SEA LETTUCE (*Ulva* sp.) BLOOM MITIGATION; A UNIQUE OPPORTUNITY USING ST.AUBINS BAY (JERSEY).A TRIAL PROPOSAL FOR 2018.

The seasonal *Ulva* blooms in St.Aubins Bay (Jersey) ,have a negative impact socially, environmentally and economically. The principal bloom driver is nitrogen discharge over base marine levels ,this is multifactorial, and although attenuation processes and operational pressures are being applied to sources ,the reduction to a point where blooms are never triggered may be elusive. This proposal 'adds value' to the expensive 'before or in pipe solutions' being applied , by employing biofouling strategies used in marine industries ,and by increasing the size of the marine N sink by a set of novel ecosystem approaches, in a very low cost approach, eventually rising to a positive 'value added' .

The management of blooms , where the beach or near beach deposit is 'cropped', may be politically obvious but is not a control mechanism. The mismatch of this approach is stark , with *Ulva lactuca* growing at a rate of up to 20% per day at 20C . The biomass increase alone is 60 barge loads per day with St.Aubins Bay in full bloom. The effect of variations in wind strength and insolation, relative to the tidal cycle, overwhelms or conversely outperforms any meaningful mechanical extraction process.

The trial proposed* ,uses the unique bathymetry of St.Aubins Bay to create minimal topological changes at very low cost, to create a cascade of pressures on the early development of *Ulva* , followed by a wave and tidal energy channelling of any developed macroalgae into the low water gyre and then a competitive N sink in the form of a resurgent *Zostrea noltii* (small leaf morphotype) canopy and potentially a nearby Native European Oyster *Ostrea edulis* aquaculture system.

*The 'failed furrowing trial' undertaken by the Department of the Environment in late May 2017 had no meaningful relationship with this proposal and was undertaken without reference to the proposer.

SUMMARY

- St.Aubins Bay may well be unique in areas suffering from summer *Ulva* blooms in that the initial bloom generating area is a shallow pitched ,water saturated, fine sand intertidal platform below half tide This has been amplified in recent years by land reclamations reducing advection currents and increasing STW discharges and particulate settlement. Using algal culture terms this is a photo-bioreactor.
- The half tide and below platform is mostly covered by random patches of slightly raised *Zostrea noltii* (a seagrass) and water filled ponding .This seagrass has all the characteristics of the small leaf morphotype , that is generally found in stressed environments and has much faster recovery rates and photosynthetic rates (x5) to overcome smothering.
- These stable ponding create an ideal environment for the adhesion of *Ulva* zoospores and the initial development of discoid thalli .The freshwater STW /outfall component concentrates N in these ponds by partial immiscibility with seawater, particulate settlement, elevated temperatures, and furthermore the sand interstitial bacteria reprocess N back into the pond water above in various bioavailable ions.
- The initial development of an *Ulva* bloom can therefore be located, in the case of St.Aubins at least ,as the first few millimetres of water saturated sand in a clearly defined platform below the half tide mark.Other authors have identified areas such as St.Brieuc where initial settlement is rock derived.
- Significant advances have been made in identifying the mechanisms of settlement of 'biofouling' organisms on to surfaces and the strategies evolving to prevent this. The settlement of *Ulva* zoospores onto wet sand is a biofouling event. This proposed trial encapsulates modern biofouling reduction principals of deter ,deny and disperse by changing the drainage pattern ,increasing atmospheric exposure, lowering surface energies ,periodically removing biofilm and creating physical instability of the first few millimetres of this aspect of `the benthos.
- Present in this area are variable densities of the Seagrass *Zostrea noltii* this has general protection and if the densities exceed a certain minimum , it has specific protection under the OSPAR convention. . Any trial or expanded operation would need to show that any impact on this species was neutral or positive.
- There are natural drainage patterns that start to develop across the below half tide platform that originate from the perched column of water left in the upper sand bank as the tide descends with increasing rate to a maximum at half tide . Naturally the water spreads horizontally across the platform maintaining the ponding throughout the tidal exposure.
- By creating narrow furrows parallel to the natural flow of the water down to the low tide mark ,self-sustaining drainage channels can be established that duct the substantial volume of water normally retained in the area, down to the low tide mark and the gyre beyond.[Disperse]
- The effect of drainage in this way dries the ponding elements and creates a beneficial environment for the seagrass proliferation . The upper few millimetres of sand loses the

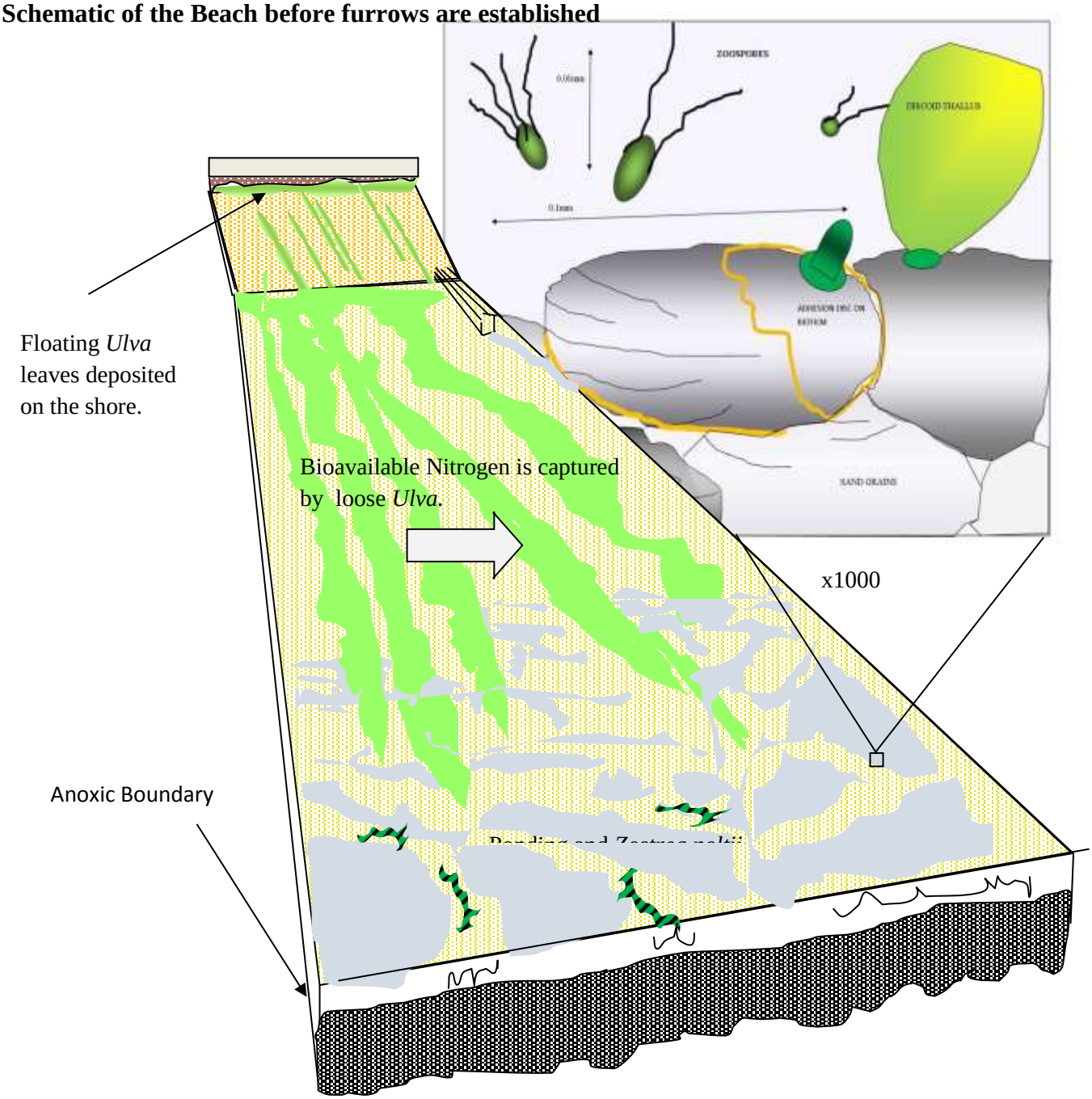
interstitial water and ionic bound biofilm that triggers zoospore settlement[Deter]. This lowers surface energies and exposes any settled zoospores or developing discoid thalli to desiccation [Deny] .

