Comparative Suitability of Native Submerged Macrophyte Species in Constructed Stormwater Wetlands in the Auckland Region: a Literature Review

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Potamogeton cheesemanii – Photo from NZPCN by Pat Enright

Auckland Council
Te Kaunihera o Tāmaki Makaurau

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Name: Judy-Ann Ansen Position: Manager Stormwater Technical Services Date: May 2013

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Comparative Suitability of Native Submerged Macrophyte Species in Constructed Stormwater Wetlands in the Auckland Region: a Literature Review

Tim Martin and Paula Reeves

Wildland Consultants Ltd

Prepared for Auckland Council

Executive Summary

A literature review was undertaken to determine the indigenous submerged macrophyte species with the greatest potential for establishment in stormwater wetlands, and any wetland design considerations that may favour the persistence of indigenous over exotic species. The most promising indigenous submerged macrophytes are two *Myriophyllum* species(*M. propinquum* and *M. triphyllum*) and manihi (*Potamogeton cheesemanii*). These species are all tolerant of the high nutrient concentrations typically found in stormwater wetlands, and through the production of floating leaves, are able to persist in wetlands with poor water clarity. Additionally, these species are all tolerant of temporary dewatering. This provides an opportunity to favour these species over drought-sensitive exotics, if wetland design can include a mechanism for temporary drainage. Other indigenous species may also have potential in stormwater wetlands, providing additional biodiversity, and ecosystem functions. The inclusion of species such as the charophytes *Chara australis*, *Nitella* aff. *cristata*, and *N. pseudoflabellata* in any establishment trials is therefore also recommended.

Stormwater wetlands may favour the establishment of indigenous species over exotic species, or at least increase the diversity of submerged communities, by varying the substrates on the wetland floor (sands, gravels, clays), including deep and shallower areas within wetland profiles, and including a mechanism for temporary wetland drainage. Although substrate may eventually be smothered by finer trapped sediment, the initial substrate variability will favour establishment of a diverse plant community. Stormwater wetlands are also more likely to support indigenous submerged macrophytes if they are planted immediately following their construction.

Planting trials are needed to determine which indigenous species are best suited for stormwater wetlands. If habitat manipulation is also trialled, monitoring is needed to determine if these measures favour the establishment and long-term persistence of indigenous submerged macrophyte communities.

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1.0 Introduction

Auckland Council has undertaken a literature review of submerged macrophytes of the Auckland region, and to assess the feasibility of establishing indigenous submerged macrophytes within stormwater wetlands.

Freshwater submergent macrophyte species associated with constructed stormwater wetlands consist almost exclusively of pest plant species, including oxygen weeds (*Lagarosiphon major*, *Elodea canadensis, Egeria densa*), alligator weed (*Alternanthera philoxeroides*), hornwort (*Ceratophyllum demersum*), and water lilies. These pest species all pose a significant threat to Auckland's waterways, and constructed stormwater wetlands consequently pose a biosecurity risk by acting as a permanent repository of invasive freshwater submerged macrophytes. As the majority of these invasive plants reproduce primarily through vegetative means (as dislodged or cut segments), physical maintenance activities in wetlands therefore have the potential to promote the spread of these plants downstream. The prolific growth of pest macrophytes can also result in low dissolved oxygen problems due to high rates of respiration, stagnant water, less oxygenation from the water surface, and increased decomposition due to light attenuation and plant senescence.

Indigenous submerged macrophyte species have historically not been included within wetland planting plans. Native emergent and littoral macrophyte species are easier to include and plant material is commercially more available; consequently deeper areas (that are not suitable for emergent and littoral macrophyte species) remain unplanted. In the absence of competition from native submergent macrophytes, exotic macrophytes are more likely to proliferate and become dominant in unplanted areas.

This report includes the following:

- A critical and evaluative account of submerged indigenous/exotic plant associations and the growth and dispersal characteristics of indigenous and exotic species, with a focus on the Auckland region where possible.

- An assessment of the likely success/resilience of submerged indigenous macrophyte species in dynamic stormwater wetland systems, considering the proposed revised wetland design.
- An assessment of design considerations or potential habitat manipulation to improve the competitive ability of indigenous macrophytes over exotic macrophytes.

The report is the product of consultations with Auckland Council staff, field work, review of existing literature and a workshop.

2.0 Submerged macrophyte associations in the Auckland Region

2.1 Original submerged macrophyte associations of ponds, wetlands and lakes

Prior to human settlement, freshwater lakes, wetlands and ponds were very localised in occurrence in the Auckland region (de Winton and Edwards 2009). Dune lakes are frequent along the Awhitu and Kaipara Peninsulas, and lakes, ponds, and wetlands were occasionally formed by volcanic activity, such as Lake Pupuke, which occupies a volcanic crater, and Western Springs Lake, which occurs at the freshwater outflow from Mount Eden's lava flows. However over the vast majority of the Auckland isthmus, small bodies of water similar in size and depth to stormwater ponds and wetlands were very rare. Using the available literature to gain an understanding of the original submerged macrophyte flora of Auckland wetlands is therefore difficult.

Most recent studies of Auckland's submerged macrophytes have occurred within dune lakes (c.f. Tanner et al 1990, Schwarz et al 2000), which typically have environmental conditions that contrast markedly with stormwater ponds and wetlands. Auckland's dune lakes are usually larger and deeper than even the largest stormwater ponds, are characterized by a sandy or peaty substrates, and, depending on catchment land use, have water quality and clarity that varies from eutrophic to oligotrophic. Conversely, Auckland stormwater ponds and wetlands are typically small, have silty or muddy substrates, have poor water clarity, and are generally eutrophic to supertrophic.

Prior to human settlement, Auckland's naturally-formed ponds, wetlands and lakes would have supported submerged macrophytes down to a depth determined by water quality or maximum lake depth (de Winton and Edwards 2009). The zonation of plant communities in shallow lakes is primarily determined by the attenuation of light with increasing water depth (Schwarz et al 2000). In clear water lakes, the shallow water margins typically supported emergent macrophytes (e.g. *Typha orientalis*, *Machaerina* spp., *Eleocharis* spp.), followed, with increasing water depth, by low turfs, milfoils (*Myriophyllum* spp.), pondweeds (*Potamogeton* spp.) and finally charophytes (*Chara* spp., *Nitella* spp.) (de Winton and Edwards 2009). In clear water lakes, charophytes are capable of growing to depths of over 30 m (Schwarz et al 2000), and most shallow lakes, wetlands and ponds in the Auckland region would have formerly been entirely vegetated (de Winton and Edwards 2009).

