Natural England Commissioned Report NECR027

Watercress growing and its environmental impacts on chalk rivers in England

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Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

Chalk rivers are found in southern and eastern England and are of international importance for their special animal and plant communities, which include watercress. They are fed by groundwater springs, and so provide favourable conditions for watercress to be grown in beds constructed near their headwaters.

Watercress is an important salad leaf, stocked by the major supermarkets. Production is concentrated on rivers in Dorset, Hampshire and Wiltshire (33 of the 39 watercress farms are on Sites of Special Scientific Interest). We commissioned Jonathan Cox Associates to compile a report on the impact of the watercress industry on the ecological condition of these rivers.

This report is being published to help Natural England:

- set a baseline for knowledge of environmental effects of watercress farming as it is practised today; and
- raise awareness in the watercress industry of the effects they may be having on chalk rivers.

Natural England is using the findings in this report to:

- contribute to the development of a Code of Environmental Practice for Watercress Production, in collaboration with the Environment Agency and the NFU Watercress Growers' Association.

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Further information
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Summary

1. Natural England commissioned this study to identify the extent of watercress production and its impact on the ecology of chalk rivers. The report lists 38 watercress farms predominantly located on the chalk streams of Dorset, Wiltshire and Hampshire.

2. Watercress farms generally depend on groundwater springs or boreholes. Mature beds of watercress utilise some 5,000 gallons of water per acre, per hour. Production methods have become more intensive, even on the so-called traditional farms. Traditional growers were considered to be low intensity in terms of inputs and effluents. They were not required to have settlement facilities on their outflow, but were limited to cleaning out each bed once a year. Fertiliser is applied normally by hand in the form of buckets of fibrophos (dried chicken manure). Pesticides such as zinc were generally not used. There are not many 'traditional' watercress farms left - none in Dorset, one in Wiltshire and 11 in Hampshire.

3. Conventional production has reversed the previous trend of harvesting watercress in the winter: this market is now supplied by farms in Spain, Portugal and Florida. Production in England is concentrated in the summer months. The system is illustrated in the report by the operational regime at Vitacress Salads unit at St Mary Bourne on the Test. This is the largest watercress farm in Europe, extending to some 8 hectares. The crop is grown from seedlings originally sown in trays of peat compost. Fertiliser is included in the seedling plugs in the form of slow-release pellets. This is supplemented by liquid fertiliser sprayed onto the borehole/spring water when the crop needs it. The use of organo-phosphate pesticides, such as malathion, to control flea beetle has been discontinued and very little zinc (none in the past few years) is used for control of crook root. The crop is harvested and the beds are cleaned mechanically. The bed washings are pumped to a settlement tank and discharged to the stream after about 12 hours. There is also a salad washing and packhouse operation at St Mary Bourne, which uses some 40,000 gallons of borehole water an hour and a two-stage screening and settlement system for leaf fragments and silt washed off them.

4. The potential impacts of watercress farming on chalk rivers are reviewed: nutrient enrichment; silt and sediment; pesticides; natural mustard oils; disturbance to bird life; and water abstraction. Results of monitoring by the Environment Agency from a number of rivers show elevated levels of phosphate downstream of some cress farms. An intensive study of the River Itchen SAC has calculated phosphate loads from watercress farms. These are a significant source of pollution in the headwaters. Monitoring has also shown some high levels of suspended solids in the receiving river linked to bed-cleaning operations on some watercress farms. Ammonia levels above the river quality objective have been recorded in a few places recently. Impacts on fish and invertebrates have been recorded. Breeding of birds such as redshank and wintering numbers of water pipits and green sandpiper have declined.

5. The report proposes four areas to be covered in an industry code of good practice for watercress growers: control of suspended solids through efficiently designed and managed settlement lagoons; control of phosphate inputs (and thus concentrations in the effluent); control of toxic discharges and clarification of the role of natural mustard oils in declines of invertebrates; and water use and the sustainability of operations more generally.

Contents

1 Introduction

1.1 Objectives

Natural England is concerned at the potential impact of watercress growing due to the concentration of watercress farms in the headwaters of chalk rivers. These rivers were the first river priority habitat in the UK Biodiversity Action Plan. Eleven of them have been designated as Sites of Special Scientific Interest (SSSI), and - in the case of the Avon, Itchen, Lambourn and Wensum - as Special Areas of Conservation (SAC) under the European Habitats Directive. This study is designed to identify the extent of commercial watercress growing, the techniques used and their potential and actual impact on the ecology of chalk rivers. It also seeks to describe the existing regulatory regime and begins to identify best practice. The Environment Agency and the main growers (via the NFU Watercress Association) were consulted on the draft report.

Figure 1: Distribution of chalk rivers in England

1.2 Watercress the plant

Watercress *Rorippa nasturtium-aquaticum* is a native British wetland plant occurring in a number of aquatic habitats but most frequently in the margins of ditches, streams and rivers. Its ability to grow terrestrially means that it is particularly well adapted to growth in streams where water flows only intermittently, such as the ephemeral winterbournes of southern England (Preston and Croft, 1997)[1]. Watercress is a typical and often dominant component of chalk streams and rivers occurring in all five categories of chalk river described by Mainstone (1999)[2].

1.3 Watercress growing today

The first commercial watercress farm in Britain opened in 1808 in Gravesend, to supply the London market (Manton, 1935)[3]. Today, watercress is grown in the south and east of England, with production centred on the counties of Hampshire, Dorset and Wiltshire.

Watercress is grown in shallow gravel beds fed by springs and bore-holes, which provide a constant flow of relatively warm, pure, chalk-filtered spring water. On a winter's day, steam can be seen rising from the beds, as the warmer spring water meets the cold air. On these days, watercress characteristically ducks its head close to the water to keep warm.

Depending on the time of the year, watercress is either grown from seed or through vegetative propagation. At the start of the UK season, watercress seeds are propagated on thin layers of compost within greenhouses and poly-tunnels. It is not an easy plant to propagate - 30,000 seeds are needed to produce 3,000 seedlings, which in turn produce 300 plants. After about 7 to 10 days, the seedlings are transplanted into the gravel beds outside.

Pure spring water is introduced to the crop, gently at first and then in ever-increasing volumes with a mature bed needing an average flow of 5,000 gallons per acre per hour. The growing time can be anything from 28 to 70 days, depending on the weather. The warmer it is, the faster the plants grow.

Watercress derives most of its nutrients from the water through floating adventitious roots and roots embedded in the gravel. It also throws out aerial roots, tiny sprouts from the stem, to enable it to absorb even more nutrients.

When the watercress is ready for harvesting, specialised harvesting machines are often used to cut as much as two or three tonnes of watercress an hour.

Apart from a few bunches available for purchase at the farm, the harvested plants are then transferred to sophisticated pack houses, located close to the watercress farms in the south of England, so that, within hours, the plant has been chilled and packed into 'washed and ready to eat' bags, which are loaded onto refrigerated lorries to be delivered in peak condition to your local supermarket.

[1] Preston, C.D. & Croft, J.M. 1997. Aquatic plants in Britain and Ireland. Harley Books, Colchester.
[2] Mainstone, C. 1999. Chalk rivers; nature conservation and management. English Nature and Environment Agency
[3] Manton, I. 1935. The cytological history of watercress (Nasturtium officinale R. Br.). Zeitschrift für induktive Abstammungs- u. Vererbungslehre 69, 132-157.

2 Description of the watercress operating regime

2.1 'Traditional' watercress production

'Traditional' watercress growers are defined by Environment Agency licensing requirements as those who replant their beds no more than once a year between the beginning of June and the end of September. They tend to be the smaller producers, and originally their production methods were based on the growing of watercress for winter harvesting using vegetative propagation methods. However, some licensed 'traditional' growers have adopted more conventional techniques which permit all year round harvesting, with the use of sown crops in spring and early summer.

Water supply to most 'traditional' growers is from natural artesian flow from boreholes at the head of chalk rivers. This is licensed by the Environment Agency through an abstraction licence for each group of beds or farm.

'Traditional' growers are only permitted to clean each bed once a year, and then are required to limit water flow through the bed to reduce the quantity of silt being flushed into the receiving watercourse. They are not required to have any settlement facilities, but some do have limited or rudimentary facilities provided on a voluntary basis. Bed cleaning is undertaken in accordance with a Code of Practice (see section 4.1.1) designed to limit releases of sediment. Beds are cleaned from mid February until the end of September, but with most cleaning and re-sowing taking place between March and July. In a small watercress farm, comprising a number of beds, one bed may be cleaned and washed out each week at this peak time of year. Cleaning of the beds is done by hand or with a tractor. It involves the removal of accumulated plant debris and organic material. On the traditional watercress beds visited in the course of this study, most of the gravel substrate was kept in situ.

Fertiliser is applied to the watercress roughly once a week during the growing season, with the philosophy of 'a little and often' to maintain growth rates and keep the crop looking in good condition. On the 'traditional' watercress farm visited, fertiliser was administered at the rate of about 2 buckets (estimated at between 8-10kg) of Fibrophos (0:24:14 NPK) per 700m^2 of bed per week.