- Much work has been done to create the correct drainage angles and furrow cross sections to minimise seagrass damage to less than 2% initially and probably much less than that given the potential for recovery with limited internodal damage.
- The furrowing should not be confused with the failed trial run by DoE which used heavy machinery, overwide furrows, double side spoil heaps, an area with little surface water drainage, no sea grass, at the wrong part of the tidal cycle, the wrong time of year and most importantly was above the half tide mark which means a quite different sand profile and anoxic layer position.
- Once the self-sustaining furrows are established the seagrass rhizomes will utilise the increased depth between the anoxic layer to increase the number of nodes and the lack of smothering competition will allow significant increase in leaf cover.
- Both *Ulva* and *Zostrea noltii* have similar N dry Weight percentages at c.5%. A resurgent seagrass density will capture a significant proportion of the available N primarily through canopy capture of the advection component ,reducing that available for *Ulva.*
- Hydrodynamic forces are increased by the alternate furrows and domes across the beach and down beach in runnels that magnify wave action , returning the water and energy downwards towards the gyre. This latter mechanism was the only positive outcome of the DoE trial .This eventually gave an opportunity to measure a sea lettuce supporting water column discharging some 40kg of wet weight sea lettuce per furrow per 12 hours. This was not reported by DoE and was not ,to best knowledge, repeated by them. As 300 such furrows could be created this gives a daily discharge potential at high densities of 24 T (or much more) discharged each day. Early on in the season this could equate to more than 20% of the biomass and in itself curtail the potential for explosive growth.[Disperse]
- The initial trigger for this proposal was to investigate the commercial exploitation of the N as a resource, through the ecosystem services that an expanded Native Oyster *Ostrea edulis* industry could provide. The author is a prime mover in creating the true aquaculture of this species in Europe through innovative equipment and increased seed supply. The study of the N fluxes soon identified the *Ulva* as cutting out any increased phytoplankton development needed. The political support for an expanded Native Oyster industry was at best muted with the advice ,'Why can't you try it somewhere else first?' (both Ministers DoI and DoE). This advice has been taken. Significant projects have been successfully run in Scotland, Ireland and in the Solent . Of direct relevance is the direct involvement with the Dornoch Environmental Enhancement Project (DEEP) where Heriot Watt University and an major whisky distiller are seeking to reduce to nothing the environmental impact of the industrial process on controlled waters by using Native Oysters as an ecosystem service provider. This project is creating ground breaking seed supply solutions and gathering hard data on pollutant sequestering and removal. All of this can be translated to a Jersey context if the *Ulva* primary N sink can be overcome.
- If the trial is approved it will be undertaken at no cost to the States of Jersey (there is a commercial potential in aquaculture that underpins this).The monitoring can be undertaken by NGO's and /or 'citizen science' , this will engage the public in 'finding a sea lettuce

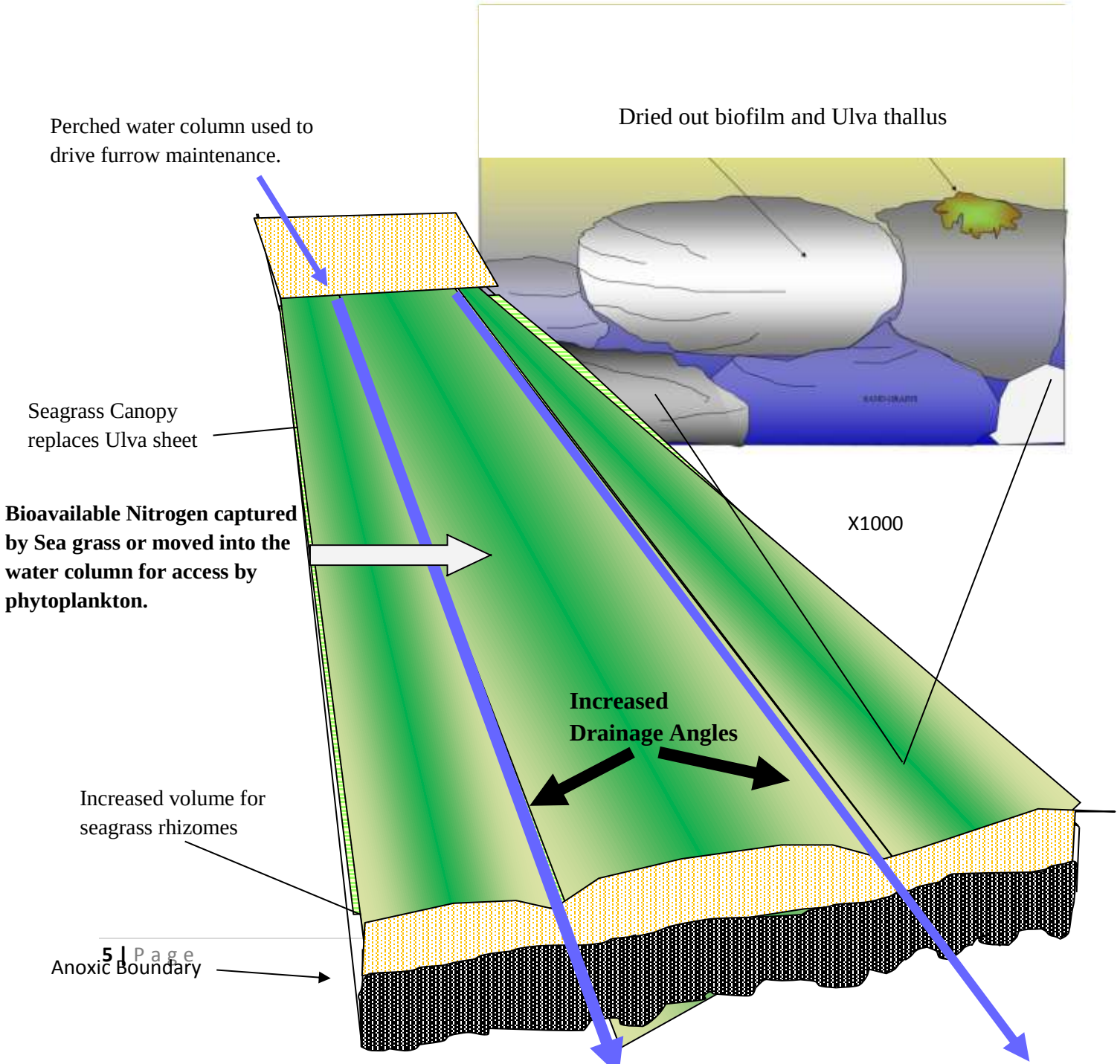
solution', that often directly affects them. Validation can be undertaken by interested academic institutes that are already engaged in equivalent projects.

