Oroklini Lake, Cyprus

Water Management Plan
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Introduction

Oroklini Lake is a Natura 2000 site to the north-east of Larnaca, consisting of approximately 85 hectares of Mediterranean salt meadows, scrub, reedbeds and other marginal vegetation, with highly variable open water bodies. The site has been designated as a Special Protection Area (CY6000010) under the Birds Directive (2009/147/EC) for its qualifying numbers of Annex 1 breeding species. The site is important as a breeding site for Black-winged Stilt *Himantopus Himantopus* (Oroklini Lake is the most important nesting site in Cyprus for this species) and Spur-winged Lapwing *Vanellus spinosus* (Cyprus has more than 50% of the EU breeding population). The site has also supported four other Annex 1 breeding species: stone-curlew *Burhinus oedicnemus*, little tern *Sterna albifrons*, common tern *Sterna hirundo* and Kentish plover *Charadrius alexandrinus*. The site is also used by a broad range of other birds throughout the year. A further 58 Annex 1 species use the site on passage or in winter, and 36 non-Annex 1 species occur regularly. Red-crested pochard *Netta rufina* have bred on the site, the first nesting records for Cyprus. The site is also classified as a Site of Community Importance under the Habitats Directive (92/43/EC) for its halophytic marsh vegetation. The site is also of significance for the European eel *Anguilla anguilla*, a critically endangered species (IUCN).

The wetland has numerous threats, including water shortages, salinity fluctuations, disturbance, and invasive alien plants. There have also been issues with the management of flood events with possible impacts on adjacent land. The EU LIFE Oroklini project started in January 2012 to tackle the many pressures through a combination of direct conservation work and community awareness initiatives. The key objective is to bring the site into Favourable Conservation Status as defined by the populations of the two key species, whilst taking into account the four other Annex 1 species and the requirements of priority vegetation communities.

Water level management is critical for the creation and maintenance of the habitat conditions for most of the six Annex 1 SPA breeding species. One of the key aims of the LIFE project has been to work towards a more suitable and predictable hydrological regime to provide more favourable conditions for key species and habitats. In particular, to minimise episodes of complete drying during the breeding season. This management plan develops recommendations and guidance for the operation of the water management infrastructure at the site, and provides a practical guide to future site managers.

The hydrology and water management infrastructure of the site - overview

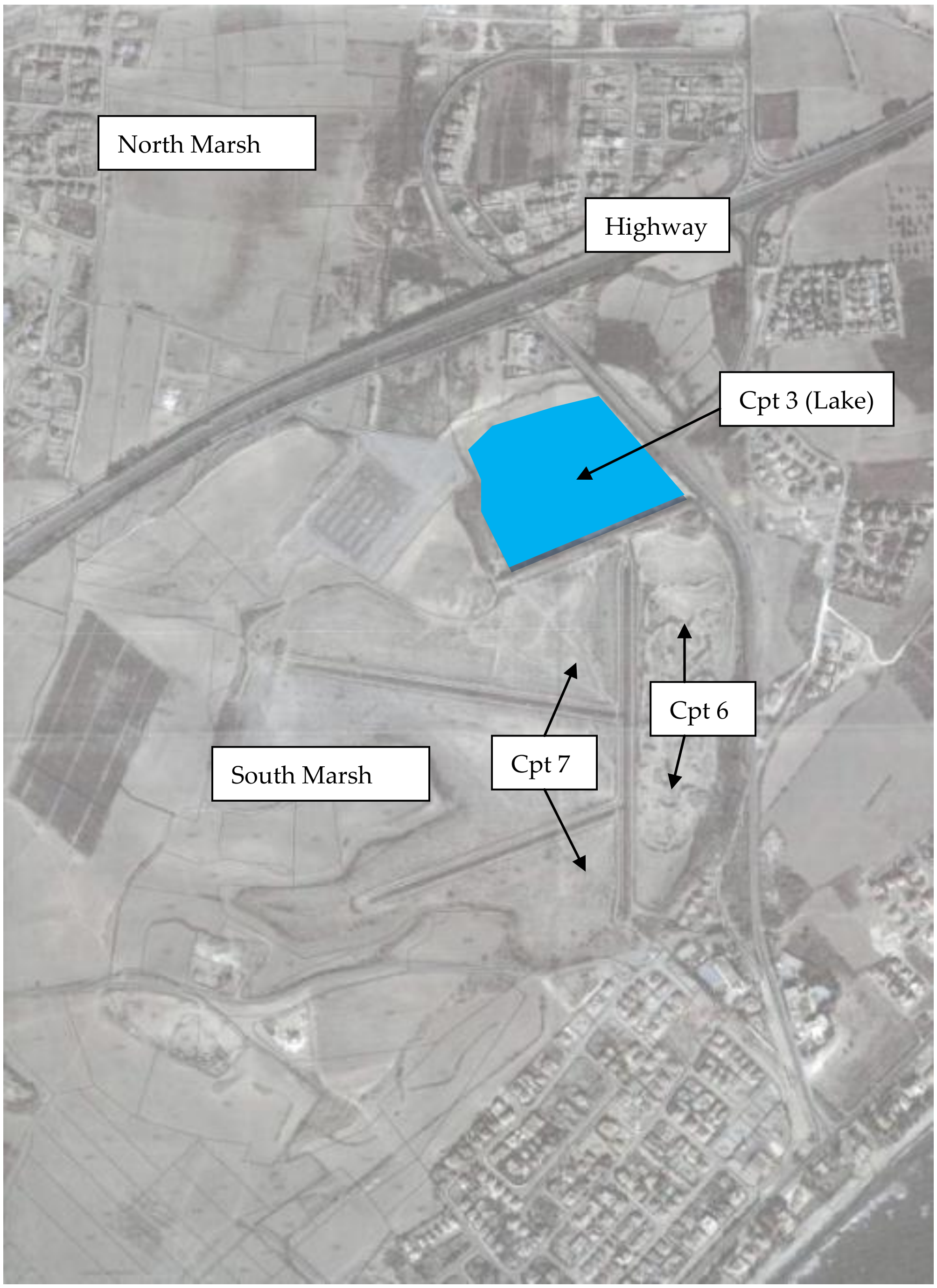
The 85ha of the Oroklini wetland is largely flat and low-lying, characterised by low permeability soils with very high residual salt concentrations, saline or hypersaline groundwater, and a highly seasonal rainfall input. In addition there is a surface water input from the catchment (3.5km2), largely consisting of grey water from drains, overflows and domestic treatment systems, typically with high nutrient levels (eg. up to 10mg/l total N) and some evidence of seasonally high BOD (biological oxygen demand) and low DO (dissolved oxygen).