From the end of March to mid July, the beds are re-stocked with watercress seedlings grown in a propagation unit. Later in the summer and in autumn, the cut tops of watercress plants can be used to re-stock a bed. These are simply strewn across the surface of the cleaned bed and allowed to root into the substrate.

In the 'traditional' watercress farm visited, no zinc was used to control crook root. A study of other watercress beds in Hampshire undertaken by the Environment Agency in 1999 also found that 'traditional' growers in the county did not use zinc.

'Traditional' watercress growers are now relatively uncommon. There is only one 'traditional' grower in Wiltshire and none in Dorset. In Hampshire there are still 'traditional growers' on the rivers Test and Itchen, as well as on rivers such as the Blackwater at Sherfield English and Loddon and Lyde near Basingstoke. Elsewhere in England, there are 'traditional' watercress growers on the Ham Brook near Chichester, West Sussex and at Pickering in Yorkshire.

2.2 'Conventional' watercress production

'Conventional' watercress production has evolved to become a sophisticated process in many locations. Two 'conventional' systems were investigated as part of this study. These had minor differences in technique but were broadly similar. The main feature of modern watercress production (both conventional and organic) that distinguishes it from more 'traditional' forms of production is the timing of maximum production. Traditionally, watercress was considered a winter crop, 'harvested during the months with an R in' (September to April). This pattern of production has been reversed with the introduction of propagating techniques and the development of watercress production overseas in Spain, Portugal and Florida to supply the UK during winter. Figure 2 illustrates the modern pattern of production at 'conventional' watercress farms, with maximum output being during the summer months.

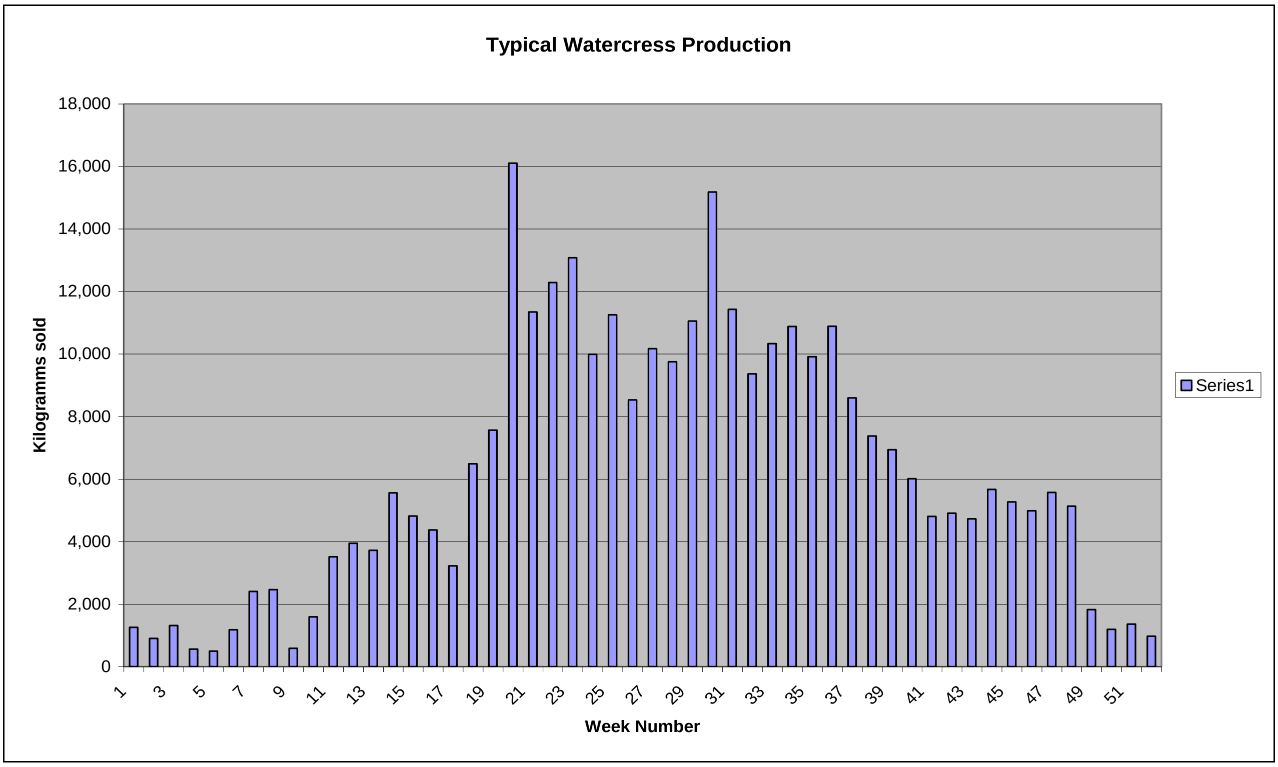


Figure 2: Typical watercress production through a year from a 'conventional' watercress farm (data supplied by Vitacress)

2.3 'Conventional' watercress production at St Mary Bourne

Conventional watercress production can be illustrated by the production process at St Mary Bourne, in Hampshire. This is the largest watercress farm in Europe, extending to an area of 8 hectares. The watercress beds at St Mary Bourne were created by Eliza Fleet in 1904 on the headwaters of the Bourne Rivulet, a tributary of the River Test. Watercress production is now operated by Vitacress Salads Ltd.

2.3.1 Abstraction

The watercress beds are located at the head of the perennial flow on the Bourne Rivulet. Upstream of the beds, the Bourne Rivulet is a winterbourne, with seasonal ephemeral flows. Since the 1950s, the beds have been fed with water pumped from boreholes. There are 25-30 pumped boreholes on the site, which raise the head of water to achieve perennial flow through the farm and to the stream below - the rate of pumping has been constant since the 1960s. The quantity of water abstracted is measured by the size and yield of the pump and the length of time it operates. Pumping is thought to have some effect on the flows in the winterbourne section upstream of the watercress beds and probably reduces the length of time when there is water in the winterbourne each year. In periods of low flow, the Bourne Rivulet is almost entirely made up of flow from the cress beds at St Mary Bourne, whilst in more typical conditions the input is less than 10% of total flows. Retention time of water in a 100-yard long watercress bed is about 2 hours.

2.3.2 Crop establishment

To prevent the watercress flowering and going to seed in spring and early summer, watercress is grown from seed. Seed is sown on compost at a high density of 10-20 seeds/cm^2. Vitacress use modular ($1cm^3$) trays filled with peat-based compost, although they hope to move to a peat-free compost medium in the near future. The sown trays are placed in a poly tunnel and irrigated with sprinklers. Fungicide is applied to the seedlings in the poly tunnels. Growth takes about 10 days and creates a dense carpet of 'mustard and cress' like seedlings. The plugs are then broadcast into the cress beds by hand or machine (hopper with moving floor, brushes fling plugs over bed). Plugs root into the bed in 2 to 3 days. The flow of water to the bed is increased as the plugs root. In the peak growing season (May - September), planting to harvesting takes only 25 days.

2.3.3 Fertiliser use

Watercress obtains its nutrients for growth from the water that passes over its roots. As with all chalk river water, phosphate is naturally at very low levels and is the limiting plant nutrient. In the past this was supplied in the form of basic slag. Nowadays, fertiliser is applied with the sown plugs in the form of pellets. These comprise a mix of lignitic clay, bone-charcoal, poultry ash, rock phosphate (plus a trace of sodium nitrate, potassium chloride and ammonium nitrate). The pellets break up giving a slow release of nutrient. The pelleted fertiliser is supplemented with liquid fertiliser that is sprayed directly into the water coming from the borehole, feeding beds at rates appropriate to crop demand. The conductivity of the water can be measured to monitor nutrient levels and regular samples are sent for laboratory analysis. Fertiliser application affects nutrient levels in the outflow typically by the following amounts:

N	borehole water 6-8mg/l	outflow 3-5 mg/l
P	borehole water 0.01 mg/l	outflow 0.06-0.08 mg/l
K	borehole water 1 mg/l	outflow 1-2 mg/l

2.3.4 Pesticide use

Flea and mustard beetles can cause damage to watercress, and populations of flea beetle can be high where there are oilseed rape and other brassica crops on surrounding farmland. In the past, organo-phosphate pesticides such as malathion were used to control flea beetle, but this practice has now been discontinued.

Crook root is a fungal disease that affects the roots of the watercress. It is spread by a mobile zoospore and can be a particular problem in winter when crops remain in the beds for longer and temperatures are lower. Zinc is used to control crook root. It is administered in the form of zinc chloride sprayed into the borehole water in a similar way to the fertiliser. With the emphasis now on summer production and an increased reliance on sown crops, much less zinc is now used. For example, none has been used for the last two years at St Mary Bourne (2003/04). When used, zinc is applied as pulses every 2 hours to achieve a short duration concentration of about 0.1ppm at the bed inlet. This declines to undetectable levels at the point of discharge.