Lake Otatoa, a deep dune lake ranked as having excellent ecological condition (de Winton and Edwards 2009) is probably one of the best available proxies for the former aquatic vegetation of degraded lakes in the Auckland Region. It has a fringe of raupo and *Eleocharis sphacelata* on the margins at 0-1 m and 0-2 m depth respectively, with low turf species such as *Glossostigma elatinoides*, *G. submersum*, and *Lilaeopsis novae-zelandiae* at approximately 0.5 m depth, and *Myriophyllum triphyllum* at 0.5-2 m depth. Between 0.5 and 10 m depth, the submerged macrophytes comprise *Chara australis*, *C. fibrosa*, *C. globularis*, *Nitella pseudoflabellata*, and *N. hyalina* (Tanner et al 1986).

2.2 Degraded water bodies

Lake Parkinson, a shallow, eutrophic dune lake on the Awhitu Peninsula, lies within a predominantly pastoral catchment (Rowe and Champion 1994). This lake can be regarded as a proxy for the submerged macrophyte communities that could be expected in moderately degraded freshwater bodies in the Auckland Region. The lake, which has a maximum depth of 9 m, supports indigenous submerged macrophytes, but these are depth limited by water clarity; at the time the aquatic vegetation was described in 1986-1987, very low light levels were present below 3 m depth, and a secchi depth of 1.6 m was recorded. *Eleocharis sphacelata* occurred as an emergent macrophyte in water 0-2.2 m depth, intermingled with *Myriophyllum propinquum* and *Chara australis*, and on the deeper fringes with *Nitela hookeri* and *Potamogeton ochreatus*. In water deeper than 2 m, submerged macrophyte communities were either dominated by *Potamogeton ochreatus* or *Nitella hookeri*, with these species occurring to approximately 5 m depth.

2.3 Devegetated water bodies

In an assessment of the ecological condition of 32 lakes in the Auckland Region, de Winton and Edwards (2009) found that submerged macrophytes were absent from lakes that either had been stocked with grass carp, or had very poor water quality. In Lake Spectacle the absence of submerged macrophytes was attributed to poor water quality (<1 m Secchi disc depth), and the presence of marginal vegetation that formed floating layers out into water over 2 m depth (de Winton and Edwards 2009). Submerged macrophytes were also absent or very rare in Lake Slipper, downstream of Lake Spectacle, to which it is connected by a drainage channel. The absence of submerged macrophytes can also be expected within stormwater ponds and wetlands with the poorest water quality.

2.4 Site surveys

Seven stormwater ponds or stormwater treatment wetlands were visited on 19 June 2012 at the following locations:

1. Little Shoal Bay wetland;
2. Chelsea Sugar Refinery ponds;
3. Buckley Avenue, Hobsonville;
4. Paremuka Stream; Henderson;
5. Albionvale Road; Glen Eden;
6. Ken Maunder Park, Avondale; and
7. Carrington Polytechnic, Mount Albert.

Manihi (*Potamogeton cheesemanii*), the only indigenous submerged macrophyte found within stormwater ponds and wetlands, was present in the wetlands and ponds at Avondale, Hobsonville and Glen Eden. The latter two had been constructed within the last two to five years and it is unknown whether the presence of manihi there is from planting or natural dispersal. At Hobsonville only a few small submerged plants were found in water 0.5 m deep, whereas at Glen Eden, manihi was well established in shallow water margins *c.*0.5 m deep, and had surface-reaching leaves (Plate 1). At Ken Maunder Park, manihi occurred in a shallow pool 0.3-0.4 m deep at the outflow end of the stormwater practice (Plate 2).

The indigenous charophyte *Nitella* aff. *cristata* was found in shallow pools on the margins of the Little Shoal Bay wetland. The hydrology of this wetland has been substantially modified by the partial damming of its mouth by a road, and by numerous stormwater inputs from the adjacent residential areas.

The stormwater ponds on the Paremuka Stream supported large areas of the exotic parrot's feather (*Myriophyllum aquaticum*) which occurred as dense submerged or emergent beds. *Egeria densa* occurs on an occasional basis within the Chelsea sugar refinery ponds which contains grass carp.

Figure 1 Manihi (*Potamogeton cheesemanii*) establishing in shallow margins of a stormwater pond at Glen Eden. Surface floating leaves visible in centre of photograph.

Figure 2 Manihi (*Potamogeton cheesemanii*) in a shallow pool within a dense reed bed of *Eleocharis sphacelata*, Ken Maunder Park, Avondale.

The wetlands at Carrington Polytechnic were dominated by emergent macrophytes such as *Eleocharis sphacelata*, and no indigenous submerged macrophytes were present.

3.0 Growth, dispersal, and environmental tolerances of submerged macrophyte species

A literature review of the environmental tolerance, growth, and dispersal characteristics of the indigenous submerged macrophytes of the Auckland Region was undertaken, and the results summarized in Table 1. For many species, information regarding preferred substrates and water conditions (e.g. clarity, pH) is sparse. The depth range of submerged species has been studied more extensively through several lake studies (e.g. Tanner et al 1986, Tanner et al 1990, Schwarz et al 2000). Water clarity plays a critical role in determining the depth to which species will grow, as depth limits for shallow North Island water bodies are primarily driven by the attenuation of light with increasing depth (Schwarz et al 2000). In water bodies with poor water quality, species that typically occur at greater depth can occur in very shallow water (e.g. *Chara australis* in Lake Parkinson (Tanner et al 1990)), and the maximum depths at which species occur can be substantially curtailed. Therefore maximum depth limits derived from studies of natural water bodies with moderate to good water clarity, are unlikely to be applicable to the establishment of macrophytes within stormwater wetlands.