- The cost of a full years operation would hinge on the number of restoration runs needed on the furrows. If this is the maximum expected (3)then 48 man/4wd hours would be needed at an approximate cost at £50/hr giving a <u>total yearly cost of £2400.</u>

Schematic of the Beach before furrows are established



Lower Beach with established furrows.



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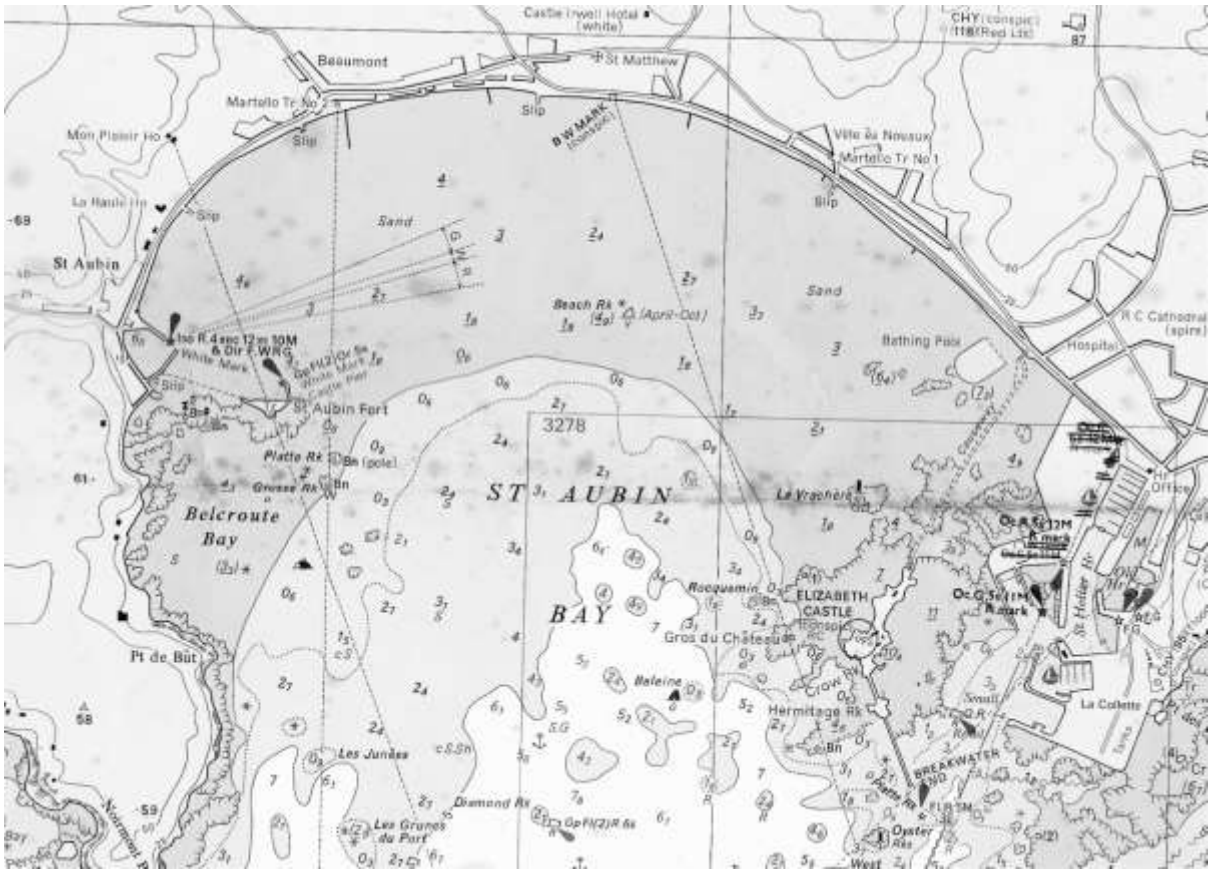
The bathymetry of St.Aubins Bay and biological colonisations.

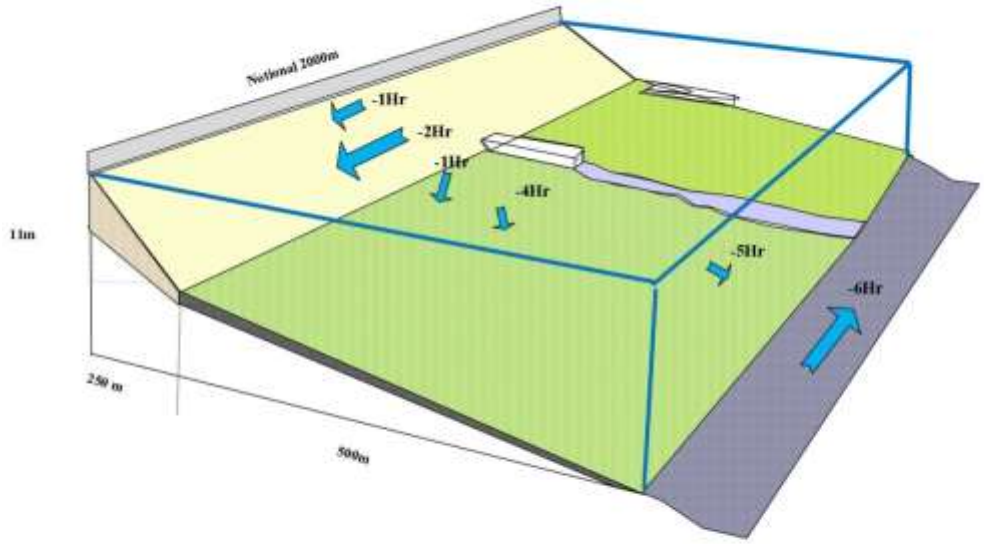
St.Aubins Bay is a shallow pitched sand/gravel to sand /mud intertidal slope approximately a 3Km crescent with up to 600m + drying area southwards. This slope can be split into two distinct sections the higher is around 250m southward at a slope of 1:50 then a lower shallower slope of 500m at 1:100. (Drawing 1)

It is the shallow slope that is of principal interest here. Prior to the land reclamation sequence east of Elizabeth Castle a strong half tide to full tide and back to half tide current flushed the upper beach. That has been considerably truncated and the flow rates seen over the entire causeway previously are only seen in a few hundred metres at the Castle end.

Tidal gyres still happen but they are weaker over the sand platform than previously.A flood tide gyre starts at low water along the sub-littoral bank to the south and provides a potential scour for mobile blooms.