2.3.5 Harvesting

At St Mary Bourne, a machine harvester is used to cut 90% of the watercress. This is a self-propelled machine that cuts and sweeps the crop into bins. The remaining 10% is cut by hand using a pushed machine or knife to produce bunches of watercress. In summer, the crop is routinely cleared and the bed cleaned following harvest, to be replanted with a new crop. However, in late summer, autumn and winter, crops can be left to re-grow from cut stubbles. To ensure an even growth, these are mown following harvest to leave an even stubble bed. This process is known as 'chipping'. During harvesting and chipping, water flow to the cress beds is very low or even stopped, but is increased again afterwards.

At St Mary Bourne, but probably not widely elsewhere, 60% of the crops are grown from sown plugs and 30-40% from re-grown stubbles. Stubble re-growth is used from July through the winter to March, and can be harvested as frequently as every 10-12 days. The last seedlings are planted in September/October for harvest the following March, when production is roughly 50/50 seedlings to stubble re-growth. Between April and June all crops are grown from sown plugs.

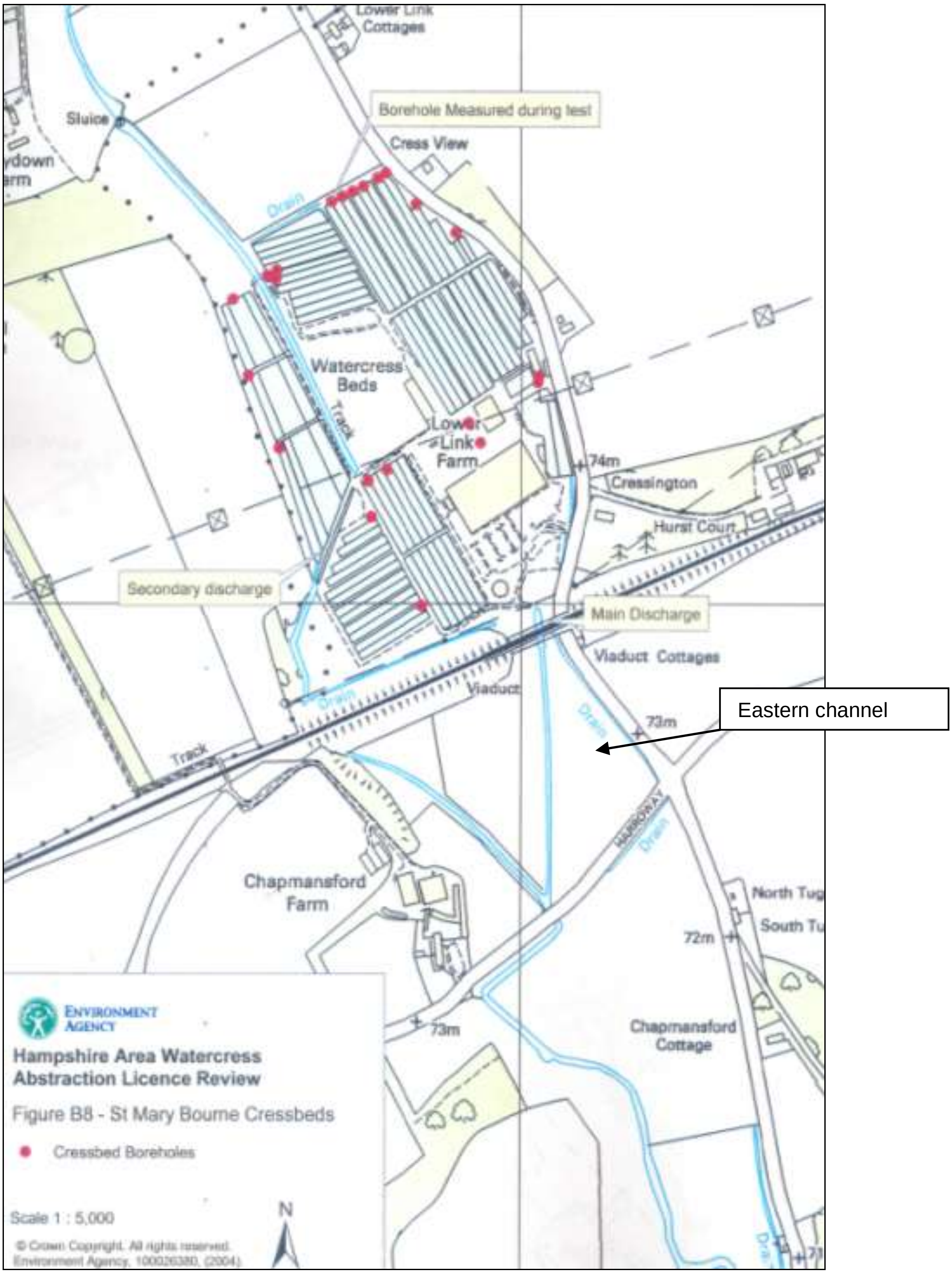


Figure 3: Layout of St Mary Bourne (Lower Link Farm) watercress beds

2.3.6 Bed cleaning

Watercress beds are cleaned prior to the establishment of sown crops. This is most frequent in spring and early summer, when production is dependent upon sown crops and declines through the autumn and winter as production switches to re-grown stubbles. Cleaning involves the following:-

- Water flow to the cress bed is stopped or reduced to a minimum.

- The bed is cleared of all solid material with rakes, tractor and trailer (this is composed of a mix of gravel, cress roots and stalks and other organic matter).
- The cleared material is heaped up to compost.
- The bed is washed to remove mud and algae with tractor and roller.
- The bed washings are pumped to a settlement tank.
- The settlement tank is discharged to the discharge stream after about 12 hours' settlement.

2.3.7 Salad-washing and packhouse operation

St Mary Bourne not only produces and packs watercress, it imports salad leaves (grown both in the UK and overseas) for washing and packing prior to sale in the UK. Three boreholes feed the packhouse with c 40,000 gallons of water/hour - (2500m^3 per day). There are 8 wash lines with two or three tanks each approximately 5-6m x 1.5m x 1.5m in size. Salad leaves are initially washed in the pure spring water using current and air bubbles for agitation. The washings are filtered through a 5mm rotating drum screen. Since 2004, the washings have also been passed over a 2mm parabolic screen which removes all leaf fragments over 2mm in size. The discharge from this screen is then sent to a settling system prior to release into the discharge channel. This second-stage process was added to remove fine, red-coloured silt from salad crops that had started to accumulate in the discharge stream.

Before July 2006, the salad leaves were rinsed in chilled chlorinated water. The chlorinated rinse water was then treated with sodium metabisulphite to remove the chlorine. This was discharged to the main settlement tank, and thence to the eastern channel or rivulet. Since June 2005, the effluent from the settlement tank has been re-circulated through a set of watercress beds prior to release into the east rivulet. Despite this, Marsden (2006)[4] has shown that the settlement tank effluent remained toxic to invertebrates. This was most likely to have been due to the de-chlorination agent, sodium metabisulphite, which is acidic (pH3.5-5), has an extremely high oxygen demand, liberates a number of toxic bi-products such as sulphur dioxide and is largely ineffective in neutralising organic chloramines.

Since July 2006, the salad-washing operation at St Mary Bourne has been completely chlorine free. This has resulted in a large reduction in the toxicity of the settlement tank discharge. However, the settlement-tank discharge continues to have high levels of iron and ammonia from iron sulphate and fertiliser used in watercress operations and hydrogen sulphide and oxygen consumption associated with decomposition of sediment from bed clearing (Hellawell, 1989)[5]. This suggests that the watercress effluents may also be contributing to the toxicity in the settlement tank, albeit to a lesser extent. This conclusion is supported by chemical analyses of the settlement tank effluent conducted by Vitacress in September 2006 which indicated elevated chemical oxygen demand (COD), biological oxygen demand (BOD), sulphide and ammonia.

The settlement tank is drained approximately every week in winter and daily in summer.

2.4 'Organic' watercress production

Organic watercress production closely follows the conventional system in terms of water supply, seedling propagation and harvesting. The differences between conventional and organic systems relate to the use of fertiliser and pesticide. Fertiliser in the organic system is mostly delivered in the form of incinerated, deep-litter chicken manure under the brand name of Fibrophos. This is rich in phosphate and potassium with elements of sulphur, magnesium, calcium and sodium. At organic farms in Dorset operated by The Watercress Company, this is applied by hand, with application rates based on experience and calibrated to the stage of growth. Detailed records are kept of all fertiliser applications to each watercress bed.

[4] Marsden, C. 2006. Combining chemistry, bioassay and biotic data to investigate the invertebrate decline in the Bourne Rivulet. Unpublished report.
[5] Hellawell, J.M. 1989. Biological indicators of freshwater pollution and environmental management. Pollution monitoring series. Elsevier Applied Science.

In the absence of pesticides to control invertebrate pests, alternative methods of pest control have been developed. This has included the installation of overhead spray irrigation to deter aphids and flea beetle. Watercress growers also maintain liaison with local farmers to limit the growth of brassicas – in particular oilseed rape – in fields near to the watercress beds, as these can support significant populations of flea beetle. In winter, crops are also frequently covered in 'fleece' which maintains warmth in the beds and prevents access by birds, mostly ducks, that can damage the crop.