Table 1 Submerged indigenous macrophytes of the Auckland Region: habitats, growth, environmental tolerance, and dispersal

Indigenous Species	Habitats	Substrate	Water Conditions (Quality, Light)	Water Conditions (Depth, Flow)	Growth (Growth Form, Height, Density, Growth Rate)	Dispersal Mechanisms	Other Notes
Chara australis	Lakes, ponds, lagoons (Woods & Mason 1977).	Mud, sand (Woods & Mason 1977), muddy or organic sediments (Tanner et al 1987).	Most abundant in lakes with low to moderate water clarity (Tanner et al 1986).	0.5-1.7 m deep (Tanner et al 1990).	Moderate growth rate (Riis & Biggs 2001), 0.4-0.6 m tall with low density canopy (Riis & Biggs 2001), to 1.5 m tall in Lake Rotoiti (Coffey & Clayton 1988).	Moderate ability for vegetative spread (Riis & Biggs 2001).	
Chara fibrosa	Lakes, lagoons, ponds, swamps (Woods & Mason 1977).	sand, muddy sand, silt (Woods & Mason 1977), sandy sediments (Tanner et al 1987)	Most abundant in lakes with clear water (Tanner et al 1986), stagnant, peaty water (Woods & Mason 1977).	0.2-18 m deep (Tanner et al 1987).	0.1-0.3 m tall (Johnson & Brooke 1998).		
Chara globularis	Streams, ponds, ditches, lakes (Woods & Mason 1977), fresh or brackish water (Johnson and Brooke 1998).		Very sensitive to increased nitrate concentrations (Lambert & Davy 2010).	0-8 m deep (Tanner et al 1987), 0-5 m depth (Woods & Mason 1977).	Moderate growth rate (Riis & Biggs 2001), 0.2-0.4 m, low density (Riis & Biggs 2001)	Moderate ability for vegetative spread Riis & Biggs 2001.	
Myriophyllum propinquum	Swampy lake margins (Tanner et al 1987).			0-2.2 m deep Lake Parkinson (Tanner et al 1990), still or flowing water (NIWA 2012).	>1 m tall with high density canopy (Riis & Biggs 2001), 2 m tall in Lake Rotoiti (Coffey & Clayton 1988), up to 3 m tall in deep water (NIWA 2012).	Moderate ability for vegetative spread (Riis & Biggs 2001), propagation by seed, fragments, or rhizomes (NIWA 2012).	Survives short-term dewatering (NIWA 2012).
Myriophyllum triphyllum		Prefers sandy substrates (Riis & Biggs 2003).		0.3-3.0 m deep (Tanner et al 1986), optimum flow <0.1-0.4 ms-1, lowest optimum depth 0.5 m (Riis & Biggs 2003), still or flowing water (NIWA 2012).	>1 m tall with high density canopy (Riis & Biggs 2001), up to 3 m tall in deep water (NIWA 2012).	Moderate ability for vegetative spread (Riis & Biggs 2001), propagation by seed, fragments, or rhizomes (NIWA 2012).	Survives short-term dewatering (NIWA 2012).
Nitella aff. *cristata*	Lakes, ponds, muddy streams (Woods & Mason 1977).	Mud, stones (Woods & Mason 1977).	pH 6.2 (Woods & Mason 1977)	1.2-5 m deep (Tanner et al 1990).	0.3-0.6 m tall (Johnson and Brooke 1998).		
Nitella hyalina	Lakes, rivers, streams, ponds and swamps (Woods & Mason 1977).	Gravel, mud, clay, sand (Woods & Mason 1977).	Clear peaty coloured water (Woods & Mason 1977).	0-9.5 m deep (Tanner et al 1986).	0.05-0.35 m tall (Johnson and Brooke 1998)		
Nitella pseudoflabellata	Rivers, streams, ponds, ditches (Woods & Mason 1977).	Mud, sand, silt, gravels (Woods & Mason 1977).	Clear or muddy water, pH 5.8 (Woods & Mason 1977).	0.1-10.0 m deep (Tanner et al 1986).	0.06-0.30 m tall (Johnson and Brooke 1998).		
Potamogeton cheesemanii	Lakes, ponds, farm dams, rivers (Johnson and Brooke 1998).	Prefers small gravels (Riis & Biggs 2003).		0.3-3.5 m deep in Lake Parkinson (Tanner et al 1990), optimum flow <0.1-0.4 ms-1, lowest optimum depth 0.7 m (Riis & Biggs 2003), still or flowing waters (NIWA	>1 m tall with high Density canopy (Riis & Biggs 2001).	Moderate ability for vegetative spread (Riis & Biggs 2001), seed dispersal important (NIWA 2012).	Tolerates short periods of emergence (NIWA 2012)

Indigenous Species	Habitats	Substrate	Water Conditions (Quality, Light)	Water Conditions (Depth, Flow)	Growth (Growth Form, Height, Density, Growth Rate)	Dispersal Mechanisms	Other Notes
				2012), up to 8 m depth (NIWA 2012).			
Potamogeton ochreatus	Lakes, slow-flowing rivers (Johnson and Brooke 1998), streams and ponds (NZPCN 2012).			0.1-7.0 m deep (Tanner et al 1986), grows in 0.3-4.9 m depth in Lake Parkinson (Tanner et al 1990).	High growth rate (Riis & Biggs 2001), height up to 4.5 m in Lake Parkinson (Tanner et al 1990), typically 0.4-0.6 m tall with low density canopy (Riis & Biggs 2001), to 3 m tall Lake Rotoiti (Coffey & Clayton 1988).	moderate ability for vegetative spread Riis & Biggs 2001	Rhizomatous (NIWA 2012).
Potamogeton suboblongus	Ponds and pools (Johnson and Brooke 1998), muddy hollows in forest and ephemeral pools, particularly in montane areas (NZPCN 2012).	Mud (Johnson and Brooke 1998)		Shallow water or wet mud (Johnson and Brooke 1998).	0.4-0.6 m tall with high density canopy (Riis & Biggs 2001).	Moderate ability for vegetative spread (Riis & Biggs 2001).	May be semi-terrestrial in dryer habitats. Prefers a cool site in lowland areas (NZPCN 2012)
Ruppia polycarpa	Estuarine water, freshwater lakes and ponds (NIWA 2012), slow-flowing streams (NZPCN 2012).		Saline, brackish, or freshwater (NZPCN 2012).	0.1-1.5 m deep (Tanner et al 1986), up to 2 m deep (NIWA 2012), to 3 m deep (Johnson and Brooke 1998).	0.2-0.4 m tall with moderate density canopy (Riis & Biggs 2001).	High ability for vegetative spread (Riis & Biggs 2001).	Rhizomatous (NIWA 2012).
Zannichellia palustris	Streams, lakes, lagoons, in fresh or brackish water (Johnson and Brooke 1998).	Silt or sand (Johnson and Brooke 1998).			High growth rate, 0.2-0.4 m tall with moderate density canopy (Riis & Biggs 2001).	High ability for vegetative spread (Riis & Biggs 2001).	Summer-green (deciduous) (Johnson and Brooke 1998).