The topography of the site and the presence of high salt concentrations indicates a history of sea water inputs, suggesting that the lower parts of the site could have been connected to the sea in historical times. However there are differences in ion concentrations between the groundwater and typical seawater suggest that the link is unclear or probably particularly ancient. Groundwater levels on the site are 2m or more above current sea level and show some pressure, so there will be no marine influence now. This is highly significant to the development of hydrological objectives for the site.

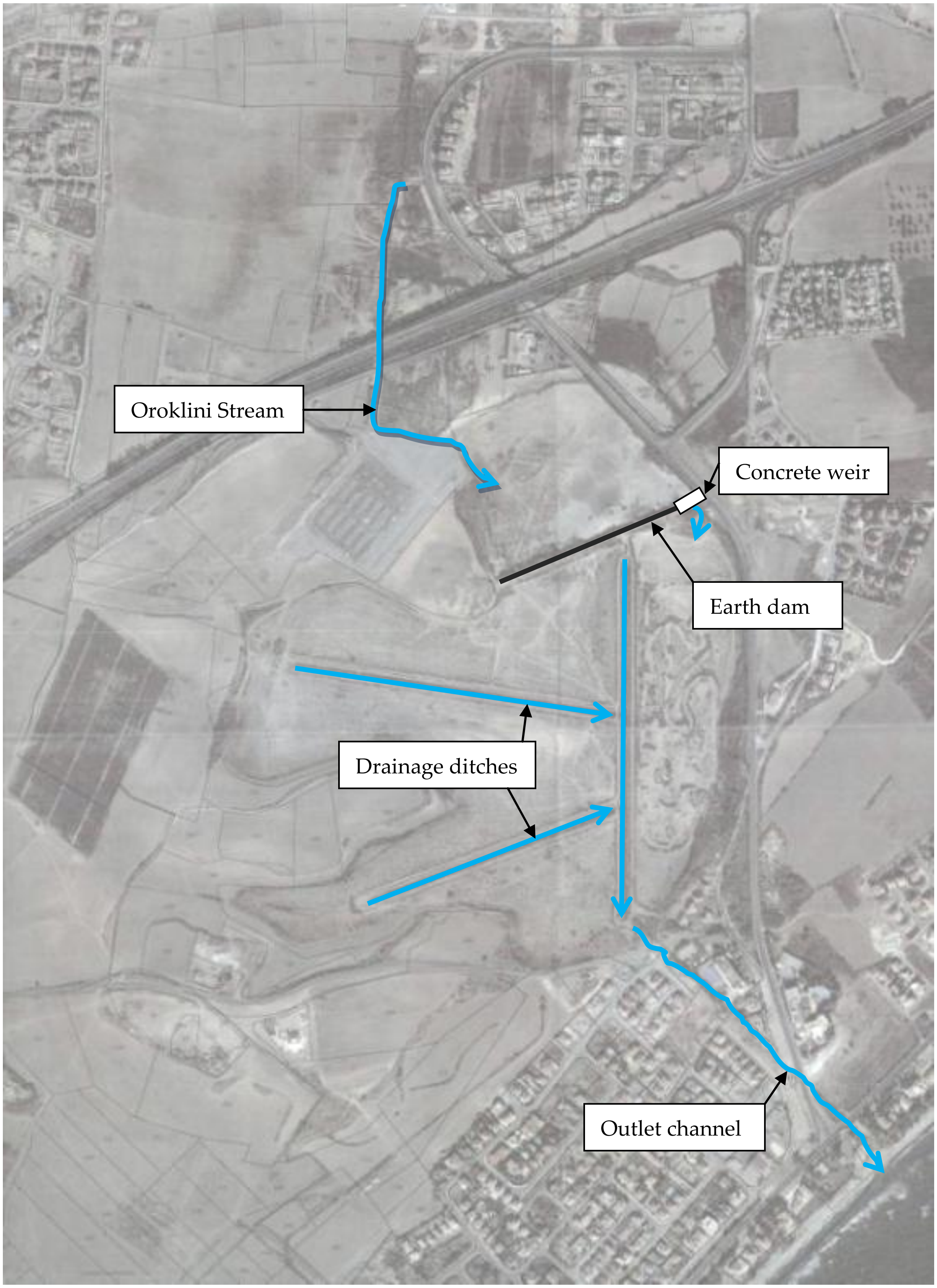
The combination of a low-lying, impermeable land and saline groundwater in a Mediterranean climate tends towards a seasonal drawdown type system with fluctuating salinity (from largely fresh in winter to hypersaline or dry in late summer), surrounded by brackish tolerant communities of *Phragmites* and salt meadows. This is largely the case at Oroklini, but there are some major differences resulting from attempts to modify the site in the last century:

- The site is divided by a major highway, separating the smaller northern marsh (c25ha) from the larger southern marsh. The northern marsh drains into the southern via culverts. This is an important area for the hydrology of the wetland south of the highway as it can buffer water inputs and could offer opportunities for additional habitat restoration. Further development is likely to increase the speed of runoff in an already 'flashy' system, and low-lying houses would be flood-prone.
- The area is further broken up by smaller roads, notably the one running north on the eastern side of the site which has fragmented a number of peripheral areas and introduced disturbance, runoff problems and constrained hydrological interchange
- There is an abundance of houses and businesses in the catchment which accelerate surface flows, produce grey water and intrude into peripheral habitats. The proximity of so many residents and visitors does offer great opportunities to get people close to nature.
- There is a network of surface drains accelerating flows out of the site. These were attempts to drain the land between 1930-50 to reduce malaria. They have since fallen into variable states of disrepair. The reduced functionality of drainage has helped in recent years to retain water on the site with benefits for wildlife.

- The most significant feature is a 292m long earth-fill dam and concrete overflow weir isolating the north-eastern corner of the southern marsh, creating up to 8ha of lake, muddy edge and marginal vegetation. The origins of this structure are not clear, but could have been an attempt at aquaculture, or possibly an irrigation water store. The result has been the most reliable open water area on the site with an abundance of wildlife interest.



Oroklini Marsh key compartments



Key hydrological features of the site and implications for water management

The Northern Marsh

This is a substantial part of the site (25ha) separated by the main highway, with reed-filled ditches draining both surface water and other mixed drainage inputs from across the roads. The area is largely higher than the southern marsh, and land levels rise significantly towards the north.   There is a mix of reed-filled ditches, salt meadow and bare ground which does occasionally become surface-wet in high rainfall situations.


Northern Marsh, looking towards the north, showing recently cleared ditch

Water from this part of the site drains under the minor road to the north of the highway, then passes under the main highway in large twin culverts.   A smaller flow from another culvert also passes under the highway at an angle from the north-west, discharging close to the ford on the minor road on the south side of the highway .   The largest drainage ditch had recently been cleared of reed, widened and deepened on the east side of the marsh.

The hydrological record (back to 1968) indicates that the Oroklini Stream frequently flows through the summer. Water quality is rather poor in the surface flows in the Oroklini Stream (I.A.Co), with elevated nutrient levels (eg up to 10mg/l of total N) and high conductivity (up to 16mS/cm).   Detailed investigation of the water composition indicates that the salt is derived from deeper soil layers, rather than direct seawater inputs.

The main culvert under the highway, draining the northern marsh towards the south.

Compartment S3 (Oroklini Lake), the dam and weir

Water flows from the highway culvert, across the access road alongside, through a narrow and reed-filled ditch, and out into compartment S3. This ditch (the Oroklini Stream) used to be culverted and had an access to an illegal market area on the west side, and the land to the east was the car park for the garden centre, but this is now an open channel all the way through.

Compartment S3 is the most reliably wet part of the site because of a 292m long earth-fill dam and a concrete weir at its easternmost end.

I.A.Co. have carried out a survey of the integrity of the dam. The dam is wide and is generally in good condition despite being constructed of rock, concrete, and fine crushings, without the use of a binding agent. Vegetation (mostly tamarisk and reed) has grown densely along the dam, and particularly in and around the weir. It is possible that roots could weaken the dam structure and certainly make inspection and maintenance more difficult. Inspection by I.A.Co. has shown a point of minor leakage (170m from the west end) and a length of subsidence (0.4-0.5m) immediately to the west of this, as well as some evidence of minor overflowing, but the overall conclusion is that the dam is in good condition and more than adequate as a part of the water management infrastructure.

At the start of the LIFE project the weir at the easternmost end of the dam had been breached using a digger to drain S3 due to bird flu fears in 2008. S3 was reportedly drained in one day, and this water was quickly lost from S6 also. The breach was originally repaired using local infill material, but has since been completed using concrete construction with a crest elevation of approximately 20.00m asl (actual 19.96m asl).

The dam on the south side of S3 looking from the west end.

Compartment S3 weir viewed from the east side, with the new wing wall on near side

Detail of compartment S3 weir, showing rebuilt section of crest on east side

Rebuilt eastern weir and wing wall, with road behind

The capacity of this compartment when water levels are at 20.0m asl is rather small (approximately 40,000m3) and levels typically fall during the spring and summer due to evaporation.

In a typical year, winter rain and inputs from the Oroklini Stream will raise water levels in the compartment to the 20.0m asl weir crest height and then overflow. The 9m width of the weir and high wing walls permit a large overflow of storm water. I.A.Co. estimated that the weir has enough capacity to cope with a 1:100 year flood event without risking overtopping of the adjacent dam crest.