2.5 Management of suspended solids

Suspended solids are controlled by discharge consents for all watercress beds, other than those classed as 'traditional' producers. Removal is achieved through the use of either settlement tanks or settlement lagoons. The results of monitoring suggest that both systems can be effective in removing suspended solids. The choice of system is largely dictated by the available space within the watercress farm, with tanks being used in places where space is limited. Operating practices within the discharge consent regime for 'conventional' growers are described in more detail in Section 3.2.3.

On many watercress farms operating settlement lagoons, most if not all of the flow from the watercress beds is passed through the settlement system, so providing a mechanism to catch any accidental release of suspended sediment between bed-cleaning operations. Settlement lagoons are only irregularly cleaned out, at most once a year and often only every 4-5 years. By contrast settlement tanks are often cleaned out 3-4 times each year. The relative effectiveness of such frequencies does not appear to have been measured.

Settlement-lagoon systems comprising a series of linked ponds appear to provide the most effective mechanism for sediment removal, although this requires adequate space. The Environment Agency's 1999 survey of operational practice in watercress farms in Hampshire collected the following information on size and operation of settlement lagoons in the county.

Table 1: Summary of settlement lagoon systems in Hampshire Watercress Beds (information from the Environment Agency)

Site name	Description	Nominal size (m^3)	Cleaning frequency
Spring Gardens	redundant cress bed	c. 400 m^2	
Abbots Ann	settlement pond	4,500	Every 3-4 years
Pinglestone	settlement pond	1,500	Every 5 years
Fobdown	two settlement ponds	2,400	Every 5 years
Springvale	settlement pond	800	Every 3 years
Manor Farm	settlement pond	1,720	Every 3 years
Nythe/Drayton	pond/two ponds	2,400/1,800	Every 3 years
Maxwells	settlement pond	1,100	
Sherfield English	redundant cress bed	c. 3000 m^2	

There is limited advice available on best practice for design and operation of settlement lagoons/tanks for cress beds, although some work done in relation to settlement lagoons for fish farms[6] is of relevance. The key elements for efficient capture of suspended solids appear to be – sufficient surface area, slow throughput of water and minimal turbulence to prevent re-suspension. Some experience of Vitacress is also of relevance: the firm paid consultant engineers to establish the settlement dynamics of watercress sediments and, using these, calculated retention times at a range of velocities. Weir widths of settlement lagoons were then designed to achieve a velocity appropriate to the maximum length of pond that could fit into a site boundary. Cleaning frequency of the lagoons is determined by the depth of the pond. Cross-flow dynamics are controlled by exit hatches. In some instances these are equipped with notched edges to accommodate net catch bags, whilst booms of oil-absorbent material can also be strung across the ponds to skim floating debris.

[6] Henderson, P, Bromage, N & Watret, R. 1989. *How to design a settlement pond*. Fish Farmer, 12, 3 , p 41

The effectiveness of settlement lagoons in reducing phosphate concentrations in discharge water was demonstrated by recent work undertaken by the Centre for Ecology and Hydrology (CEH) in assessing the effect of the proposed expansion of the Dodding's Farm watercress beds on the Bere Stream in Dorset (CEH, 2007)[7]. Intensive monitoring of water samples at Dodding's Farm allowed CEH to quantify the specific amounts of nutrient lost from individual cress beds during a range of cress farm operations. This showed large, short-term phosphorus losses associated with specific farm practices. This monitoring also showed the effectiveness of the settlement lagoon in reducing phosphorus in the discharge from a cress-bed, with an average of 62% removal and a maximum of 94% removal before it reached the Bere Stream.

However, the potential for settlement lagoons to reduce phosphate levels in bed discharges depends upon all flows from the beds passing through the settlement lagoons. This is often not possible due to constraints on the size of settlement lagoon or, during winter, high ground water levels. This is the case at Doddings Farm, where a significant proportion of the discharge from the watercress beds normally by-passes the settlement lagoon, though discharges may be diverted to the settlement lagoon during bed-cleaning and other operations.

[7] Centre for Ecology and Hydrology. 2007. An Assessment of the effect of the proposed expansion of the Dodding's watercress farm, Dorset on the nutrient status of the Bere Stream. Report to Vitacress Salads Ltd.

3 Environmental impacts of watercress farming

3.1 Nutrient enrichment

3.1.1 Effects of nutrient enrichment

Application of phosphate elevates the concentration of this nutrient in the water discharged from watercress farms (see 2.3.3 above). Nitrate is already in excess in most chalk streams, principally due to the impact of agricultural operations on groundwater aquifers. It is, therefore, important to limit levels of phosphate, as the two elements act in combination to stimulate plant growth. Mainstone (1999) identified four principal ways in which elevated phosphorus levels can affect plant communities in chalk rivers:-

1. by increasing growth rates and creating unnaturally large stands of vegetation in the river channel, which re-grow rapidly after cutting;

2. by encouraging rooted plant species whose growth rates are geared to higher nutrient levels, thereby altering the composition/balance of species;

3. by increasing growth rates of epiphytic and filamentous algae, thereby reducing the amount of light reaching rooted plants and shifting the balance of the plant community towards shade-tolerant species and, ultimately, algal dominance;

4. by reducing rooting depth and, thereby, making plants more susceptible to being ripped out of the substrate.

Phosphate levels in chalk rivers are typically measured as concentrations of soluble reactive phosphate (SRP). This is broadly similar to the concentration of ortho-phosphate dissolved within the water column and differs from concentrations of total phosphate, which includes that bound in sediments and not biologically available. Common Standards for conservation objectives for rivers were published by the Joint Nature Conservation Committee on behalf of the UK Conservation Agencies in 2005. For chalk rivers, these follow the standards developed by English Nature in collaboration with the Environment Agency. Target standards for soluble reactive phosphate (SRP) in chalk rivers are:-

Perennial headwater	0.04mg/l
Classic chalk stream	0.06mg/l
Large chalk river	0.1mg/l

The applicability of these SRP concentrations to chalk-river catchments has been re-inforced by recent research undertaken at CEH in Dorset (Bowes, Smith, Hilton, Sturt & Armitage, 2006[8]). This used a series of artificial stream-side flumes to determine the concentration at which phosphorus (P) limits algal growth in the River Frome. In this research, the SRP concentration in each flume was manipulated by adding phosphorus to increase SRP concentration, reducing SRP with the addition of iron sulphate solution or left unaltered (control). Interestingly, the addition of phosphorus to the river water did not result in an increase in algal growth, showing that the background level of SRP within the River Frome was already in excess at the mean concentration 0.109 mg/l recorded during August 2005. However, algal biomass declined as SRP concentration was reduced below 0.09 mg/l, with a 60% reduction in algal biomass at SRP concentrations below 0.04 mg/l.

[8] Bowes, M.J., Smith, Jim T., Hilton, John, Sturt, Michael M. and Armitage, Patrick D. 2006. Periphyton biomass response to changing phosphorus concentrations in a nutrient-impacted river: a new methodology for phosphorus target setting. Can. J. Fish. Aquat. Sci 64: 227-238. NRC Research Press