4.0 Feasibility of restoring indigenous submerged macrophyte communities within stormwater wetlands

4.1 Predicted environmental conditions of Auckland stormwater wetlands

The proposed design of stormwater wetlands marks a shift away from open water ponds to a wetland marsh system. Low marsh (0.2-0.3 m water depth) is to cover 40% of the wetland area, high marsh (0.5 m water depth) is to cover 50% of the wetland area, and deeper water (1.5 m depth) is to cover approximately 10% of the wetland area. The marsh is to occur along a sinuous pathway to maximize the length of the flow path and water retention times, with deeper pools at intervals along the flow path. The system is designed so that during storm events, the low marsh, high marsh, and deeper pools can increase in depth to a maximum of 0.545-0.645 m, 0.845 m, and 1.845 m respectively. A key aspect of the design is to minimize flow velocities so that scour of biofilms does not occur; the maximum peak flow through the wetland vegetation is designed to reach a maximum of 0.05 ms^{-1}. To achieve this, stormwater runoff greater than 1/3 of a two-year rainfall event will be routed around wetlands via a bypass.

Stormwater in the Auckland region is known to contain a wide range of pollutants, and all of these can be expected within constructed stormwater wetlands. Pollutants include heavy metals (e.g. Zn, Cu), PAH, pesticides, and hydrocarbons. Other stressors, and potential constraints for the establishment of indigenous macrophytes, include suspended sediments, elevated temperatures, and low dissolved oxygen (Mills and Williamson 2008). Auckland streams, which are the primary water source for wetlands that are constructed on-line, are characterized by variable water quality and flow, high turbidity and high concentrations of suspended solids, and elevated plant nutrient concentrations (Mills and Williamson 2008). These characteristics result in many online stormwater wetlands also being difficult environments for the survival of sensitive flora and fauna.

4.2 Potential species

A preliminary assessment of indigenous submerged macrophytes, and the feasibility of their establishment within stormwater wetlands, is provided in Table 2.

This assessment indicates that the indigenous submerged macrophytes with the greatest potential are *Potamogeton cheesemanii*, and two *Myriophyllum* species (*M. propinquum* and *M. triphyllum*). These species can develop a high density canopy, and can establish from vegetative fragments, rhizomes, or seed. Notably, all three of these species are capable of forming a canopy at the water surface, thereby having a competitive advantage in turbid waters over species with a prostrate, entirely submerged growth form (Barko et al 1986). The ability for these species to tolerate temporary dewatering is also a significant advantage as many of the key exotic macrophytes (e.g. Canadian pondweed, egeria, and hornwort) are intolerant of drought. Riis and Biggs (2001) classify these three species as being most competitive in environments with a high level of resource supply (nutrients, light, and carbon) and intermediate levels of disturbance frequency. Other species that shared this habitat classification were the indigenous species, *Potamogeton ochreatus* and *Potamogeton subulatus*, and the exotic species starwort (*Callitriche stagnalis*) and *Ranunuculus tricophyllus*. Notably, Riis and Biggs did not classify any indigenous species as characterising habitats with high resource availability and high frequency of disturbance; this habitat grouping was entirely comprised of exotic macrophytes such as *Elodea canadensis, Egeria densa* and *Lagarosiphon major*. Thus Riis and Biggs independently indicate the three species identified here as the most likely indigenous species to persist in aquatic habitats with high concentrations of nutrients.

Charophytes are predicted to have low tolerance of the environmental conditions within stormwater ponds and wetlands, due to their greater need for clear water and mineral substrates. However of the species naturally found in the Auckland Region, the species with the greatest potential for stormwater wetlands are *Chara australis*, *Nitella pseudoflabellata*, and *Nitella* aff. *cristata* (de Winton, pers. comm.). These three species are prolific producers of oospores, from which new plants arise, and have the greatest tolerance of poorer water conditions. Establishment trials of these species are recommended to determine their ability to establish and persist in stormwater wetlands.

Table 2 Assessment of the feasibility of establishing indigenous macrophytes in stormwater wetlands in the Auckland Region

Species	**Environmental Condition**	**Corresponding Character Trait**	**Selection (For, Against, Neutral)**	**Overall Feasibility**
Myriophyllum propinquum, M. triphyllum	Fluctuating water levels.	Tolerates short-term dewatering.	For. May provide a mechanism for selection over exotic macrophytes vulnerable to desiccation (e.g. *Egeria*, hornwort).	Good
	Periodic removal of silt from wetlands.	Moderate ability for vegetative spread.	Neutral. Species may recover from fragments or rhizomes.	
	Silt deposition.	Submerged stems to *c.*3 m tall.	Neutral. Plants unlikely to be entirely buried but will not be favoured by accumulation of fine sediments on submerged leaves.	
	Moderate to poor water clarity.	Unknown.	Unknown.	
	Competition with exotic macrophytes.	High density canopy.	For. Once established may achieve densities less favourable for establishment of exotics.	
	Browsing by exotic fish.	Low palatability to rudd.	For. If rudd is present other species will be preferentially eaten.	
Potamogeton cheesemanii	Fluctuating water levels.	Tolerates short-term dewatering. Floating leaves able to elongate to reach surface if levels increase.	For. May provide a mechanism or selection over exotic macrophytes vulnerable to desiccation (e.g. *Egeria densa*, hornwort).	Good
	Periodic removal of silt from wetlands.	Moderate ability for vegetative spread. Dispersal from seed also important.	Neutral. Species may recover from remaining rhizomes or by reestablishment from seed.	
	Silt deposition.	Surface floating leaves.	For. Surface floating leaves not prone to clogging with fine sediments.	
	Moderate to poor water clarity.	Surface floating leaves.	For. Surface floating leaves able to function independent of water clarity.	
	Competition with exotic macrophytes.	High density canopy.	For. Once established may achieve densities less favourable for establishment of exotics.	
	Browsing by exotic fish.	Unknown. May have similar palatability to *P. ochreatus*.	Unknown.	
Potamogeton ochreatus	Fluctuating water levels.	Found in water 0.1-7 m deep.	For. Unlikely to be adversely affected by water level changes unless dewatering occurs.	Poor
	Periodic removal of silt from wetlands.	Moderate ability for vegetative spread.	Neutral. Species may recover from remaining rhizomes or by reestablishment from seed.	
	Silt deposition.	All leaves submerged.	Against. Likely to be vulnerable to excess deposition of fine sediments on leaves.	
	Moderate to poor water clarity.	Unknown.	Unknown.	
	Competition with exotic macrophytes.	Low density canopy.	Against. Unlikely to establish a dense canopy that is resistant to invasion.	
	Browsing by exotic fish.	Preferentially eaten by rudd.	Against. Establishment unlikely if rudd is present.	
Stuckenia pectinata	Fluctuating water levels.	Unknown.	For. Unlikely to be adversely affected by water level changes unless dewatering occurs.	Average
	Periodic removal of silt from wetlands.	Ability for vegetative spread.	Neutral. Species may recover from remaining rhizomes or by reestablishment from seed.	
	Silt deposition.	All leaves submerged. Thrives in soft sediments.	Neutral. Likely to be vulnerable to excess deposition of fine sediments on leaves, but thrives in fine silts.	
	Moderate to poor water quality	Tolerant of eutrophic water conditions	For. Likely to tolerate nutrient enriched waters in wetlands if turbidity not too high.	
	Competition with exotic macrophytes.	Density of canopy likely to be low as for other similar species (*Potamogeton ochreatus*).	Against. Unlikely to establish a dense canopy that is resistant to invasion.	
	Browsing by exotic fish.	Likely to be browsed by rudd as for other similar species (*Potamogeton ochreatus*).	Against. Establishment unlikely if rudd is present.	
Chara australis (formerly *C. corallina*)	Fluctuating water levels.	Found in water 0.1-11.5 m deep.	For. Unlikely to be adversely affected by water level changes unless dewatering occurs.	Average
	Periodic removal of silt from wetlands.	Moderate ability for vegetative spread.	Neutral. Species may re-establish from vegetative fragments or oospores.	
	Silt deposition.	Unknown.	Unknown.	
	Moderate to poor water clarity.	Recorded in one study as most abundant in lakes with low to moderate water quality.	For. Possibly the most suited charophyte to the water conditions of stormwater wetlands.	
	Competition with exotic macrophytes.	Moderate growth rate with low density canopy.	Against. Unlikely to establish densities unfavourable to	