1.General Chart of St.Aubins Bay



2. Diagram showing an exaggerated slope and tidal current directions and relative strengths.

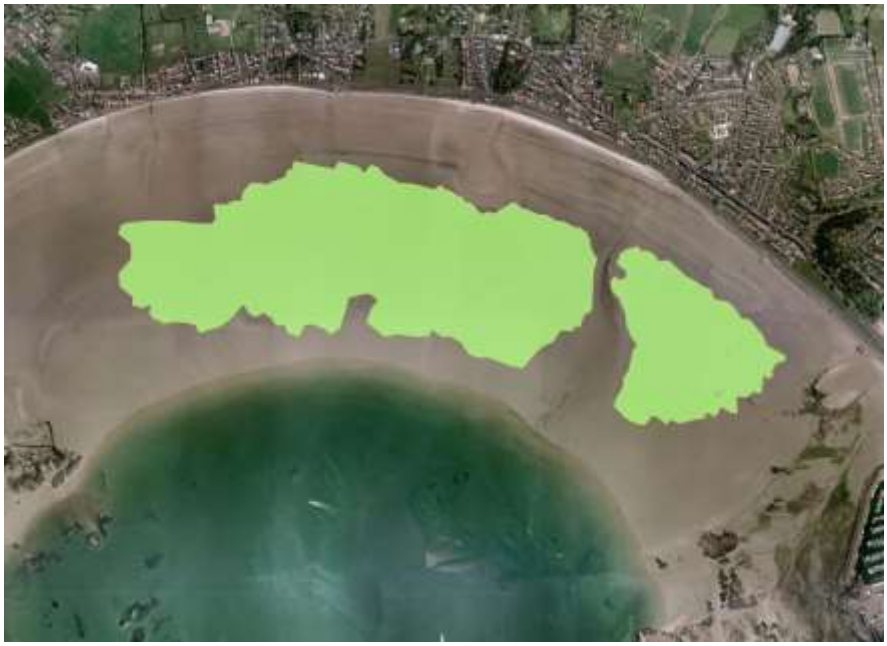
The Bellozanne outfall discharges both STW and stream contents on to the top of the lower area and in Summer low flow conditions is by far the major fresh water and nutrient input.

The reduced purging currents and increasing particulate and colloidal material on to the lower platform has levelled it off somewhat. This area has been colonised year round by the seagrass *Zostrea noltii* . This seagrass has created random marginally raised areas with corresponding marginally lower 'ponding' . This has had a further slowing effect on drainage and has increased deposition. The ponding are in this case , the principal first growing point of the *Ulva* from early spring onwards, they also provide a catchment structure for developed leaves that is assisted by the changes in relative densities of the fresh and seawater components .

The Seagrass *Zostrea noltii.*

The *Z.noltii* beds are important in this proposal as they perceived as ‘ untouchable and unaffected by *Ulva* blooms’, in some quarters. This anxiety is addressed .

The reality is that these beds vary in size significantly year on year and are showing long term persistence . (Photo 1) Shows the beds in 2015.

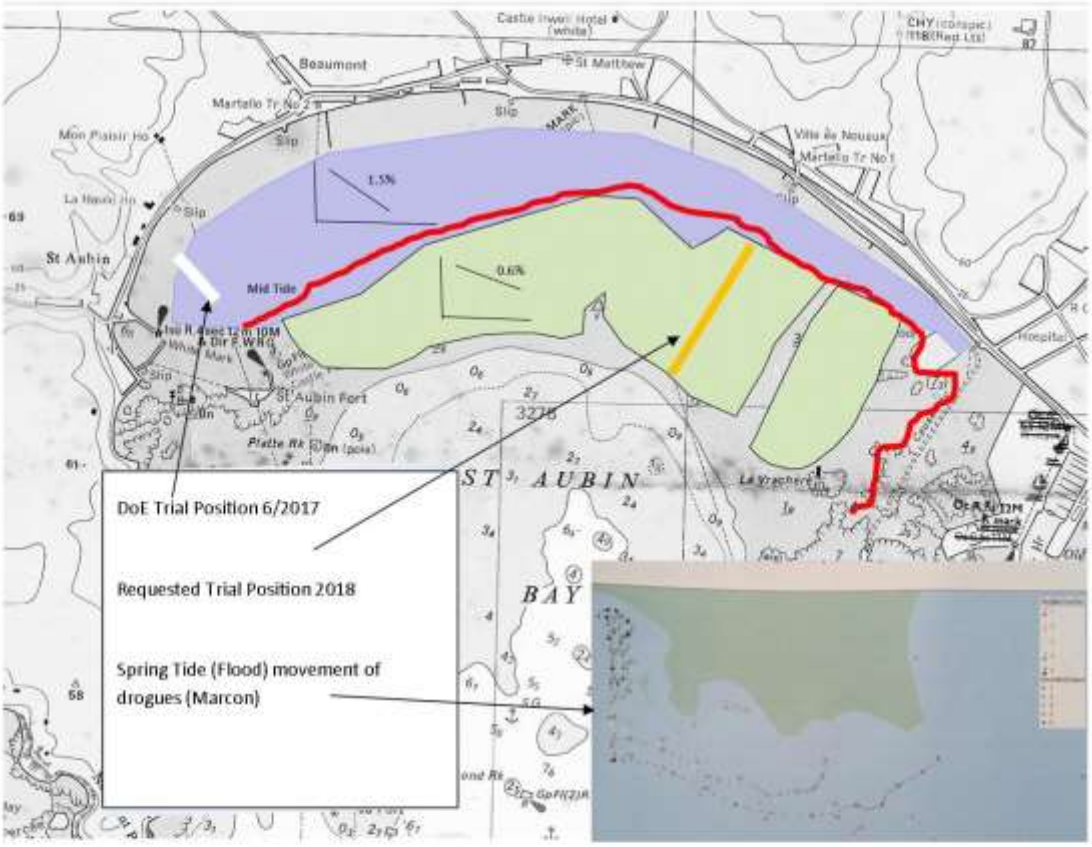


3. Showing seagrass beds in 2015

4. *Zostrea noltii* showing sub-sand rhizomes and above sand leaves.

Z.noltii is species capable of responding to environmental pressures in numerous ways. It responds by smothering by sand in storm effects by rapid horizontal rhizome growth and it has been reported up to 9cm vertical growth. Brun (Botanica Marina 2005) reports , ' Plasticity in this trait (vertical growth) allows *Z.noltii* populations to withstand moderate burial in highly dynamic environments'.

Another technique employed by *Z.noltii* to survive in problematic environments involves ecomorphing into one of two morphotypes. Peralta (Helgo Mar Res (2000)) reports that the short leaf type (which appears to be the main type in St.Aubins Bay) has 5 times the photosynthetic rate of the 'normal' grass, shoot growth is twice as fast (at 2.7cm/day) and rhizome growth also twice as fast (at 4.6cm/day). This has all the hallmarks of a species reacting to a difficult environment.



5. Halftide mark and flood tide drogue movements. This shows the relationship between the seagrass beds ,the half tide mark and the actual positions of the beach slope types. Also marked are the positions of the DoE furrowing trial 2017 well above the half-tide and away from the seagrass beds and the proposed position of a meaningful 2018 trial.

The inset image comes from an investigation by MARCON looking at the feasibility of a long sewage outfall. It clearly shows that anything deposited on a flooding tide on the lower Castle side of the Bay is dispersed eastwards in a rapid current.

Z.noltii canopies capture advective current detritus and then proliferate in the raised areas but do not in the corresponding low points. It is argued here that this is due to the spacing between the anoxic sub-sand boundary and the surface being reduced when there is standing water with a freshwater nutrient mix and high oxygen demand. In *Zostrea Biotopes.An overview of dynamics and sensitivity characteristicsof marine SACs European Seagrasses Davidson and Hughes 1998,* They specifically state ' *Z.noltii* typically occurs on hummocks that are free draining at low tide'.

There is evidence that small scale disturbance can have positive consequences (Rae P.A. Seagrasses of the Moray Firth; Their Response to adjacent industrial development PhD thesis Univ.Aberdeen).

Conversely, Den Hartog (1994) reports that a dense blanket of *Ulva* in Langstone Harbour ,England in 1991 resulted in the loss of 10Ha of *Z.marina* and *Z.noltii* which did not recover.