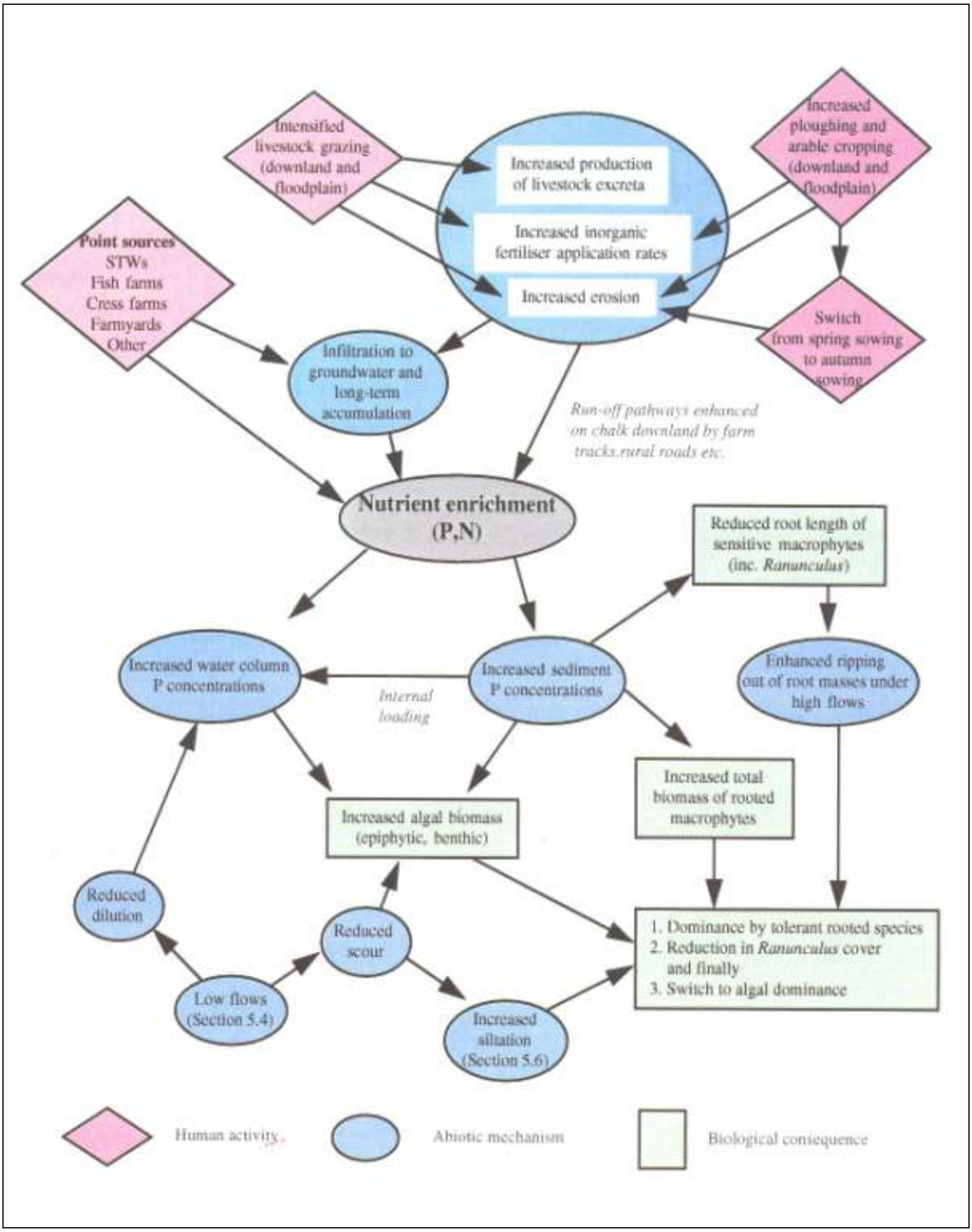


Figure 4: Causes and consequences of nutrient enrichment in chalk river systems (from Mainstone, 1999)

3.1.2 Phosphate in chalk river catchments

Phosphate levels in chalk aquifers are naturally very low and are typically less than 0.02mg/l. Records of phosphate levels in borehole water at St Mary Bourne on the River Test show concentrations of 0.01mg/l. Similar low levels have been recorded from borehole water on watercress farms at the head of the Frome and Piddle rivers in Dorset. The aquifer of the River Itchen in Hampshire appears to have elevated phosphate levels, probably due to infiltration from arable farming practices in the catchment.

The background phosphate level in chalk rivers arising from these aquifers is generally low. However, inputs of phosphate to the river derive from a number of both point and diffuse sources which rapidly elevate the phosphate concentrations above the target levels. Studies by the Environment Agency have demonstrated that, in terms of total phosphate loading, sewage treatment works are the single largest point sources of phosphate in chalk river catchments. Diffuse pollution from non-point sources, including agricultural run-off, contribute an estimated 40% of the phosphate loading of some chalk rivers, for example the upper Hampshire Avon[9]. In general, inputs from sewage treatment works are almost continuous, while agricultural diffuse inputs are sporadic, usually occurring after rainfall events.

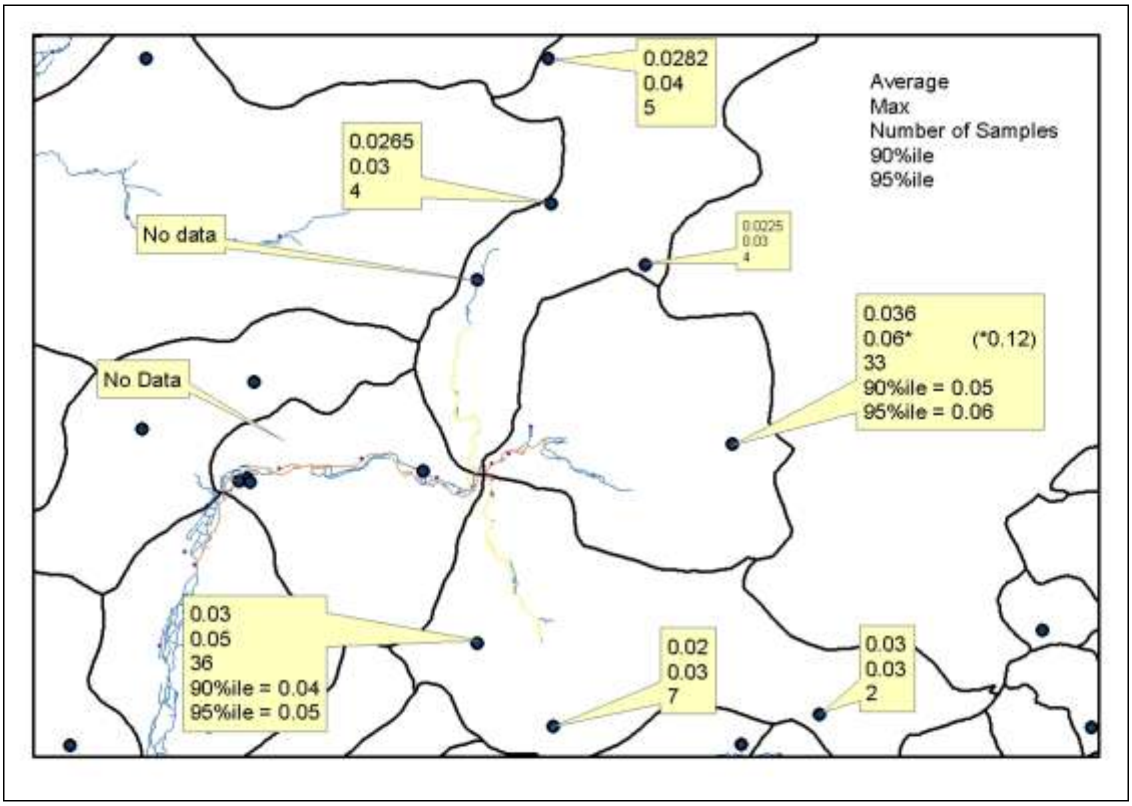


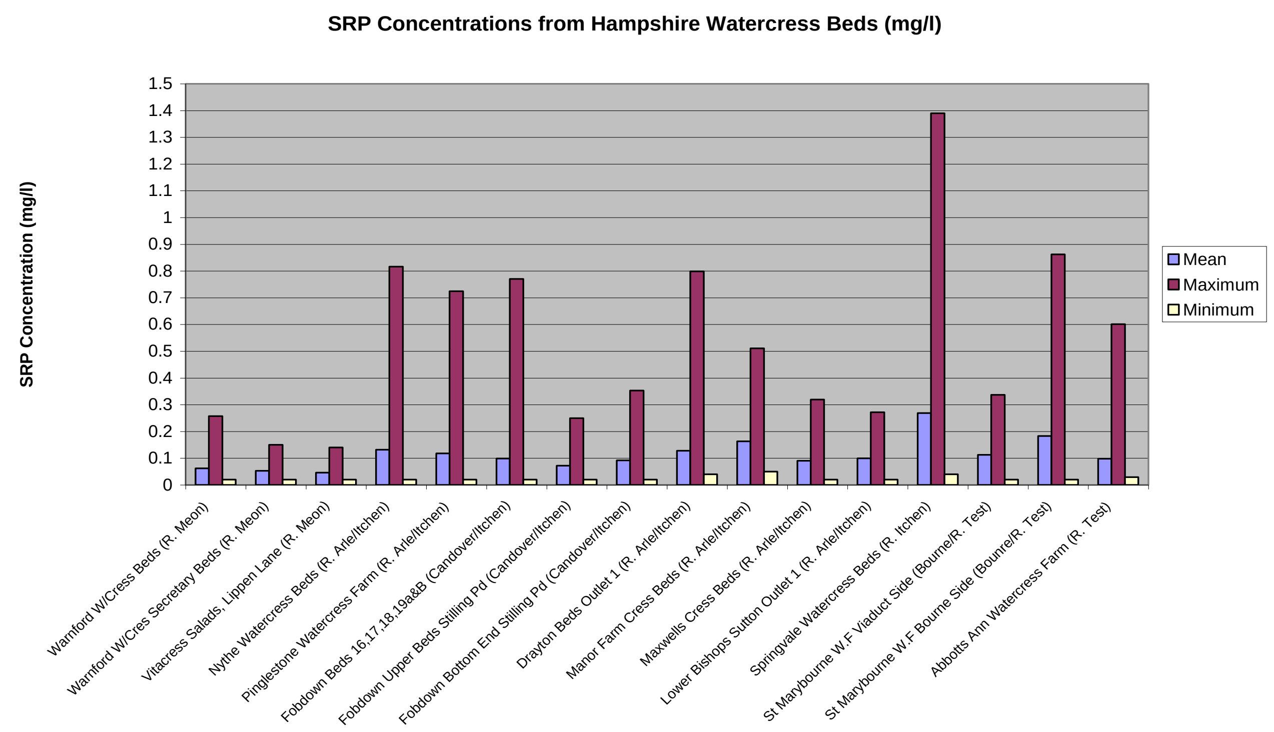
Figure 5: Groundwater concentrations of SRP in the River Itchen catchment showing average concentrations of between 0.02 – 0.036 mg/l. Average, maximum, number of samples and percentile concentrations have been calculated where possible. 0.06* is the maximum recorded after the aberrant 'outlier' of 0.12 had been removed from the data set.

