.05	0.04 ± 0.07
Copper	1.7 ±1.1	0.76 ± 0.83
Mercury	0.02 ± 0.02	2.36 ± 3.63
Nickel	1.7 ± 1.0	1.06 ± 0.85
Lead	2.9 ± 1.5	0.4 ± 0.5
Zinc	5.0 ±4.0	1.02 ± 1.58

Key conclusions to be drawn from these tables include:

- Water column nutrient concentrations are greatest at UNA and least at SA (Table 4). Dissolved Inorganic water column stocks are ~ 2-fold greater than at the other two sites and is primarily due to the greater concentration of oxidised N (NOX). Ortho-phosphate (PO4) and silicate concentrations are also greatest at UNA.
- Fluxes were consistent with aerobic oxidation of organic matter, with some fluxes attributed to groundwater intrusion and / or bioturbation (Table 4). The labile carbon in the sediments was a mixture of diatomaceous and macrophytic material (possibly seagrass blades epiphytes and macroalgae). About 22–55% (mean 45%) of the remineralised N was lost through denitrification. Fluxes were similar to, or lower than those reported from other Australian bays and estuaries.
- Estimated nutrient pools—scaled to the surface area of Western Port—of phytoplankton contain ~ 60 tonnes N and ~ 8 tonnes P. Seagrass are estimated to contain 1.5 tonnes N and 0.05 tonnes P. Annual nutrient requirements may be in the order of 7000 tonnes N and 950 tonnes P fro phytoplankton and 2.6 tonnes N and 0.1 tonnes P for seagrass. Other data also indicate that the N requirements of epiphytes may be greater than seagrass N requirements.
- No data is available on nutrient concentrations in sediment (key knowledge gap).

- Suspended sediment and Chl *a* levels at the UNA site are ~ 4-and 2-fold respectively greater than at sites in LNA and SA segments (Table 5). Long term trends at UNA show a 1.5–fold increase in median Chl *a* concentrations from 1973–1977 (0.96 μgL^{-1}) to1998 (1.39 $\mu g\ L^{-1}$). Mean water column residence times of suspend particulate matter (SPM) is lowest (~0.6 d) in UNA and greatest (~1 d) in the EA (Wallbrink pers. comm.).
- Metal concentrations in sediment and the water column are low (less than ANZECC 20-00) and relatively uniform around the Bay, suggesting that Western Port is essentially uncontaminated.

4.0 Research

This section provides a list of past research into the Western Port marine environment and research that is relevant to the seagrasses in Western Port.

4.1 Research in Western Port

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