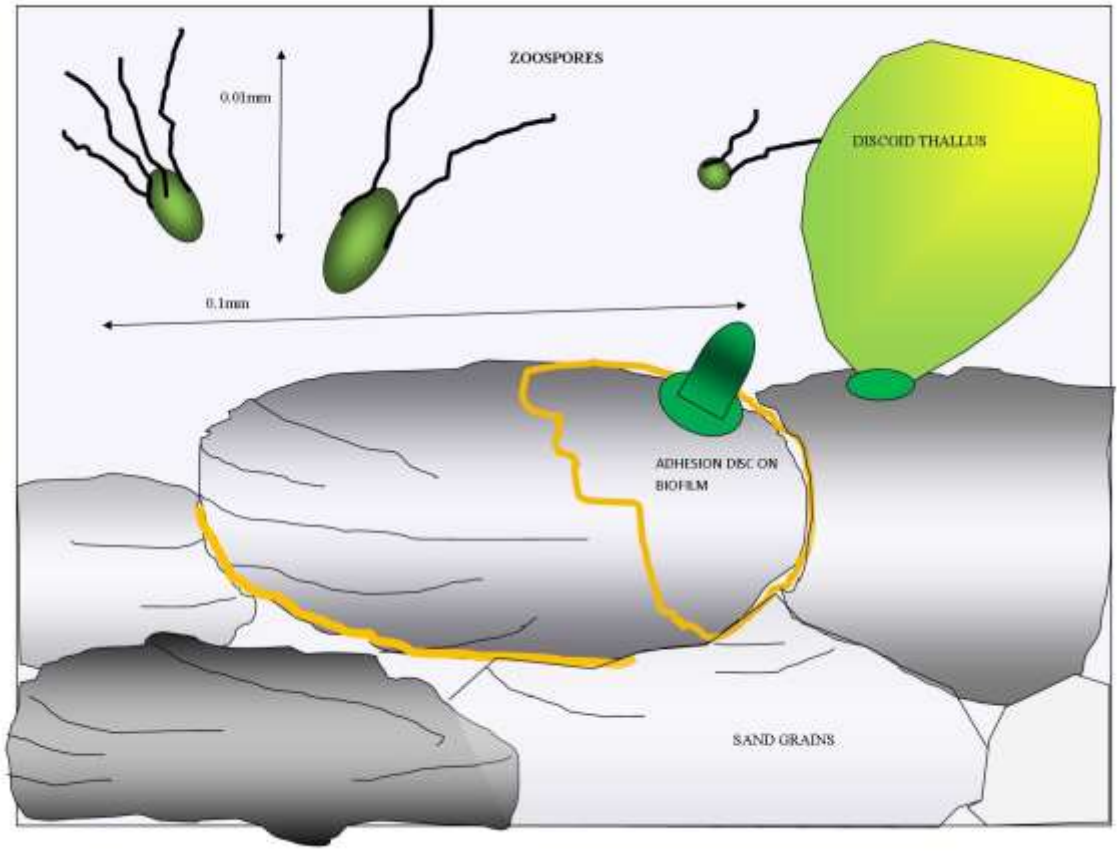
6.*Z.noltii* raised 'banks' and unoccupied 'dips'.

The random ponding retains water across the platform . The focus of this proposed trial is to disrupt this and deny the sea lettuce a favourable environment while enhancing that of the seagrass.

The Sea Lettuce *Ulva* species.

The *Ulva* present in St.Aubins Bay blooms appears to be at the minimum an over lapping development of *Ulva lactuca* then *Ulva rigida* , there is also a bloom of a mix of these and *Ulva intestinalis* ,the latter thalli normally being attached to firm substrates and most noted on the sharp andesite fragments mid tide to low water in the remaining passage between the St.Helier Marina and Elizabeth Castle to the east of the causeway.

A principal element in this proposal is that the mix of STW/stream discharges , a poor mixing at certain tide sizes and states and retained water in random ponding created by the seagrass , creates an ideal environment for *Ulva* zoospores to settle, adhere and then develop attached to sand grains as the initial discoid thalli before partial release as semi-buoyant 'leaves' in a euryhaline environment with fluctuating relative densities .Eventually these fully buoyant in full density seawater as a full scale bloom.



7.Schematic of *Ulva* settlement on wet sand grains.

The fresh STW/stream water has an additional temporary effect that is directly analogous to Norwegian 'pollen' . The pollen are semi-enclosed bays with seawater overlain by fresh water. The effect of this is to act like a greenhouse ,elevating ambient seawater temperatures from 15C to above 30C in bright sunlight. Although less persistent , it is suggested that in certain tidal conditions often present in mid summer, an overlay of nutrient rich and particulate material with colloidal mixing on the boundary with seawater exists for many hours. This can elevate the benthic boundary temperature to considerably above ambient seawater. Simply applying a standard Q10 enzymatic rate increase could give a long period in the day where the zoospores and thalli are growing at twice the rate to be expected at ambient seawater temperatures.It also creates an equivalent increase in the metabolic rate of interstitial nitrogen cycle bacteria and therefore the influence of substrate/water N fluxes (see (Brandes et al New Developments in the Marine Nitrogen Cycle Chem Rev 2007).

If the opportunistic sea lettuce were not present then the available N in the water column would be mixed in the tidal gyre more readily, the seagrass binds mostly from the rhizomes and are bounded by canopy height outside the sand level. This would therefore aid N dispersal generally.

In summary at this stage; the bloom initiation can be linked to the relationship between the STW /stream discharge, *Z.nolti* pondings on the mid tide and below platform and complex physico-chemical reations between nutrient rich fresh water and seawater with a overlay of variable tidal depths and energies. This has created a 'bio-reactor' environment that has been exploited by the opportunistic *Ulva* genus. The challenge is to deter, deny and disperse the *Ulva* at this early stage while maintainingor improving the seagrass environment, all at low cost.

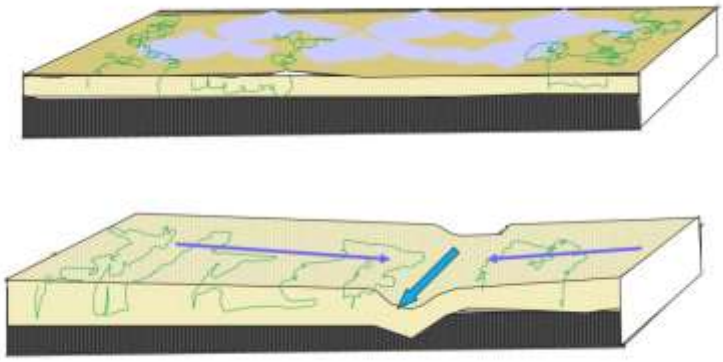
The Furrowing Process.

The deter , deny, disperse process hinges on drainage patterns.

DETER.A drying surface of sand is unattractive to zoospores , this is due to complex energetic reactions relating to biofilm surfaces on the sand grains . A dry sand surface will deter initial settlement, but the recovery of that surface towards being an attractor re-starts in under a day of full immersion. This means that on neap tides the dry sand deterrence is ineffective but on a sunny day with spring tides is highly effective. The deterrent effect of a drained sand surface is intermittent and dependent on tidal conditions.

DENY. Given that deterrence can only be partially successful it has to be assumed that some zoospores will successfully adhere to sand grains and will develop into initial thalli. A drying surface in bright sunlight will rapidly desiccate the delicate discoid thallus stage . Alongside this effect is that of hydrodynamic disturbance. To achieve drainage a 1.5% -2% overall angle down beach is needed in porous structures . This generates surface currents on the upper boundary that do not arise in the ponding at present. Any surface sand grain with a 'sail' of thallus will be gradually moved down stream into any drainage channel.