Species	Environmental Condition	Corresponding Character Trait	Selection (For, Against, Neutral)	Overall Feasibility
			establishment of exotic macrophytes.	
	Browsing by exotic fish.	Moderate palatability to rudd.	Against. May be unlikely to establish if rudd is present.	
Chara fibrosa	Fluctuating water levels.	Found in water 0-5 m deep.	For. Unlikely to be adversely affected by water level changes unless dewatering occurs.	Very poor
	Periodic removal of silt from wetlands.	Unknown.	Unknown.	
	Silt deposition.	Plants 0.1-0.3 m tall.	Against. Smaller plants could be buried by silt layers.	
	Moderate to poor water clarity.	Recorded in one study as most abundant in lakes with clear water.	Against. Water conditions of stormwater wetlands unlikely to be suitable.	
	Competition with exotic macrophytes.	Height to 0.3 m, likely to have low density canopy like other Chara species.	Against. Unlikely to establish densities unfavourable to establishment of exotic macrophytes.	
	Browsing by exotic fish.	Likely to be moderately palatable to rudd as for other Chara species.	Against. May be unlikely to establish if rudd is present.	
Chara globularis	Fluctuating water levels.	Found in water 0-8 m deep.	For. Unlikely to be adversely affected by water level changes unless dewatering occurs.	Poor
	Periodic removal of silt from wetlands.	Moderate ability for vegetative spread.	Neutral. Species may re-establish from vegetative fragments or oospores.	
	Silt deposition.	Unknown.	Unknown.	
	Moderate to poor water clarity.	Unknown, but occurs at greater depths in clear water.	Against. Water conditions of stormwater wetlands unlikely to be suitable.	
	Competition with exotic macrophytes.	Height to 0.4 m with a low density canopy.	Against. Unlikely to establish densities unfavourable to establishment of exotic macrophytes.	
	Browsing by exotic fish.	Likely to be moderately palatable to rudd as for other Chara species.	Against. May be unlikely to establish if rudd is present.	
Nitella aff. cristata (*N. hookeri* in Auckland area fall within this taxa)	Fluctuating water levels.	Found in water 0.1-10 m deep.	For. Unlikely to be adversely affected by water level changes unless dewatering occurs.	Average
	Periodic removal of silt from wetlands.	Moderate ability for vegetative spread.	Neutral. Species may re-establish from vegetative fragments or oospores.	
	Silt deposition.	Plants to 0.3-2 m tall.	Neutral. Smaller plants could be buried by silt layers.	
	Moderate to poor water clarity.	Unknown, but occurs at greater depths in clear water.	Against. Water conditions of stormwater wetlands may not be suitable. However this species can occur in ditches with moderate water quality.	
	Competition with exotic macrophytes.	Likely to have a low density canopy as for other charophytes.	Against. Unlikely to establish densities unfavourable to establishment of exotic macrophytes.	
	Browsing by exotic fish.	Preferentially eaten by rudd.	Against. Unlikely to establish if rudd is present.	
Nitella pseudoflabellata	Fluctuating water levels.	Found in water 0.1-10 m deep.	For. Unlikely to be adversely affected by water level changes unless dewatering occurs.	Average
	Periodic removal of silt from wetlands.	Ability for vegetative spread	Neutral. Species may re-establish from vegetative fragments or oospores.	
	Silt deposition.	Short plants to 0.3 m tall.	Against. Small plants could be buried by silt layers.	
	Moderate to poor water clarity.	Found in a wide range of water conditions	For. Probably the most likely charophyte to tolerate water conditions of stormwater wetlands.	
	Competition with exotic macrophytes.	Likely to have a low density canopy as for other charophytes.	Against. Unlikely to establish densities unfavourable to establishment of exotic macrophytes.	
	Browsing by exotic fish.	Unknown, but likely to be preferred as for *N. cristata*.	Against. May not establish if rudd is present.	
Ruppia polycarpa	Fluctuating water levels.	Found in water 0.1-3 m deep.	For. Unlikely to be adversely affected by water level changes unless dewatering occurs.	Some potential within brackish water systems.
	Periodic removal of silt from wetlands.	Moderate ability for vegetative spread.	For. High ability for vegetative spread. May also recover from rhizomes.	
	Silt deposition.	Plants 0.2-0.4 m tall.	Neutral. Smallest plants may be buried by silt deposition but the effect of this is unknown.	
	Moderate to poor water clarity.	Unknown.	Unknown.	
	Competition with exotic macrophytes.	Height to 0.4 m with moderate density canopy.	Against. Density of canopy unlikely to resist invasion by exotic macrophytes.	
	Browsing by exotic fish.	Unknown.	Unknown.	
Zannichellia palustris	Fluctuating water levels	Unknown.	Unknown.	Some potential within

Species	Environmental Condition	Corresponding Character Trait	Selection (For, Against, Neutral)	Overall Feasibility
	Periodic removal of silt from wetlands	High ability for vegetative spread.	For. High ability for vegetative spread.	brackish water systems
	Silt deposition	Plants 0.2-0.4 m tall.	Neutral. Smallest plants may be buried by silt deposition but the effect of this is unknown.	
	Moderate to poor water clarity	Unknown.	Unknown.	
	Competition with exotic macrophytes	Height to 0.4 m with moderate density canopy.	Against. Density of canopy unlikely to resist invasion by exotic macrophytes.	
	Browsing by exotic fish	Unknown.	Unknown.	