Detailed analysis of phosphate loading has been modelled by the Environment Agency for some chalk rivers, notably the Hampshire Avon and River Itchen. Total phosphate loading of these rivers is heavily influenced by sewage treatment works which contribute a major component of the total load. For example, the Environment Agency (David Brain pers comm.) has calculated that, using mean flow data and the long-term SRP average for the Itchen, sewage works contribute 84.2% of the total SRP load in the river, discharged mainly in the lower reaches. By the same method, the total load from watercress beds has been calculated at 5.4% of load and fish farms 3.2%. Other sources, including diffuse sources account for some 7.2% of SRP load.

3.1.3 Impact of phosphate effluent from watercress beds

At a catchment scale, the quantity of SRP from watercress beds is relatively small when compared to the contribution from sewage works and in many cases from diffuse sources. However, the inputs of phosphate to the headwaters and upper reaches of chalk rivers from watercress beds is more significant, and is often upstream of sewage discharges.

[9] Environment Agency. 2004. The State of England's Chalk Rivers, EA Bristol.



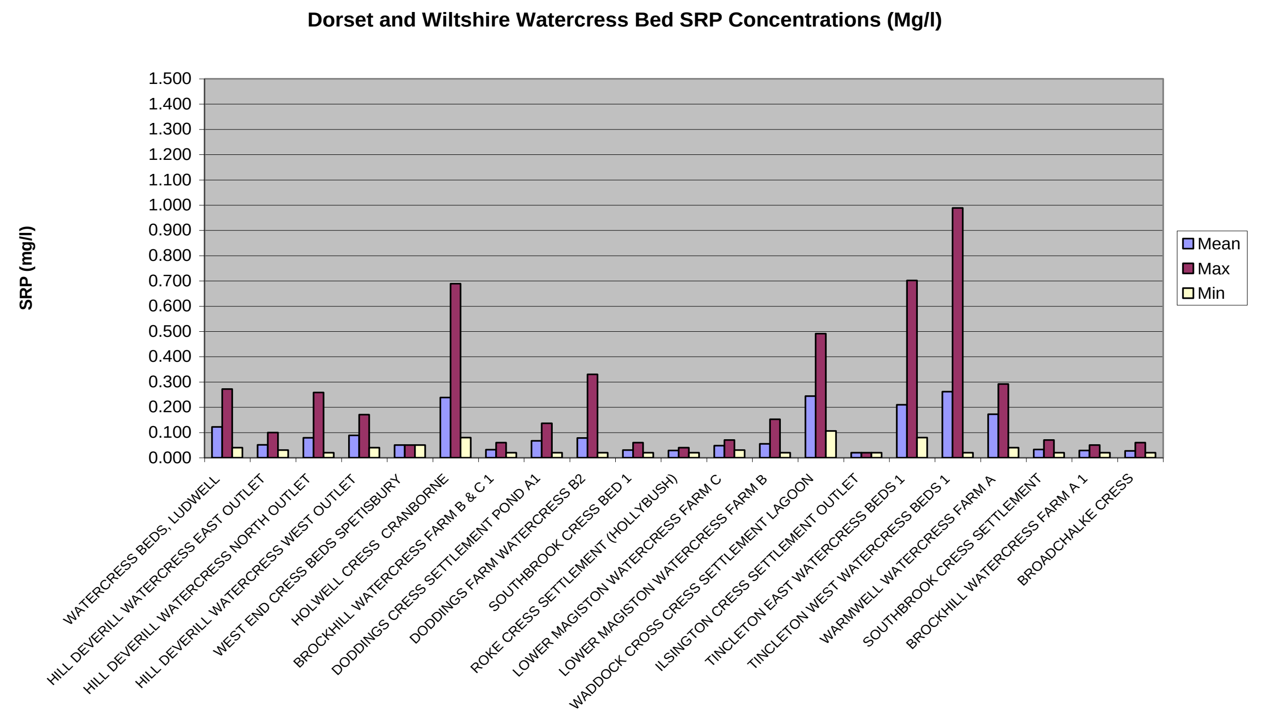


Figure 6: Soluble reactive phosphorus concentrations recorded from watercress beds in Dorset, Wiltshire and Hampshire (data from the Environment Agency)

Monitoring programmes have been undertaken by the Environment Agency of SRP concentrations below watercress beds with licensed discharges. The results for chalk rivers in Hampshire, Dorset and Wiltshire are reproduced in Appendix 1 and shown graphically in Figure 6 above. The Dorset and Wiltshire data (21 sampling points) were collected between February 2003 and December 2004. Hampshire data (16 sampling points) were collected mostly between September 2002 and December 2004. The number of samples at each sampling point is listed in the appendix. These data demonstrate the highly variable concentrations of SRP recorded, with a maximum concentration of 1.39 mg/l at one site on the Itchen and a maximum mean concentration of 0.269 mg/l at the same site. The peak concentrations may reflect short-term pulses of nutrient, possibly related to fertiliser application or bed-cleaning operations, or to upstream pollution events unconnected to the watercress farm. The lowest mean concentrations of between 0.02 and 0.03 mg/l are in Dorset - on the Frome and the Bere Stream. Overall, 24 of the 37 sampling points had mean concentrations in excess of the target levels set by Natural England for chalk streams.

The influence of watercress discharges on river SRP concentrations is illustrated by reference to data from routine river water quality monitoring undertaken by the Environment Agency. Data from the upper Itchen catchment are reproduced in Table 2. The concentration of watercress beds and fish farms on the River Alre appears to have the effect of elevating SRP concentrations in this part of the Itchen catchment, with an average at Drove Lane sampling point at the bottom of Alre of 0.08mg/l. Further downstream, below the confluence of the three Itchen tributaries, river SRP concentrations have dropped to a mean of 0.05mg/l at Itchen Stoke, illustrating the significant dilution effects of the river.

Table 2: Total reactive phosphorus statistics from routine water quality sampling sites in the upper Itchen catchment

River sample point name	Number of samples	Date of first sample	Date of last sample	Average conc. TRP mg/l	TRP Min mg/l	TRP Max mg/l	TRP 90%itle	TRP 95%tile	River target TRP mg/l
Drove Lane	74	05/01/99	02/02/05	0.07872	0.0066	0.341	0.1175	0.1395	0.06
U/S Manor Fish Farm	59*	13/01/00	26/01/05	0.1257	0.058	0.689	0.177	0.213	0.04
U/S Franklyns Fish Farm	74	05/01/99	26/01/05	0.0793	0.025	0.18	0.1285	0.162	0.06
Borough Bridge	40**	05/01/99	26/01/05	0.03074	0.0066	0.068	0.05	0.0519	0.04
Itchen Stoke	74	05/01/99	02/02/05	0.0475	0.02	0.098	0.06	0.0785	0.06

* An outlier has been taken out of this data set (a result is considered to be an outlier when the observation is >10x the average).
** The site was not sampled for a number of years for Health and Safety reasons.

Measurement of SRP concentration through the year gives a useful indication of seasonal trends in SRP concentration in watercress bed effluent. David Brain of the Environment Agency (pers comm.) has analysed SRP concentration data for the River Itchen and St Mary Bourne watercress beds using the Aardvark statistical software package. A data chart resulting from analysis of these data is in the graph below. This reveals a seasonal trend where the highest concentrations are expected in June/July and the lowest in March and October.

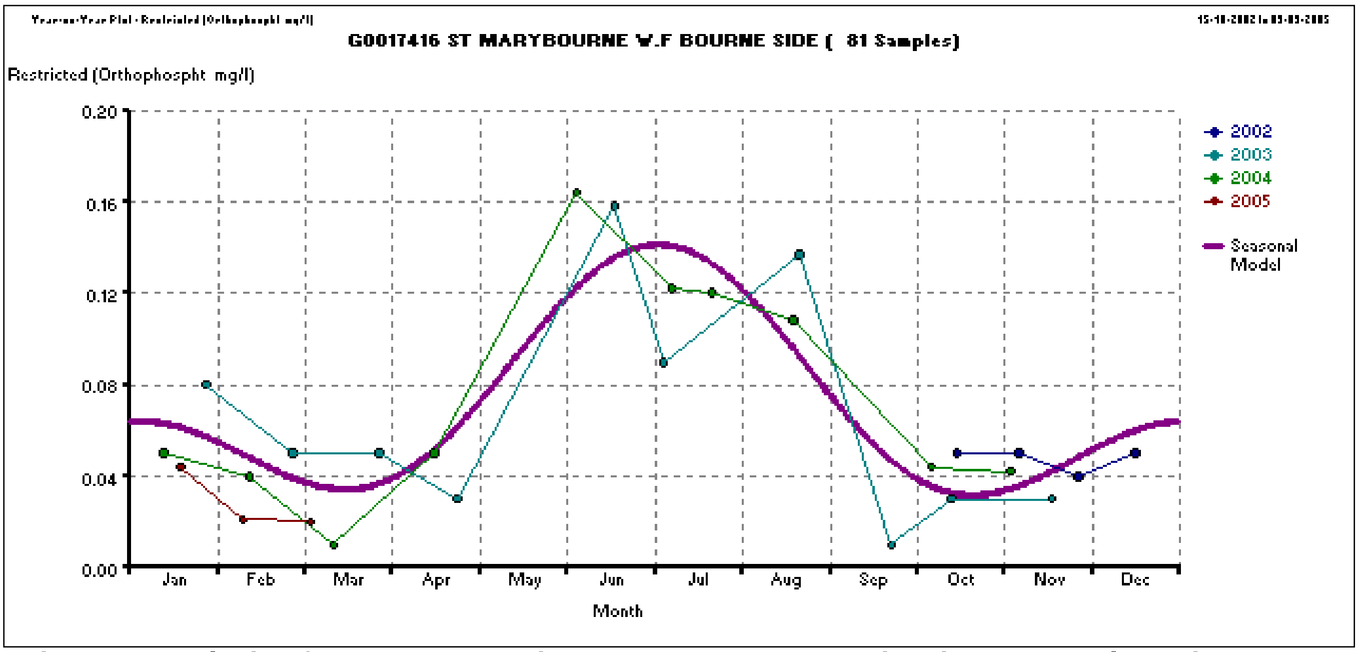


Figure 7: Analysis of SRP concentrations at St Mary Bourne showing seasonal trends