DISPERSE.If drainage channels run at right angles to the shore then at its simplest the drainage flows will carry dislocated thalli and leaves.



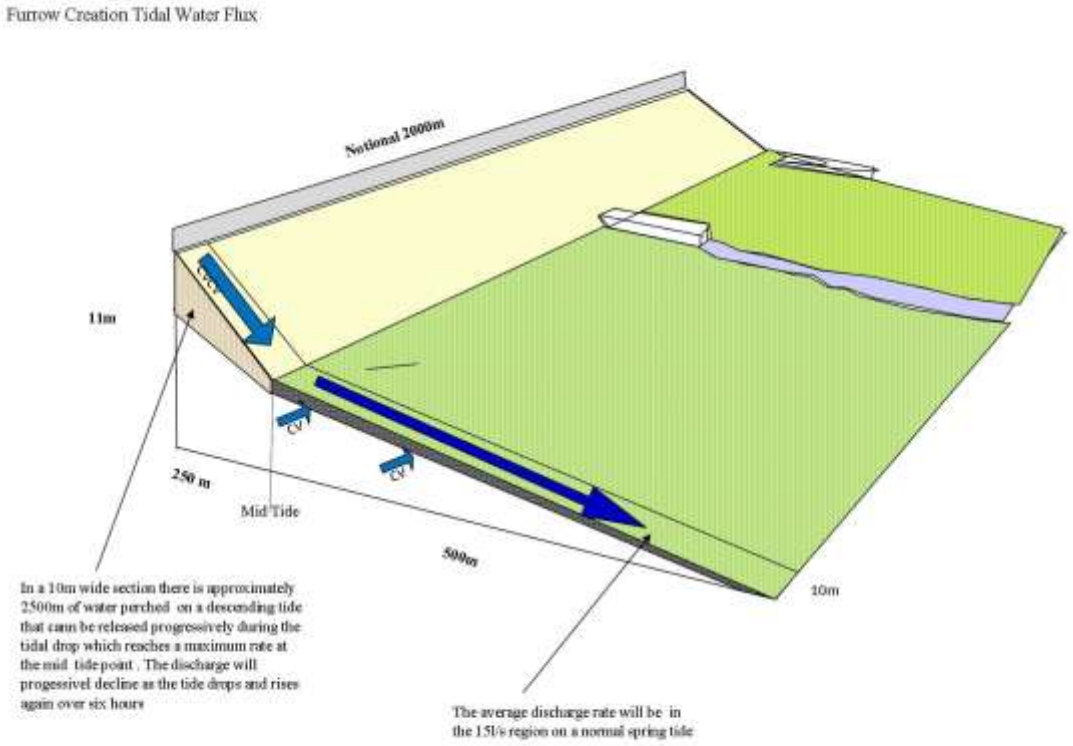
8.A simple schematic showing how a furrow drainage channel would change the surface ponding configuration.

How could self sustaining furrows be established?

The St.Aubins Bay beach profile holds the answer , it can be split into two areas in the central section .

The first 250m is a relatively steep slope of coarse sand that drains completely over a tidal cycle, the remaining 500m is half the slope and contains the ponding.

As the tide drops every 10m length of shoreline parallel to the seawall and down to the mid tide mark contains 2500m^3 of water that is available to flow out.



9. Perched sea water in the beach profile.

At present this breaks the surface or is retained at the half tide boundary/substrate change and often runs over the surface increasing the ponding persistence.

10.The boundary at half tide is clearly marked and the energy in the discharged water over the lower ponding is just enough to mobilise the deposited 'leaves'.

If a furrow at right angles to the shore is cut from the mid tide point to low water this would create a preferential drainage channel ,substantially focussing the water flow and consequent water velocities. The increased velocities generate enough energy to keep the sand particles and weed deposited in the channel mobile and moving down stream. There is also a change in oxidation which makes sand previously bound by anoxic conditions more mobile.

If the furrows are cut at the start of a spring tide sequence the repeated tidal pumping will establish the structures over a period of ten days or thereabouts.

(it should be noted that the DoE trial was not done at this beach position or level and was commenced on shortening tides)

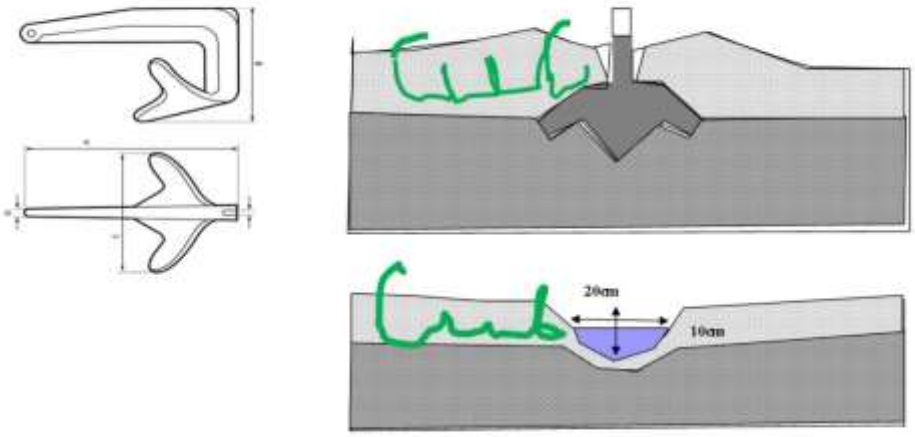
Much work has been done to maximise the effectiveness of the furrows at the same time minimising damage to the seagrass and keeping costs to a minimum.

The result is a remarkably simple and light solution. In order to cut as few seagrass rhizomes as possible because recovery is possible from as few as two nodes , a process of ploughing below the rhizomes was investigated with a thin shaft as the initial drainage channel cutter.

Once the optimum profiles were drawn it became obvious that the shape needed was exactly that of a 'Bruce' style anchor. A trial was run ,drawing the anchor behind a modest 4wd vehicle and could not only could it run at 15kph with a 25kg anchor but the wheels did not cut into the sand surface damaging rhizomes. The resultant furrow soon established itself and the rhizomes in the disturbed section did not emerge from the sand except at the

final point of cutting. The negative is that it creates a slightly shallower furrow than was desired but with a much smaller cross section. This means that effective drainage can be achieved but at the expense of slightly closer furrows than the initial proposal.

The initial proposal expected 15m between furrows and 25cm wide channel a 1.66% loss of initial seagrass habitat before recovery, whereas the new solution using the Bruce anchor will be every 10m but ony 15cm wide approximately , also 1.66% estimated.



11.A ‘Bruce’ anchor and the shape of the submerged furrow and resultant channel.