4.3 Constraints

4.3.1 Exotic macrophytes

In many wetlands the presence of exotic submerged macrophytes is likely to be the most significant constraint for the establishment and growth of indigenous macrophytes. A literature review of the environmental tolerance, growth, and dispersal characteristics of the exotic macrophytes of the Auckland Region was also undertaken, and the results summarized in Table 3. Exotic macrophytes, compared with indigenous macrophytes, are generally faster growing, more tolerant of poor water quality, and more tolerant of disturbance (Riis and Biggs 2001).

Table 3 Submerged exotic macrophytes of the Auckland Region: habitats, growth, environmental tolerance, and dispersal

Exotic Species	**Habitats**	**Substrate**	**Water Conditions (Quality, Light)**	**Water Conditions (Depth, Flow)**	**Growth (Growth Form, Height, Density, Growth Rate)**	**Dispersal Mechanisms**	**Other Notes**
Ceratophyllum demersum	Lakes, rivers, lagoons, drains, wetlands (NZPCN 2012).	Sandy or silty substrates (NIWA 2012).	Fertile, nitrogen-rich, slightly alkaline waters (NZPCN 2012).	Up to 10 m deep in still or slow-flowing water (NZPCN 2012).	Moderate growth rate, >1 m tall with moderate density canopy (Riis & Biggs 2001), up to 6 m tall with dense sub-surface canopy (NIWA 2012).	High ability for vegetative spread (Riis & Biggs 2001), propagation by fragmentation of brittle stems, no evidence for seed production in NZ (NIWA 2012).	Does not form roots (NIWA 2012). Sensitive to dewatering (NZPCN 2012).
Egeria densa	Streams, lakes, ponds, ditches, and wetlands (NZPCN 2012).	Silty organic or sandy-gravels (NIWA 2012).	Tolerant of low to high fertility (NZPCN 2012). Turbid, enriched water (NIWA 2012).	Slow-flowing water (NIWA 2012)	High growth rate and moderate density canopy (Riis & Biggs 2001), to 5 m tall (NIWA 2012).	Moderate ability for vegetative spread (Riis & Biggs 2001), only male plants in NZ, spread by apical and bud-bearing fragments (Tanner et al 1990).	Slightly tolerant of shade and intolerant of drought (NZPCN 2012).
Elodea canadensis	Lakes and rivers (NZPCN 2012).	Fine sediments with 10-25% organic matter, not too coarse or too fine (Nichols and Shaw 1986), prefers sand and small gravels (Riis & Biggs 2003).	Suited to eutrophic, alkaline waters (Nichols and Shaw 1986). Requires moderate to high light conditions (NZPCN 2012).	4-8 m deep, sometimes to 12 m (Nichols and Shaw 1986), optimum flow <0.1-0.4 ms-1, lowest optimum depth 0.9 m (Riis & Biggs 2003).	High growth rate (Riis & Biggs 2001), moderate density canopy (Riis & Biggs 2001), up to 8 m tall (NZPCN 2012).	Dependant on vegetative reproduction (Nichols and Shaw 1986) with no seed set in NZ (NZPCN 2012). New plants grow from stem fragments (NIWA 2012).	
Lagarosiphon major	Lakes, ponds, rivers, streams, wetlands (NZPCN 2012).	Sandy and silty substrates (NIWA 2012), restricted by coarser sediments, wave exposure (Howard Williams & Davies 1988)	Low to high fertility waters (NZPCN 2012)	Shallow water to 6.5 m deep (NIWA 2012).	Can reach the surface from 4 m depth (NIWA 2012), high growth rate, moderate density canopy (Riis & Biggs 2001)	High ability for vegetative spread (Riis & Biggs 2001) new plants grow from stem fragments (NIWA 2012), only female plants present in NZ, no evidence for seeding (NIWA 2012).	
Ottelia ovalifolia	Lakes, ponds, slow moving water bodies (NZPCN 2012), most common in fertile farm dams (NIWA 2012).	Sandy or rich organic sediments (NIWA 2012).	Nutrient rich waters (NZPCN 2012).	Shallow water to 3 m depth (NIWA 2012).		Seeds freely (NZPCN 2012).	
Potamogeton crispus	Lakes, rivers, streams, and drains (NZPCN 2012).	Fine sediments with 10-25% organic matter, not too coarse or fine (Nichols and Shaw 1986).	Freshwater or brackish waters (NIWA 2012). Most suited to eutrophic, alkaline waters (Nichols and Shaw 1986).	Still or flowing water to 10 m deep (NZPCN 2012), tolerates flows to 0.3ms-1 (Nichols and Shaw 1986).	High growth rate, with low density canopy (Riis & Biggs 2001), can grow to 4 m tall in deep water (NIWA 2012).	Seed can be spread via waterfowl (Tanner et al 1987), but strongly dependent on vegetative reproduction (Nichols and Shaw 1986) via fragments or rhizomes (NZPCN 2012).	
Vallisneria gigantea	Lakes (NZPCN 2012).	Lake sediments (NIWA 2012).		Still or flowing water (NZPCN). To 9 m deep (NIWA 2012).	Up to 5 m tall (NIWA 2012) moderate density canopy (Riis & Biggs 2001).	High ability for vegetative spread (Riis & Biggs 2001), no evidence of seed production in NZ (NIWA 2012).	Rhizomatous. Very restricted in distribution. Present in Lake Pupuke (NIWA 2012).