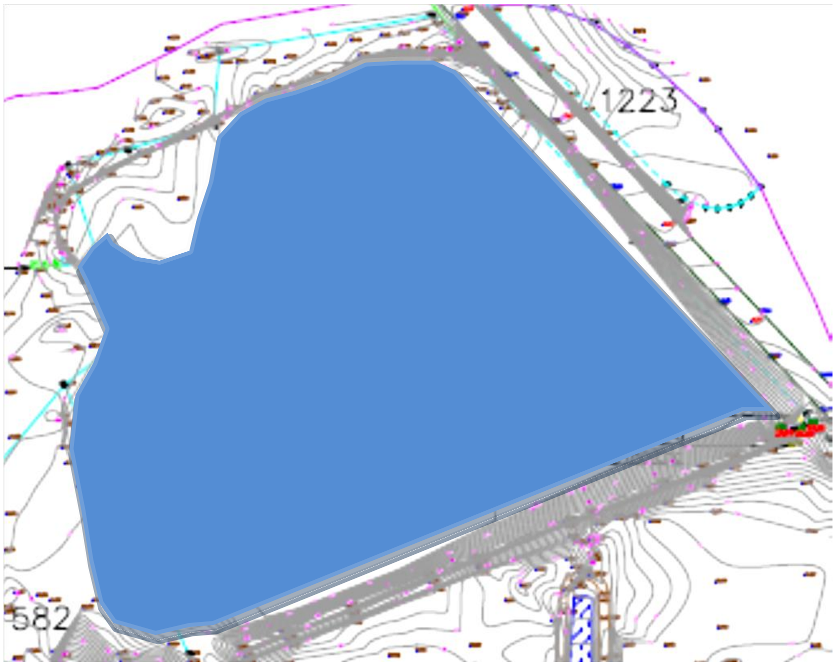
Ground levels in compartment S3 vary from approximately 19.4m asl to in excess of 20.0m asl, particularly in the north west corner which has a broad band of mature reeds and a sinuous muddy margin. This means that at a typical late winter peak water level of 20.0m asl, water will cover around 85% of the compartment, with an additional 20% of the compartment with water less than 20cm deep, suitable for a broad range of waders (including black-winged stilt) and wildfowl. Evapotranspiration is likely to increase during the spring, from 1mm/ day in March to up to 6mm/day in June, resulting in a fall in water levels to approximately 19.55m asl, and covering approximately 40% of the compartment, much of which is less than 10cm deep. The retreating water level leaves an exposed muddy edge as it progresses.

Falling water levels and evaporation also lead to a rise in salinity due to capillary rise of groundwater, but continuing surface inputs from the Oroklini Stream counteract this and should prevent the onset of hypersalinity which is associated with poorer breeding outcomes. Stream inputs and the rebuilt weir should prevent complete drying which has been damaging to bird, fish and invertebrate interests on the site.

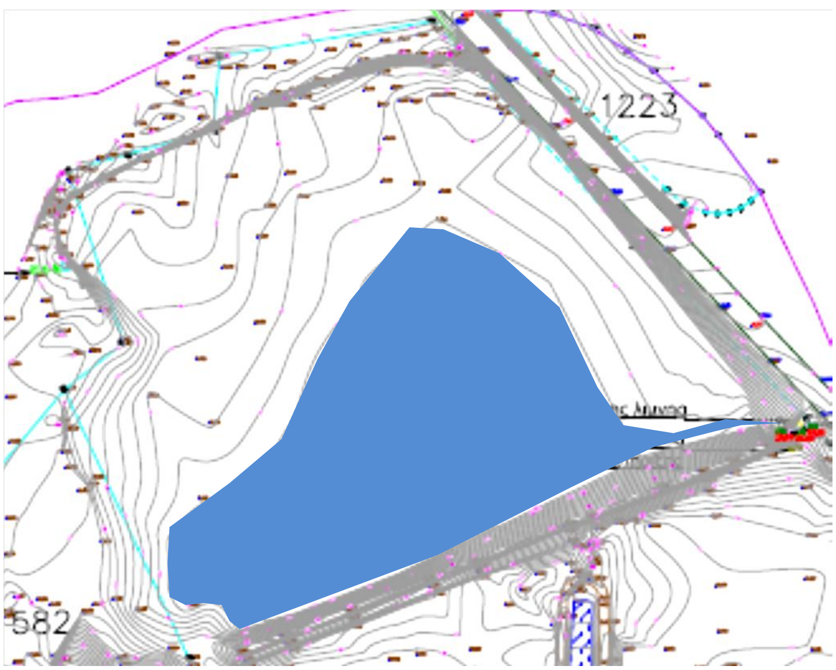
View over compartment S3 from new viewing hide, the weir is towards the far left corner, with water levels at approximately 20.0m asl.

View over compartment S3 from new viewing hide, looking towards the west

The new viewing hide overlooking compartment S3



Compartment S3, water extent at approximate weir crest elevation of 20.0m, expected in late winter



Compartment S3, water extent at 19.5m asl, expected by June in typical year.

The Southern marsh, Compartments S6 and S7

Compartments S6 and S7 make up the largest part of the site. They are low-lying areas of sporadically flooded bare ground and salt meadow with clumps of tamarisk. The compartments are crossed by deep ditches constructed between 1930-50 which originally drained by gravity to the sea, supplemented by pumping at lower water levels. The remains of the pump station were removed in 2013.

Excess water from Oroklini Lake (compartment S3) overflows the weir and feeds into S6. There are now culverts linking S6 with the main drain running north to south on its western side, and from there into the three sections of compartment S7. Before the LIFE project this area was prone to rapid and prolonged drying during the spring and summer, and was frequently used by vehicles. Feral dogs and cats and other predatory species had easy access to areas that were isolated by open water and suitable for bird breeding early in the spring. The drying was probably accelerated by seepage through the backfilled but porous southern end of the main ditch. There were also periods of extensive flooding in high rainfall situations due to the lack of an actual outflow channel. These large water level fluctuations also resulted in wide variations in salinity during the breeding season, and a lack of suitable feeding edge with available prey species. The few edges that remained along the drainage ditches were very close to dense cover where birds were vulnerable to predation.

In addition, a series of small islands (c10m diameter) were created using material excavated from new, gently-shelving ditches around each one and connected to the main drain. These islands are intended to provide nest sites secure from flood events, and with some protection in falling water conditions from predator and human access. The perimeter ditches also increase the length of feeding edge at a range of water levels. Vegetation was also removed from some existing islands to make them more attractive, particularly for breeding spur-winged lapwings and little terns. The ditches have been connected to adjacent main ditches so that they can be both supplied and drawn down, while allowing fish and eel access.

Compartment S7 (middle), looking west

Compartment S7 (south) showing new island, ditch, and culvert connecting to the main drain, after an exceptionally dry winter and water levels below 18.7m asl.