It is worth contrasting this approach with the DoE trial furrows that were reported as showing furrowing was a failure in all aspects. Apart from the positional choice , the choice of machinery appears to be a very large 4wd tractor drawing a form of double sided plough . The result is a furrow at a maximum depth as suggested before the Bruce solution was found in February 2017, of nearly 50cm but as the tip of a triangular cut with a steeply inclined final furrow single share plough. The resulting profile from the DoE experiment was a wide cut base at 50cm necessitating a big tractor and discharge spoil heaps on both sides

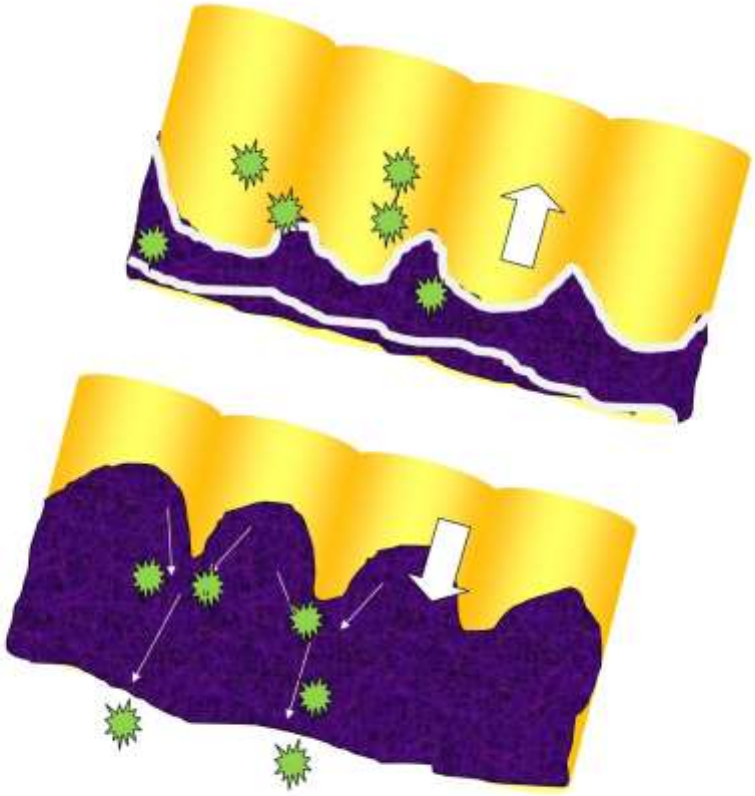
that hinder the establishment of the furrow shape and results in slumping in on both sides on first immersion.

The criticism then arose that it required too large a tractor, they back filled rapidly and the damaged area was in excess of 10% compared with a 1.66% prediction.

12.The DoE trial 30th May 2017 with selected observers.

Part of the furrowing effect is to generate hydrodynamic currents in order to dislodge and disperse significant quantities of ‘leaf’ should they develop.

This element employs a micro version of a rip tide found on beaches with surf. An incoming wave runs over the top of the ‘corrugated’ surface de-accelerating at different rates depending on where it is on the curve. As the wave retreats the water runs into the furrow and increases in velocity dragging any suspended contents with it. On a descending tide the net movement is downwards towards the low tide gyre.



13.A graphic showing how the micro-rip functions with wave activity.Four ‘corrugations ‘ represent 40m width.

Despite the negative reporting of the DoE trial , this aspect was observed to work for a number of days after ploughing. The photographs below show, i. The end of furrow discharge point with a higher density of deposited sea lettuce than the surroundings, and ii. Weed captured in the channel on the descending tide at a much greater density than the surroundings.

This process alone , early in the season when the biomass is small could be capable of forestalling a bloom by displacing more than the daily growing volume into the gyre for dispersal away from the bay.

14.End of furrow discharge showing weed collected at a high density than the surroundings

7 days after furrowing.

15.Weed collecting in the depression 3 days after furrowing.

Ecosystem services and competitive nutrient extraction.

A significant element of this approach is to create an environment that favours *Z.noltii* over *Ulva*. The creation of the domes and furrows is part of that, the seagrass is observed in slight hummocks in normal conditions. This is probably due to two factors, firstly the canopy tends to trap sediment at the point of the rhizome emergence into external leaves and secondly the slight raising improves drainage and therefore the gap between the surface and the anoxic boundary that forms a bottom limit for the rhizomes . These surface drying conditions are part of the deter/ deny effect for limiting *Ulva.*

In a straight competition between the two the *Ulva* would be the most successful but by shifting the surface conditions towards the *Z.noltii* preference , it is predicted that the seagrass will increase in density significantly . This means that a greater biomass of seagrass will be present to further stabilise the furrow/dome system and to extract more N from the water column and sand. The dry weight nitrogen concentrations of the seagrass and the sealettuce are equivalent at approximately 4% and with a potential standing crop of 2-3000T of seagrass compared to a current 2-300T this represents a significant nutrient sink. Unlike the sealettuce the seagrass can continue to photosynthesise out of water and the rhizomes continue to extract nutrients from the sand column. Additionally, a reduction in smothering allows further a acceleration in photosynthesis this is especially pronounced as the seagrass is a C4 cycle plant (as in tropical plants) due to the osmoregulatory requirements of the genus.

Some of the nutrients in the water column will now not be intercepted by the *Ulva* and will not pass through the seagrass canopy or sand column for capture. This element will become available for phytoplankton blooms and the next level of proposed ecosystem services Native European Oysters *Ostrea edulis.*

Ostrea edulis is a keystone species that significantly enhances biodiversity and has European action plans and is an OSPAR priority species.There are indications that St.Aubins Bay is near to eutrophication and is MFD Moderate for species diversity. It is also rapidly becoming an economically important true aquaculture product due in large part to research undertaken in Jersey.

With regard to ecosystem services , this oyster is a significant sink for nitrogen both into tissues and shell but also as contributor to the benthic bacterial flora. Work is currently underway to enumerate the level of services especially in an associated project the Dornoch

Environmental Enhancement Project (DEEP) led by Professor Bill Sanderson of Heriot Watt University. The combined limiting factors of seed supply and culture techniques have been addressed . Sites for seed and nursery production have been established outside the Island (as have ongrowing sites), as both Ministers for Infrastructure and Environment had suggested. The unique culture equipment has been IP protected and is in full manufacture by Jersey Sea Farms.

When this was first mooted as an option in 2015, without reference to the proposer the comment from the Minister for the Environment was 'it will probably not work ',and' it would not be appropriate to have that level of tractor and trailer activity on St.Aubins beach'.

The reality is quite different, the oysters up to 20g would be grown elsewhere on intertidal sites some in Jersey but others in disease free areas of the UK ,Ireland and Denmark using seed produced in ponds in those countries. These sites are already established and are using Jersey Sea Farms ORTAC4 units (see image). These units utilise 'beyond state of the art' (hence IPR achievement) in biofouling control and this forms some of the basis for the deter,deny,disperse approach above .

16.The ORTAC4 Nursery system in use in 2017 in Ireland. The system uses numerous biofouling reduction strategies in conjunction, the research involved formed the basis for this proposal.

The ongrowing system is nothing like the intertidal bag and trestle system used locally for Pacific Oysters that the Minister alluded to. This is the Jersey Sea Farms Microreef (IPR protected) system. This contains 1000 oysters to be grown from 20g to 75 g in one year. In this case they are placed on the sea floor by boat and harvested a year later in the same way. There is no intervening labour requirement.

17.The Jersey Sea Farms Microreef system containing 1000 Native Oysters. This system can produce 300T/Ha in specific conditions.No intervening labour is required.

The potential for the generation of thousands of tonnes of premium oysters with positive economic and environmental consequences is a real one . The irony that it could rapidly become the size of the Jersey Royal industry while controlling that industries nutrient excesses should not be lost.

However, what was ‘unkown’ by the European aquaculture industry in 2015 is now out of the bottle and European Aquaculture Society Annual Conference 2017 has as its main impetus ‘How to re-create the European Native Oyster industry’, Jersey Sea Farms are the

thematic leader.There are other major projects that JSF are involved in that seek the same restoration and ecosystems services outcomes , such as the Blue Marine Foundation ,Solent Project, and a German one looking at windfarm areas in the North sea (AWI university).