Although some watercress beds show a clear seasonality in SRP concentrations, this is not universal and, for several beds, there is no detectable trend. For those beds that show a seasonal trend, there are generally high concentrations in summer and low concentrations in winter. However, within this generality, there is again considerable variation in the timing of peak SRP concentrations from June/July to September for the summer peak and between October and February/March for the winter low. Generally, higher SRP concentrations in watercress-bed effluent in summer is likely to have the greatest effect on the receiving water, as during the summer months most biological activity is taking place in the river and river flows are at their lowest. Similar summer peaks of SRP concentration from watercress-bed discharges in the Itchen can be seen in the chart reproduced in Appendix 1.

Measures of SRP concentration provide useful information, but also have limitations when determining the impact of watercress beds on river ecology, as records of SRP concentration within the water column may vary widely through time. A better indicator of the effect of SRP on river ecology is a calculation of phosphate loading, measured as grams/kilograms of SRP per second. Measures of SRP load take into account flow rate as well as concentration of SRP. They also allow a comparison to be made between different contributions of SRP to the total for the river.

Detailed analysis of phosphate loading on the River Itchen was undertaken by Halcrow in 2003 as part of the Itchen Sustainability Study[10], and it is summarised in Table 3 below. The Halcrow model divided the river into 6 management units (MU 1-6). Management Units 1, 2 and 3 correspond to the three main tributaries at the head of the river (the Cheriton Stream, Alre and Candover), where the watercress industry is concentrated. The model shows that SRP in these three tributaries is heavily influenced by the watercress beds which contribute 35%, 62% and 27% of the SRP load respectively. Phosphate loading in the upper catchment of the Itchen is, therefore, significantly elevated due to the operation of the watercress farms.

Equally of concern is the influence of the watercress discharges on the downstream sections of the river. The three tributaries mentioned above form a confluence at Alresford and then flow to the west towards Winchester within MU 4 – a distance of some 8km. The modelling undertaken by Halcrow demonstrates that 73% the SRP load of this significant section of the River Itchen is derived from the three tributaries - the Cheriton Stream, Arle and Candover.

[10] http://www.riveritchensustainability.org.uk/

Discharge site	**Average phosphorus load (g/s)**	**Average load/ total load in management unit (%)**
MU 1: R. Cheriton		
Watercress farms	0.006	35
Fish farms	0.002	12
Rural activities	0.003	18
Background	0.006	35
Total MU1 load	**0.017**	
MU 2: R. Alre		
Watercress farms	0.086	62
Fish farms	0.015	11
Rural activities	0.021	15
Background	0.016	12
Total MU2 load	**0.138**	
MU3: Candover Brook		
Watercress farms	0.004	27
Rural activities	0.006	40
Background	0.005	33
Total MU3 load	**0.015**	
MU4: R. Itchen		
Fish farms	0.019	8
Rural activities	0.002	1
Background	0.042	18
Load from MU 1, 2 & 3	0.170	73
Total MU4 load	**0.233**	
MU5: R. Itchen		
Harestock STW	0.346	53
Watercress farms	0.011	2
Fish farms	0.004	negligible
Background	0.053	9
Load from MU 1, 2, 3 & 4	0.233	36
Total MU5 load	**0.647**	
MU6: R. Itchen		
Chickenhall STW	1.276	64
Industrial discharges	0.004	negligible
Fish farms	0.001	negligible
Background	0.058	3
Load from MU 1, 2, 3, 4 & 5	0.647	33
Total MU6 load	**1.986**	

Table 3: Average phosphorus loads for the River Itchen from trade effluent and sewage treatment discharges, 1997-2002. (Source: Brown et. al., 2003)

More detailed analysis of the SRP load derived from each of the watercress beds has been undertaken by Halcrow. The results of this are summarised in Table 4 and Figure 8. From this analysis, estimates of SRP load were calculated for all watercress beds in the upper Itchen, including the ‘traditional’ watercress beds at Spring Gardens and the West Lea Farm Shop that are not subject to routine water quality monitoring. A calculation was made of the ‘allowable’ SRP load at each discharge point related to target standards and average river flows.

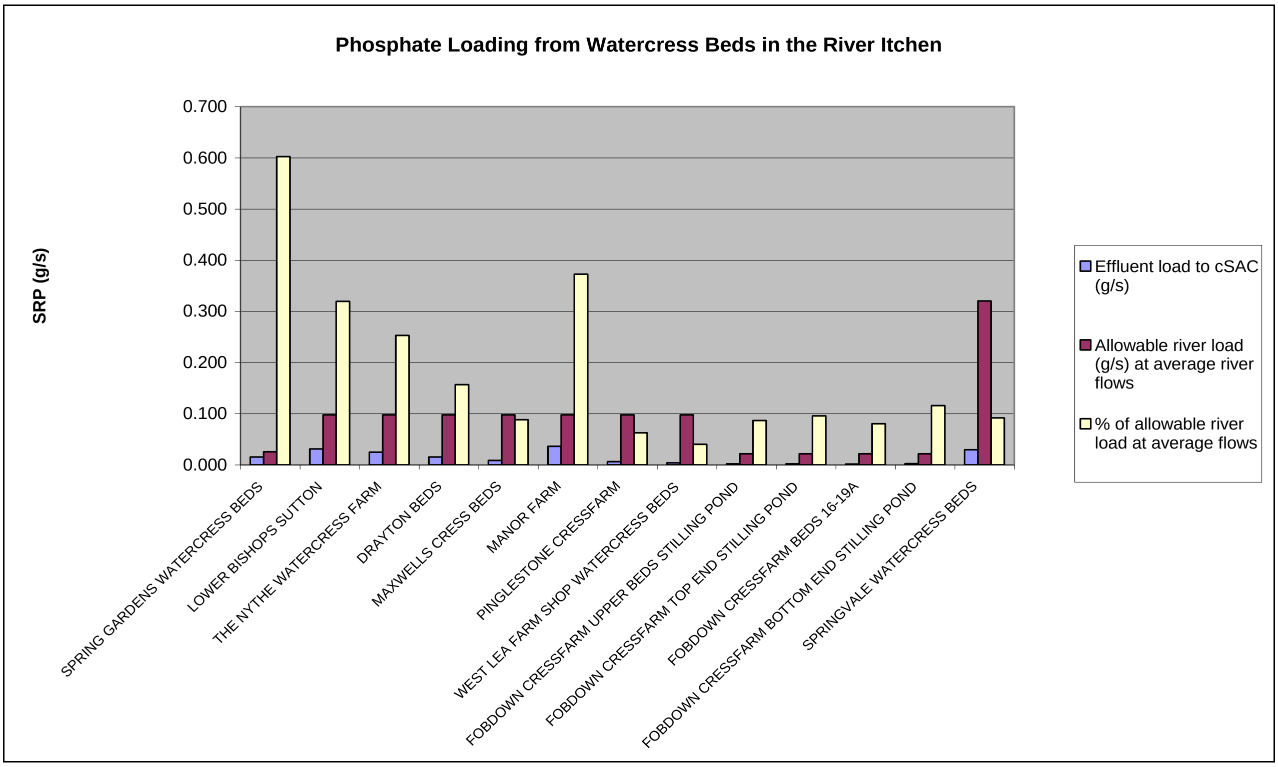


Figure 8: Soluble reactive phosphorus loading from watercress beds in the upper Itchen

This analysis shows the considerable percentage of allowable SRP load that arises from certain watercress beds. For some, such as the ‘traditional’ Spring Gardens beds, this is due to the much smaller flow in the receiving Cheriton Stream and the stricter target standard on this tributary. For others, such as Lower Bishops Sutton, The Nythe, Drayton and Manor Farm, the high proportion of ‘allowable’ SRP is due both to high concentrations of SRP in the discharge, high standards and relatively small flows in the River Alre. By contrast, the highest recorded concentrations of SRP are from Springvale Watercress beds at Kingsworthy. These are some distance downstream of the other watercress beds in this study within MU 5 where flow is significantly higher, and hence the ‘allowable’ SRP load is also much higher.