Ground levels in compartments S6 and S7 are typically 18.3m asl to 18.9m asl, with islands at around 19.2-19.8m asl. The lowest areas tend to be in the middle of S7 and in the centre of S6, and this is apparent as water levels fall in typical spring conditions. Most of these areas are around 18-4-18.6m asl but the lack of variation in ground levels results in a rather small water capacity at target levels, so much of the area is vulnerable to drying.

New hide at the south end of the main ditch, in place of the old pump station

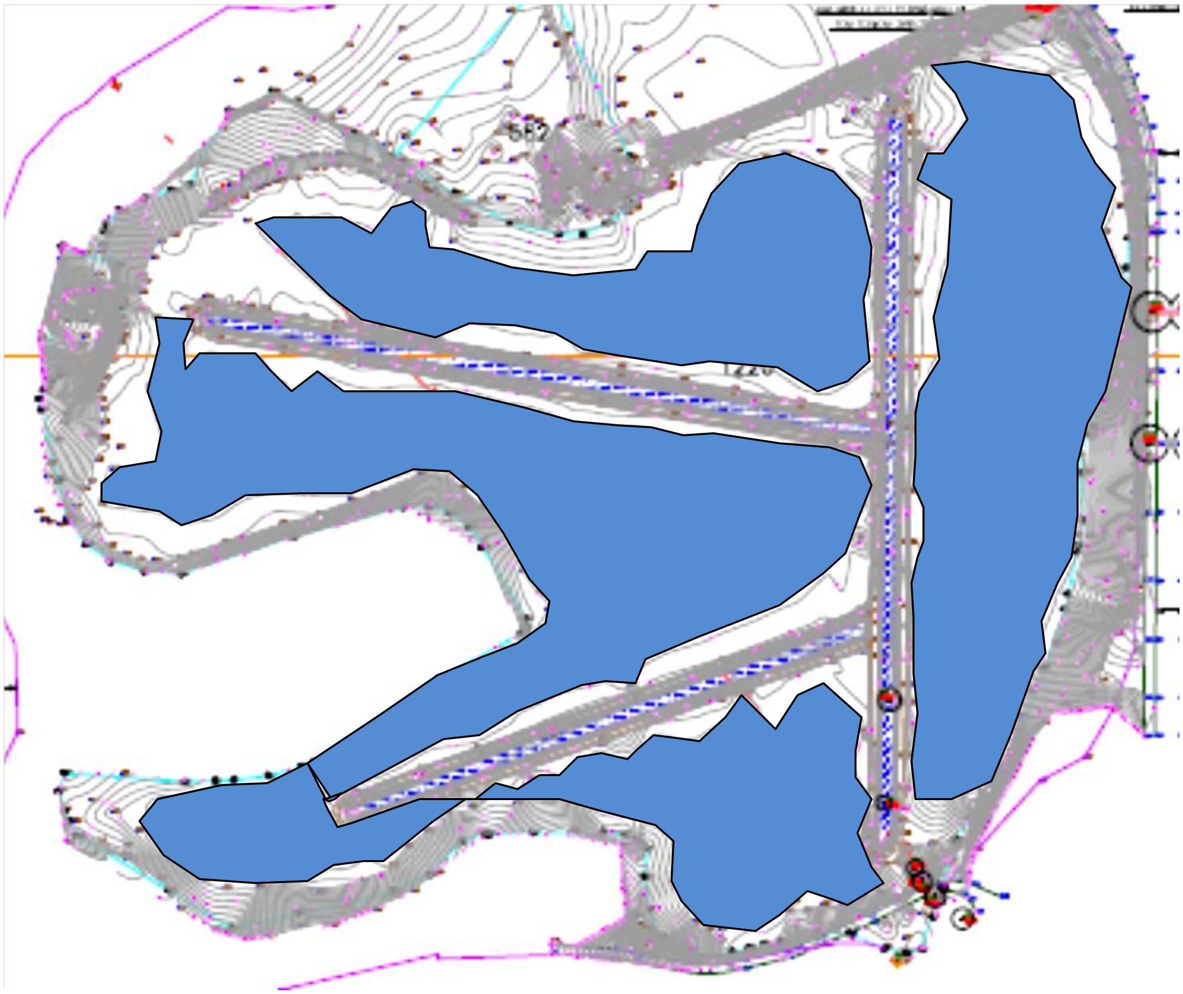

Views over compartments S7 and S6 from the new hide

The drainage channel to the south of the road is functional, but follows an arc around an electricity pole before joining a recently cleared section before the substantial culvert pipes at the beginning of the concrete lined channel. These pipes have an invert level of 18.45m asl, so a further small fall. The curved ditch has steep and eroded sides and a loose electricity cable across it. High flows are likely to cause further erosion (and are more likely with the new outlet pipe and channel) and may endanger the electricity pole and cable.