4.3.2 Water quality

Poor water quality is also a significant constraint for the establishment of indigenous macrophytes in stormwater wetlands. Growth of submerged macrophytes can be limited by both suspended sediments, with associated increases in light attenuation, and by excessive nutrient concentrations. Suspended sediments increase the attenuation of light with increasing water depth, and in extreme situations, heavy loads can result in the complete loss of submerged macrophytes.

High nutrient concentrations can also limit the growth of submerged macrophytes. The enrichment of water bodies with phosphate and nitrate can lead to eutrophication, with the loss of clear water, the dominance of phytoplankton and algae, and the loss of submerged macrophytes (Lambert and Davy 2010). However there is recent evidence that pollutants can inhibit the growth of submerged macrophytes even within clear water. Lambert and Davy (2010) conducted experimental studies on the effects of nitrate, phosphate, boron, and other heavy metals on charophyte growth. All of these pollutants inhibited charophyte growth with nitrates having the greatest effect; growth of the charophyte *Chara globularis* was inhibited above a very low concentration of 0.5 mg l^{-1}. The presence of pollutants in stormwater wetlands may therefore inhibit the growth of charophytes through toxicity, independent of flow-on effects such as the proliferation of algae, and poor water clarity.

4.3.3 Water velocity

Submerged macrophytes in temperate lowland streams are typically exposed to velocities from 0.05 to >1m s^{-1}. High flow velocities can be detrimental to aquatic plant growth through breakage or uprooting, and preventing seeds or fragments from settling and anchoring (Reeves et al 2004). However photosynthesis at first typically increases with greater flow, but then declines at high velocities. Conversely, submerged macrophytes may be disadvantaged at very low flow velocities that facilitate sedimentation if there is an abundance of fine material; the accumulation of fine sediments under very low flows can cause unstable substrates that reduce plant anchoring (Madsen et al 1993).

In a study of a Swedish stream, the abundance of submerged macrophytes increased at velocities up to 0.3 ms^{-1}, and then decreased with increasing flow (Nilson 1987). Aquatic plants are generally not found where flow velocities are greater than 1 $m\,s^{-1}$ (Chambers et al 1991).

The maximum water velocity that is predicted to occur within constructed wetlands designed in accordance with Auckland Council stormwater guidelines (0.05 ms^{-1}) will not exceed the tolerance limits of any of the potential macrophyte species. However if low flow causes excess sediment accumulation, particularly on submerged leaves and stems, species that have emergent or floating leaves will be favoured (e.g. *Potamogeton cheesemanii* and *Myriophyllum* sp.).

4.3.4 Pest fish

Pest fish, including rudd, koi, goldfish, bullhead catfish, and tench, are widespread in the Auckland region, and many of these occur in stormwater ponds and wetlands. These species can pose a significant threat to the growth of indigenous submerged macrophytes, particularly during their early establishment.

Rudd are likely to preferentially consume the indigenous species *Nitella* sp. and *Potamogeton ochreatus*, and also browse *Chara globularis*, *Chara fibrosa*, and *Myriophyllum propinquum* (Lake et al 2002). Furthermore, in this study, even the least preferred species hornwort was an important component of rudd diets, indicating the significant effect high density populations of rudd are likely to have on submerged macrophyte communities. In an experimental study in Lake Rotoroa, Hamilton, the use of fish exclosures demonstrated that pest fish (rudd, perch, tench, goldfish, bullhead catfish) were the primary cause of poor charophyte establishment, through both browse and direct disturbance (de Winton et al 2002). Where rudd are present in adequate numbers, this species is likely to prevent the establishment and growth of macrophytes in de-vegetated lakes, and facilitate the development of monospecific stands of exotic species. Rudd may also be a significant cause of macrophyte loss if other factors such as algal blooms and suspended sediments are occurring (Lake et al 2002).

Koi, and to a lesser extent, goldfish and bullhead catfish, contribute indirectly to the loss of submerged macrophytes by their benthic feeding, with disturbance and resuspension of sediments and nutrients (Hicks et al 2010). Pest fish may also feed on invertebrates (Lake et al 2010), leading to a reduction in species that that feed on algae and subsequent increases in algae growth.

4.3.5 Wetland maintenance

Stormwater wetlands periodically require de-silting to remove accumulated sediments and this maintenance can result in significant disruption of submerged macrophyte communities. However de-silting may also facilitate the establishment of submerged macrophytes if these are absent, by reducing turbidity, and promoting rooted macrophytes by providing firmer, more stable substrates (Sabine et al 2006). Sediment removal, if not immediately followed by replanting with desirable species, is likely to favour the growth of fast growing exotic weed species that can re-establish from stem fragments or rhizomes, or from seed. Within Auckland stormwater wetlands, recently excavated wetlands are likely to be colonized by species such as *Egeria densa* and *Elodea canadensis* that, through natural or human-assisted dispersal, colonise new unplanted wetlands.

4.4 Design considerations and habitat manipulation

4.4.1 Substrate

At the time of construction, the substrates of most, if not all, stormwater wetlands are determined by the underlying soils and geology of the catchment in which they are constructed. Surfaces below the proposed water level, which most commonly are clays, are compacted to ensure water retention, and wetland liners are used if pervious substrates such as sands are encountered. Topsoil is then imported and spread on the shallow margins prior to planting. Over time, fine sediments accumulate within the wetland.

Species that favour substrates comprised of fine silts and clays are likely to establish better within wetlands than species that prefer sandy or organic substrates. Of the species for which literature regarding substrates are available, *Elodea canadensis* has been noted as being successful in both fine sediments (Nichols and Shaw 1986) and sand and small gravels (Riis and Biggs 2003), *Lagarosiphon major* and *Potamogeton crispus* prefer fine sediments (Nichols and Shaw 1986), *Myriophyllum triphyllum* prefer sandy substrates (Riis and Biggs 2003) and *Potamogeton cheesemanii* prefer small gravels (Riis and Biggs 2003) and sands (Lacoul and Freedman 2006). The charophytes, in both the *Chara* and *Nitella* genera, can grow on a wide range of substrates including mud, gravels, sand, silt, and clay (Wood and Mason 1977), but favour mineral sediments such as clays, sands, and gravels without the accumulation of organic material (e.g. fallen leaves) (Stewart and Lambert 2010).

It is unknown to what degree substrates might determine the competitive ability of indigenous macrophytes over exotic species. Trials that investigate the establishment and growth rates of indigenous and exotic macrophytes on coarse (sands and gravels) versus fine sediments may indicate whether the use of sands and gravels can favour indigenous species.