The Proposed Trial.

It is proposed to fully undertake the trial using donated time and equipment and monitored by volunteers under supervision from an external academic body (there are two who have expressed interest).The equipment needed includes access to a beach suitable 4WD vehicle, 25 kg Bruce anchor, short length of chain ,sample phials, x 1000 optical microscope (can be a bolt on to smart phone) and access to a camera drone.

The period would be March to September inclusive and sampling fortnightly on spring tides.

Early 2018 Permission to undertake a trial of two furrows within the seagrass zone below the half tide mark, and designate an equivalent control position.

March 2018 Plough the furrows at the beginning of a spring tide sequence. Commence monitoring fortnightly.

If the furrows need reconstituting along the original path due to storm activity to do this as and when needed.

September 2018 Complete sampling and compile a report.

2019 Estimate of full operational costs.

Depending on the results an expectation of cost would be related to driver and vehicle costs .

Given an expected 10kph furrowing sped (conservative) it will take 12 hours running to cut the furrows. As only three hours per day are possible and that there would be an hour preparation/return time this would take 4 days at 4hrs to complete. If it needs refreshing twice more in a season that would give 48hrs of vehicle and driver time. At a notional £50/hr the cost is likely to be £2,400 a year.

Annex.

Prior to the DoE Trial a dialogue developed between Gareth Jeffreys Chair Societe Jersiase Marine Biology Section, and myself (Tony Legg) on some details surrounding the proposal. As these questions may well be raised again I thought it would be valuable to show them and the responses.

Has your research into the effectiveness of the furrows been based principally on the life cycle traits of *Ulva rigida* ?

No, it was both species and there is more to the process than just furrowing. Some of the knowledge comes from clam farming where similar furrows are made. There was also a trial in Denmark that showed 20cm/s flow was enough to dislodge Ulva from the substrate.

Can you provide the calculation , based on samples taken of the estimated volume of interstitial N retained in St.Aubins Bay and the predicted release of N per individual furrow (stating furrow length and width) to quantify its effectiveness?

I have asked both Jacqui Carrel and Tim du Feu to take interstitial water samples , the circumstantial evidence and experience elsewhere is a strong indication, it should be noted that high N is a negative factor for Znoltii especially when linked to a high S boundary.This factor could be regarded as an indicator of it being industrially impacted, in that it should be doing even better and more often.The evidence from oyster ecosystem calculations is that N release can be very variable . The effect I am looking for with the furrows in this respect is that of fluid flow draining a large area making the low salinity discharge that would normally sit in a stationary ponding , instead flow out beyond the MLWS.

The effectiveness of the furrows is related to the suppression of Ulva blooms the quantification of the release of N from fresh furrows is an academic nicety only and a complex one to assess anyway.

What areas in St.Aubins Bay have the necessary profile for furrow use to work in respect to reducing Ulva. Is the presence of seagrass a requisite for furrows, or is it that in the Bay it is only the areas where seagrass is present that has the correct profile?

I do think that it is important for seagrass to be present for two fundamental reasons. First that any damage/recovery should be looked at and monitored otherwise it would need to be repeated at some other time anyway. Secondly only the areas with seagrass have both the ponding problem and the higher beach steep profile underlain by coarse grit at 20cm and below.

Is there evidence available that suggests in order to maintain the state and abundance of seagrass in St.Aubins Bay, artificial human intervention is required?

The point of the ecosystem services use of Znoltii is not to maintain it at its current modest state of abundance, which is only just adequate to attain OSPAR protection, and probably one fifth of a potential maximum. It is to increase it substantially by creating a competitive edge against the Ulva with the structural and physico-chemical environment to maintain that edge.

Is there a reason why the disbursement of interstitial N and the lowering of the anoxic layer through furrow use cannot be tested in the absence of seagrass.

As above , there are no areas that have the right profiles and also have no seagrass.

What I would actually like to talk about is in the fact that the likely consequences if an initial trial was to prove successful. The proposal seems only to cover certain aspects of tidal flow and the effects of intensifying current speeds , principally being in relation to those on an outgoing tide.Obviously if you are proposing to artificially manipulate the topography of a beach for the intent purpose of intensifying current speed you must review the effects of an incoming tide and extreme weather conditions, In this respect I have two major concerns that I wanted to confirm that you had considered as part of the project design;

1.Due to the ability of the seagrass and associated bacterias to fix N,S and C, as well as pollutants, the areas necessary for furrows will have naturally higher levels of retained N,C and S which the act of digging trenches at low tide will expose. Consequently N, and S, in particular will be released into the water column in the greatest concentration on an incoming tide to be mixed up and dispersed within the bay , not out of it. Ultimately , by digging furrows the short term result would most likely be an increased inflow of N that is maintained in the water column, creating conditions better suited for the growth of Ulva than Zostera.

It must be remembered that this is only 2% of the photo-bioreactor zone , dug over a ten day period in one month split into two low tide periods a fortnight apart.A modest storm event far exceeds this in the movement of the Bellozanne channel from its discharge to LWMS.[the developed 'Bruce' anchor furrows negate this concern almost completely].

2. The second is regarding the biggest human consequence and not one addressed in the EIA, where it states you forsee no longterm impacts to the environment or to land use around the project.This concern is two-fold in its impact, the first being that of the reduction of a natural defence in seagrass. Seagrass has the ability to slow currents and disperse wave energy , and the loss of seagrass alone can therefore increase the shore's susceptibility to erosion.People may try to argue that the low percentage cover of seagrass in St.Aubins Bay would not have a huge reduction on wave energy on its own , however, the effects of its loss would be compounded by the additional act of building channels perpendicular to the shore for the express purposed of increasing current flow.As stated in the EIA the furrows

will act like rip tides, which creates a vulnerability to a sea defence system as storm waves will preferentially attack a beach along srip channels.The process of intensifying current flow out of the bay would conversely intensify potential wave energy into the bay and hitting the sea wall. All of which would greatly impact upon public spending.Notwithstanding the results of any furrow trials , having multiple rip channels spaced 15 m appart right across the bay , in place of the natural defence of seagrass , could therefore have very major consequences that haven't been addressed in the project application , especially in light of rising sea levels and more volatile weather conditions.

<u>Sorry but you are seriously mis-understanding the desired outcome, scale and position ,I fear!</u>

[The aim is to increase the overall volume of the seagrass by up to five fold not reduce it , that said the swell rarely exceeds 1.5m in the bay and only then near high tide.At that point the depth over the furrows would be at least 8m with the wavelength also at 8m maximum ,standard theory puts the energy contact 4 m below the surface and therefore 4m above the furrows.They have no effect on land use or sea defences]

The conflation of the micro-rip type flow mechanisms with storm wave rips destroying seawalls is simply not credible. These are shallow furrows constrained by new canopies of seagrass at least 250m from any sea wall and 8 m below any surf zone. A cursory view of St.Aubins Bay in storm conditions from due south an half tide or lower shows a massive attenuation of wave action to minimal.

Again I would use the example of the Bellozanne outfall stream line , this is a significant 'rip channel' 80cm deep and 600m long perpendicular to the shore and it has no discernible effects on the beach or wall to the north of it.

The negative effects you suggest that I haven't considered ,do not exist , and the consideration of for instance the significant increase in volumes of seagrass has been ignored and you have assumed the seagrass will be significantly reduced which is definitely NOT the case.