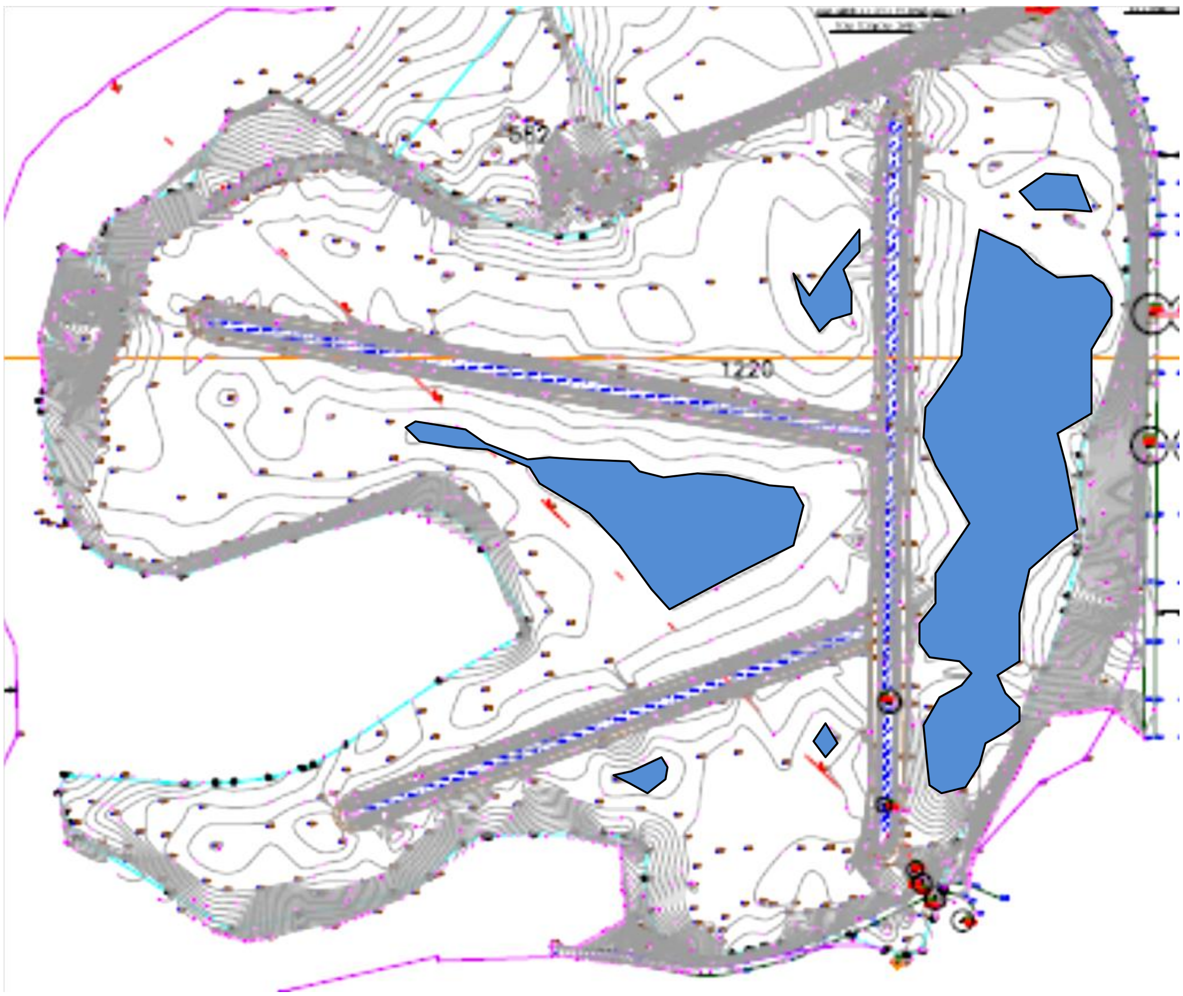
The curved channel and electricity pole to the south of the road

Newly cleared section before the large concrete channels leading to the sea

The final outlet to the sea, recently piped.



Compartments S7 and S6, cover of water at a level of 18.90m asl, a desirable level at the beginning of the breeding season



Compartments S7 and S6, cover of water at a level of 18.70m asl, a desirable level in the later part of the breeding season.

Evapotranspiration is likely to increase during the spring, from 1mm/ day in March to up to 6mm/day in June, resulting in a fall in water levels of approximately 3cm in March, 6cm in April, 12cm in May and 18cm in June, a total fall of 39cm (21cm by the end of May). A water level of around 18.7 and 18.8m asl is desirable in the latter part of the breeding season (late May) to provide significant areas of wet muddy edge and shallow open water adjacent to drier ground. With no freshwater inputs from compartment S3 or direct rainfall this would need a late winter water level of around 18.9-19.0m asl. In a normal year there is likely to be both surface inputs and some rainfall during this period.

Falling water levels and evaporation also lead to a rise in salinity due to capillary rise of groundwater, but continuing surface inputs from compartment S3 and rainfall are likely to counteract this and should prevent the onset of hypersalinity which is associated with poorer breeding outcomes. The freshwater inputs combined with the new water distribution culverts from the main drain into compartment S7 will also go some to preventing complete drying which has been damaging to bird, fish and invertebrate interests on the site. The connections between the remaining water bodies will also allow some fish movement and promote survival. It is possible that the water management infrastructure may lead to some improvements in water quality by retention of winter rainfall - this will have a diluting effect on the high nutrient surface inputs later in the spring.

Water management objectives

Favourable Reference Values for the two key species at the site have recently been set (Tye *et al.*, 2014) at 15 breeding pairs of spur-winged lapwings and 60 breeding pairs of black-winged stilts, based on broad reserve areas, site history and presence at similar sites. These targets assume that the site will be managed optimally for both species, whilst providing benefits for the other Annex 1 species and key halophytic communities.

Achieving a balance for all these objectives is difficult in the context of a site that has a number of constraints, most notably a sporadic freshwater input during the breeding season and no on-site storage. However, recent modifications to the water management infrastructure will allow the manager to make full use of available water. An additional problem is that the micro-habitat requirements of all these target species and communities are rather inexact. Species show a degree of resilience to sub-optimal conditions, by making use of less suitable habitats and showing higher nesting and feeding densities, that can lead to imprecise management recommendations. However in the context of a site with certain unavoidable variations in water levels, specifying seasonal water level ranges is more achievable and may be as effective for key species outcomes.