4.4.2 Water depth

The literature regarding optimum water depths for indigenous and exotic submerged macrophytes in New Zealand is sparse. However for *Elodea canadensis*, Riis and Biggs (2003) state that 0.9 m is a minimum optimum water depth, and growth is less vigorous in water less than 0.7 m depth (Stewart and Lambert 2010). In contrast, the minimum optimum depths for *Myriophyllum triphyllum* and *Potamogeton cheesemanii* are 0.5 and 0.7 m respectively (Riis and Biggs 2003). Riis and Biggs do not provide minimum optimum water depths for any other indigenous submerged macrophytes of the Auckland region. However, this literature suggests that some indigenous species may be favoured over *Elodea canadensis* by water depths of 0.7 m or less. Field trials may be able to determine if shallow water depths favour the establishment and persistence of indigenous submerged macrophytes over exotic species.

4.4.3 Wetland profiles

The areas of open water in the new stormwater wetland design are small in area and have a maximum depth of *c.*1.5 m. One of the greatest threats to the long-term persistence of submerged macrophytes in the wetlands is the encroachment into open water habitats by emergent macrophytes in the adjacent low marsh habitats. Species such as *Machaerina articulata* (until recently named *Baumea articulata*) and *Eleocharis sphacelata* are capable of growth in water at least 1.5 m depth, but do so by establishing on the shallow margins and spreading vegetatively into water of increasingly greater depth. The establishment of emergent macrophytes within the deeper pools can be discouraged by increasing the slope of the pools, so that there is an abrupt drop off between the low marsh and the maximum depth of the pools.

4.4.4 Water level fluctuations

Fluctuating water levels provide the greatest opportunity for facilitating the growth of indigenous submerged macrophytes over exotic macrophytes. *Myriophyllum propinquum*, *Myriophyllum triphyllum*, and *Potamogeton cheesemanii* are all tolerant of temporary dewatering, whereas hornwort and *Egeria densa* are intolerant of drought (NIWA 2012). Designing stormwater wetlands so that water levels can be easily lowered and raised as part of routine maintenance may allow for the control of hornwort, *Egeria densa*, and other drought sensitive exotic macrophytes. Trials would be needed to determine the optimum duration of water drainage required to control the growth of exotics whilst retaining indigenous species.

4.4.5 Wetland shading

Shading of wetlands by terrestrial vegetation is likely to limit the growth of both indigenous and exotic submerged macrophytes. As the depth limit of submerged plant growth is primarily limited by light availability, shading of the water surface is likely to further limit the depth to which growth can occur. However, some species may be less affected by wetland shading. Charophytes such as *Nitella* aff. *cristata*, which can grow to 10 m depth (Tanner et al 1986), were found during the field survey growing in very shallow water in partial shade, and *Lagarosiphon major*, *Elodea canadensis*, hornwort, and *Potamogeton crispus*, all exotic species, are able to grow at depths over 5 m. Species that are able to grow with a limited light resource at depth may have a competitive advantage in shallow water with significant shade, but shading may not favour indigenous macrophytes over exotic macrophytes.

5.0 Conclusions

A literature review, incorporating both New Zealand studies and key international papers, was used to summarise the ecology of submerged macrophytes found in the Auckland region. The ecology of these species was then assessed with regards to the expected environmental conditions within stormwater wetlands of the proposed new design; this design reduces the extent of open water, and maximises the extent of shallow reedbeds and the length of the flow path through the wetlands.

The indigenous submerged macrophytes with the greatest potential for establishment and persistence in stormwater wetlands are two *Myriophyllum* species (*M. propinquum* and *M. triphyllum*), and manihi (*Potamogeton cheesemanii*). These species are tolerant of high nutrient concentrations, and through the growth of floating or emergent leaves, are able to persist in wetlands with poor water clarity. The ability of these species to survive short-term dewatering also provides an opportunity to favour these species over drought-sensitive exotics such as hornwort and *Egeria densa*, if wetland design can include a mechanism to temporarily drain stormwater wetlands.

In contrast, the indigenous charophytes are less suited for cultivation in stormwater wetlands due to their preference for cleaner water, and their entirely submerged growth form. However, *Chara australis*, *Nitella* aff. *cristata*, and *N. pseudoflabellata* should be included in any planting trials of indigenous macrophytes. Charophytes have important functions within freshwater ecosystems (de Winton 1999, Sabine et al 2006), and these species tolerate the widest range of water conditions, and produce abundant oospores from which new plants can establish.

If resources permit, trials could also include species that, whilst not as promising as the *Myriophyllum* spp. and *Potamogeton cheesemanii*, are also noted as having potential within stormwater wetlands. *Stuckenia pectinata*, a regionally and nationally threatened plant, may be a suitable species for stormwater wetlands with better than average water quality. *Ruppia polycarpa* and *Zannichelia palustris* (a rare species in the Auckland region) are the most promising indigenous species for stormwater wetlands that have a saline influence. Incorporation of *Stuckenia pectinata* and *Zannichelia palustris* into constructed wetlands would possibly serve to improve their distribution, which may be encouraged. The inclusion of species other than *Myriophyllum* spp. and *Potamogeton cheesemanii* in planting trials would acknowledge the relative scarcity of literature available for this review, and therefore the potential for the apparently less promising species to perform better than predicted. The establishment of diverse submerged macrophyte communities is also highly desirable as species-rich communities will be less prone to collapse and loss than monocultures or communities containing only a few species (Sabine et al 2006).

Stormwater wetlands design may be able to favour the establishment and persistence of indigenous submerged macrophytes, or at least increase the species richness of submerged communities whether indigenous or exotic, by including deep and shallow areas within wetland profiles, varying the substrates of the wetland floor (sands, gravels, clays), and including a mechanism for the temporary drainage of wetlands. Planting stormwater wetlands immediately post construction will also facilitate the establishment and persistence of indigenous species that are usually slower growing, and less competitive, than exotic species (Smart et al 1998). If the wetland design is modified to favour indigenous macrophytes, monitoring should occur to determine the effectiveness of these design modification in facilitating the establishment and persistence of indigenous macrophytes.

Efforts to establish indigenous submerged macrophytes in stormwater wetlands are likely to succeed, at least for a small number of the most tolerant species; indigenous species such as *Potamogeton cheesemanii* do occur in existing Auckland stormwater wetlands, and their occurrence is likely to increase if they are planted immediately following wetland construction. Planting trials are recommended to determine which species are most suited, and the best methods of establishment.

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