The water surface level in each of the two key hydrological units (S3, and S6/S7) affects the distribution and depth of water according to topographical variations across the site. It is these small variations in water depth that provide the diversity of niches for the species, primarily for the distribution of feeding habitat, but also the provision of unvegetated ground (recent flooding, good visibility, nest sites), wet muddy edge and water less than 10cm deep (available surface and benthic invertebrates), deeper water (fish, pelagic invertebrates, aquatic vegetation), connection to deeper water bodies (fish access).

Connections to the sea are also of importance for the European eel, which migrates into the site in its immature life stages, and leaves when at breeding age. The variations in water levels are also crucial: recently exposed soft mud is particularly suitable for feeding waders, and periodic inundation and surface drying provides the conditions for mobilisation of salts and capillary rise to retain halophytic communities.

The broad habitat preferences of the key species are as follows:

- Black-winged Stilt: muddy fringes and shallow water up to 30cm depth
- Spur-winged Lapwing: bare ground close to open water, muddy fringes
- Kentish plover: muddy fringes and bare ground close to water
- Stone-curlew: dry, disturbed ground
- Little tern & common tern: open water with fish, islands or bare ground (nesting)

Water management objectives on the site set out to create significant areas and distribution of recently exposed muddy edge habitat with associated shallow water during the breeding season, combined with previously inundated bare or lightly vegetated ground and deeper, interconnected water bodies.

Water management on the site will also:

- prevent complete drying of either of the two compartments, particularly the Lake in compartment S3 and the large drainage ditches in compartments S6 and S7.
- avoid the tendency for hypersalinity in remaining water bodies during the summer and autumn by retaining adequate water volumes and making full use of any continuing freshwater inputs
- prevent excessive winter water levels and their potential impacts on adjacent land and neighbouring properties.

The broad tendency on the site is for water levels to be at their highest after rainfall in winter, then decline during the spring due to lack of rainfall and increasing evapotranspiration, sometimes drying completely by June. Water levels then sporadically recover in autumn to the peak winter level. The water level targets work with this general trend, but aim to ensure a reliable late-winter/early-spring peak, and a controlled drawdown through the breeding season with no complete drying.

These broad objectives are developed into detailed operational requirements in the following sections.

Target water levels

Optimal water levels in metres above sea level, based on the best assessment of the available micro-habitats at differing water levels, modulated by the predicted likelihood of achieving these levels.

	Compartment 3	**Compartments 6&7**	Notes
Jan	20.0	19.0	Peak level, floods prevented
Feb	20.0	19.0	Peak level
Mar	20.0	19.0	Peak level
Apr	19.8	18.8	Drawdown begins
May	19.6	18.7	Ongoing drawdown
June	19.5	18.6	Drawdown slows
July	19.5	18.5	
Aug	19.4	18.5	
Sep	19.4	18.4	Minimum levels
Oct	19.4	18.4	
Nov	19.6	18.6	Levels rise
Dec	19.8	18.8	

For reference, the crest of the weir in S3 is at 20.0m asl

Compartment S3 cannot be managed by the operation of any structure.

Specific operational detail for water management

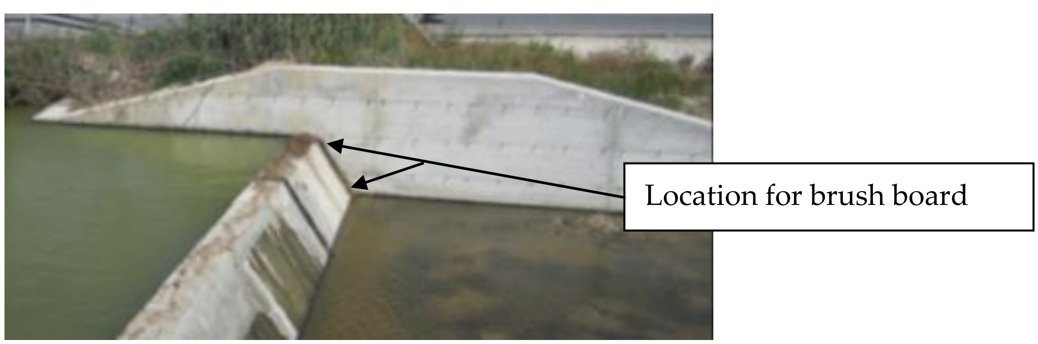
Compartment S3, Oroklini Lake

Maintain the weir. There is potential for the weir to be damaged or modified in an attempt to lower water levels. This may include an attempt to open up a bypass channel between the wing wall and the road. This could have a disastrous effect on the breeding birds.

Clear mature tamarisk from earth-fill dam. The roots are infiltrating the structure, potentially opening up seepage paths and loosening the compacted material. However, leave some to grow around the weir and possibly in the first 10m of the dam to provide some screening.

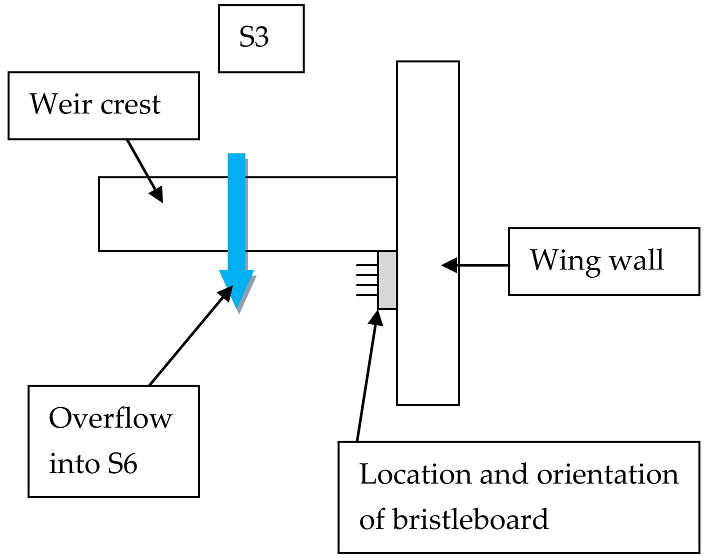
Undertake inspections of the earth-fill dam every 3 years, focusing on previously identified points of potential weakness (see I.A.Co. report, 2012), and any locations where Tamarisk is mature.

Install an eel pass on the weir. Eels will benefit greatly from being able to move upstream into compartment S3 where there is the greatest chance of water being retained. Immature eels will tend to attempt to move up in the angle between the weir face and the wing wall. This can be facilitated by the installation of a 5-10cm width strip of climbing medium, preferably of the 'bristleboard' type, but loosely rolled garden mesh or Astroturf can also work. Even the heads of sweeping brushes screwed to the wing wall would work. The critical factors are to ensure it is right in the angle, and that there is a water flow through it (although this can be infrequent, as eels will move en masse in good conditions).



The angle between the weir face and the concrete wing wall. This eastern side is slightly lower than the west so will overflow for longer and is likely to be preferred by eels

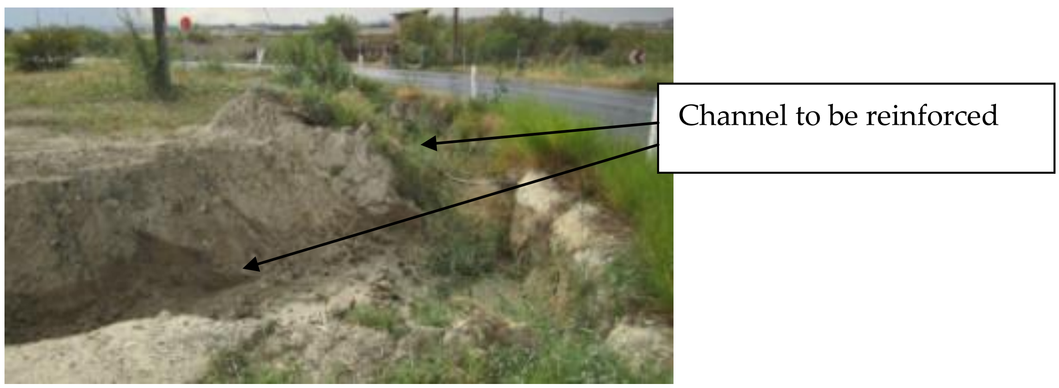
An example of bristleboard.



Compartments S6/S7

Inspect culverts between compartments S6 and S7 and the large drainage ditches, annually, in autumn.   If there is evidence of significant siltation (more than 10cm depth in a 600mm diameter pipe) then they should be manually cleared using a long rod (eg drainage clearing rods).

Continue work to **improve the outflow channel** between the road culvert ÈÕËÛÏÌÓÈÙÎÌ concrete culverts and channels at the housing estate.   At present this is a ÕÈÙÙÖÞÊÜÙÝÌË ditch around an electricity pylon, with a recently enlarged straight section, and ÐÛÏÈÚÕÖ reinforcement.   The sides are eroding in high flow situations. There is also an ÌÓÌÊÛÙÐÊÐÛà cable draped across the ditch.   This channel would ideally run straight from the road culvert to the major culverts to the south, but an underground cable makes this unlikely.   A secondary solution is to retain the alignment around the pylon and reinforce the sides with concrete.   Modular concrete liner sections could be used to line the channel, or constructed in situ. The culvert under the road could also be set lower to enhance outflow and prevent ponding in the channel .



The outlet channel with recently enlarged section.

Associated management actions (not directly related to water management)

Undertake reed control if it spreads into areas lower than that defined by the 19.9m asl contour. There may be a tendency for reed to colonise new areas if water levels are held consistently higher during the growing season, which will reduce the available habitat areas for spur-winged lapwing and black-winged stilt in particular. Reed should be controlled by cutting in late autumn or winter when ground conditions are suitable and there is no risk of damage to breeding birds.

Other vegetation management.

Remove Tamarisk from islands in compartments S6 and S7, primarily for the benefit of breeding spur-winged lapwings. Consider removal of Tamarisk in front of the new hide at the south end of compartments S6 and S7 to open up the view of these compartments. It would also be desirable to remove some of the vegetation along the trackways alongside the main drains in compartments S6 and S7.

Monitoring and review

Water levels. Continue water level logging at the weir in compartment S3 for at least two full seasons (ie until end of March 2016). Supplement these data with occasional readings from two gauge boards. Install one gauge board in S3 close to the weir. The second should be in the main drain (compartment S6/S7). Install the boards securely to strong wooden posts hammered into the substrate. The boards should be set so that they read directly relative to sea level - eg. If the water level in S3 is 19.8 asl at the time of installation then the water surface should be at 0.80 on the gauge board.

Salinity. Take monthly readings of conductivity in both major hydrological units in the site. One reading at the weir in S3, the other in S6/S7. Continue until March 2016 if possible. If monthly readings are not possible, less frequent readings will still be valuable.

Water quality. If possible, take a sample for water quality analysis four times per year, one at the S3 weir, one at the main outlet. Undertake a basic laboratory analysis for the following:
Chloride (mg/l), pH, Total Nitrogen (mg/l), Oxidised Nitrogen (mg/l), Ammonia (mg/l), Total Phosphorus (mg/l).

Monitor development and other interventions in the northern marsh (north of the highway)

This area has some interesting habitat, and acts to buffer the water inflows going under the highway. Any built development in this unit would probably speed up flows and amke water management more difficult in the main wetland. It is recommended that the northern marsh is retained free of development, and that options are developed to restore habitats in the future to increase the resilience of the site to climate change impacts and other land use changes in the wider catchment.

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