Largely as a consequence of the work on phosphate inputs to the River Itchen SAC, the Environment Agency has been able to review the discharge consents for the watercress farms in accordance with the EU Habitats Regulations (1994). This review has found that ten of the farms on the Itchen have an actual or potential adverse effect on the integrity of the SAC. To resolve this, the Environment Agency has proposed a number of consent conditions, restrictions or modifications that will result in these discharges no longer having an adverse effect. One of these conditions will be a limit on total-phosphorus concentration set at an annual mean of 0.04 mg/l, or where concentration of incoming ground water is an appreciable proportion of this, an inlet/outlet differential limit will be applied.

Site name	maximum effluent concentration (mg/l)	effluent load to river (g/s)	river P standard (mg/l)	average river flow (m3/s)	allowable river load (g/s) at average river flows	SRP as % of allowable river load at average flows
Spring Gardens Watercress Beds	0.103	0.016	0.04	0.644	0.026	61.54%
Lower Bishops Sutton	0.128	0.031	0.06	1.629	0.098	31.63%
The Nythe Watercress Farm	0.165	0.025	0.06	1.629	0.098	25.51%
Drayton Beds	0.102	0.015	0.06	1.629	0.098	15.31%
Maxwells Cress Beds	0.109	0.009	0.06	1.629	0.098	9.18%
Manor Farm	0.192	0.036	0.06	1.629	0.098	36.73%
Pinglestone Cressfarm	0.069	0.006	0.06	1.629	0.098	6.12%
West Lea Farm Shop Watercress Beds	0.103	0.004	0.06	1.629	0.098	4.08%
Fobdown Cressfarm Upper Beds Stilling Pond	0.05	0.002	0.04	0.545	0.022	9.09%
Fobdown Cressfarm Top End Stilling Pond	0.055	0.002	0.04	0.545	0.022	9.09%
Fobdown Cressfarm Beds 16-19a	0.047	0.002	0.04	0.545	0.022	9.09%
Fobdown Cressfarm Bottom End Stilling Pond	0.068	0.003	0.04	0.545	0.022	13.64%
Springvale Watercress Beds	0.351	0.029	0.06	5.34	0.32	9.06%

Table 4: Soluble reactive phosphorus (SRP) load from Watercress Beds on the Itchen

The Itchen studies have demonstrated that phosphate loading in the headwaters of chalk rivers can be significantly elevated as a consequence of discharges from watercress beds. The influence of these elevated phosphate loads on river ecology is more difficult to demonstrate, but there is a growing body of anecdotal evidence to suggest that summer growths of filamentous green algae in the upper reaches of the River Itchen have increased (David Withrington, pers. comm.). Growth of algal communities in chalk rivers has been shown to be dependent upon elevated phosphate levels, leading to undesirable changes in chalk river ecology. This is supported by the research undertaken by CEH on the River Frome in Dorset referred to in section 3.1.1.

3.2 Silt and sediment

3.2.1 Impacts of suspended solids on chalk river ecology

Clear chalk-stream water flowing over clean gravel beds is a key habitat requirement for the rich diversity of typical chalk river plants and animals. The swaying fronds of river water crowfoot *Ranunculus penicillatus* subsp *pseudofluitans* that are characteristic of chalk rivers require clean gravels for successful seed germination and rooting of shoot fragments. A range of benthic (or bottom-dwelling) invertebrates also rely on clean gravels, but it is the typical fish of chalk streams that are particularly dependent upon well-oxygenated clean gravel for spawning. Intra-gravel spawning species include not only brown trout *Salmo trutta* and salmon *S. salar*, but also all three lamprey (Lampetra) species and dace *Leuciscus leuciscus*. As silt accumulates in the gravels where these species spawn, the survival of eggs and juveniles declines due to lack of interstitial water flow and consequent reductions in dissolved oxygen. The effect is even more acute if the silt carries a high proportion of degradable organic matter.

Once chalk river gravels have become clogged with silt, the limited natural flushing capacity of chalk rivers makes it difficult for them to clean themselves. River managers have traditionally raked gravels to release silt, whilst the 'redd' cutting activity of gravel-spawning fish can also release silt from the surface layers of the gravel bed. Cyclical growth of *Ranunculus* and starwort *Callitriche* spp. followed by ripping out of the starwort root mass by high winter flows also helps to clean gravels. However, given the natural lack of energetic flushing in chalk rivers, they are highly susceptible to inputs of solids and particularly organic rich solids, such as those that are likely to derive from watercress beds.

3.2.2 Watercress beds as a source of suspended solids

The 'traditional' system of watercress growing and harvesting resulted in beds being cleared and replanted once a year with maximum production taking place in the autumn and winter months from cyclically cut and re-grown stubbles. The cleaning of the watercress beds can release considerable loads of suspended solids into the receiving watercourse, comprising a mix of organic material, inorganic silt and plant remains. Suspended solid levels exceeding 10,000 mg/l have been measured in the discharge from beds, and levels in receiving waters can reach 100 mg/l. Bed cleaning tends to produce very high levels of suspended solids for short periods of perhaps two hours, but for the great majority of the growth period the watercress bed will add little or nothing to the suspended solid load in the receiving watercourse.

With the shift to more intensive methods of watercress production, in particular the regular clearing and replanting of beds during the spring and early summer, the frequency of bed cleaning increased, and steps were taken by the National Rivers Authority in the 1980s to license the discharges of all watercress farms. The licences of 'conventional' watercress producers contained specific limits on a number of parameters including the concentration of suspended solids. 'Traditional' watercress producers were required to abide by a Code of Practice to limit discharge of suspended solids to the receiving water courses (see section 4.1 for further details).

3.2.3 Control of suspended solids discharges by watercress producers

For the conventional watercress producers to meet their consent conditions for suspended solid load, they have been obliged to install silt settlement systems. Two systems have evolved using either settlement tanks or settlement lagoons.

Settlement tanks are used on a number of watercress farms, for example at St Mary Bourne in Hampshire and at Spetsbury in Dorset. Tanks are constructed above ground within the watercress farm and are generally cylindrical in shape. The flow of water to the beds is slowed to a minimum or stopped prior to clearing and cleaning. Dirty water used to wash and clean the beds is then diverted to a sump and pumped to the settlement tank. The dirty water is left in the tank until the sediment has settled – usually about 24 hours but may be as little as 3 hours – before the cleaner water is pumped from the tank to the receiving watercourse. The discharge from watercress beds between cleaning operations is direct to the receiving watercourse.

A detailed operating procedure has been drawn up for the settling tank at St Mary Bourne. This is reproduced in Appendix 2.

Settlement lagoons are used in probably the majority of watercress farms. These comprise lone or a series of linked pools or ponds through which the discharge from most of the watercress beds is channelled. On farms where the size of the settlement lagoons is limited by available space or the shape of the site boundary, a number of different arrangements have been adopted to allow clean water to by-pass the lagoons. The design of settlement lagoons has evolved over time, so that on some watercress farms they incorporate a series of baffles and skimmers and reed-planted weirs through which the discharge water is filtered. Others consist of concrete-lined, rectangular- shaped pools.

Problems with water quality from watercress-bed discharges can occur when settlement lagoons are cleaned out, particularly where unsupervised contractors are used or where there is no facility to divert the flow around the settlement lagoon during cleaning out. These risks to water quality can be overcome through better design of settlement-lagoon systems and careful supervision of contractors.

A sketch of the layout of the settlement system operated by The Watercress Company at Warmwell watercress farm in Dorset is reproduced in Appendix 3. The average size of the settlement lagoons is 1,400m^2. This is made up of a number of smaller ponds to create separate settlement areas. The company estimates that this will manage approximately 1 million litres of water per day. Settlement lagoons are cleaned out periodically, often once a year, but require much less regular cleaning than settlement tanks.

Watercress growers operating under the ‘traditional’ growers Code of Practice are not required to have settlement systems, although some have a basic settlement lagoon. For example, at Spring Gardens watercress beds in Hampshire, the discharge water is channelled through a former watercress bed at the bottom of the site, where some of the suspended sediment load is deposited. However, there are reports that the Cheriton Stream downstream of these watercress beds can flow with the ‘colour of the Yangtze River’ (Jess Pain, Hampshire Wildlife Trust, pers comm.), which suggests that this system is not always effective.

Vitacress have produced a ‘Suspended Solids Settlement Systems Policy Statement’ (November 2001). Although they have a range of settlement systems, the following principles apply to all watercress farms operated by the company:-

1. Plant material and silt should be removed from the bed prior to washing down, with all flows in and out reduced to a minimum.
2. In ‘wet’ beds (those with uncontrolled flows) the system should be in operation for cleaning out and washing down.
3. No unnecessary volume of clean waste should be allowed into the dirty water system in operation.
4. Filter systems must be checked and in place during operations.

3.2.4 Results of suspended solids monitoring on chalk rivers

All ‘conventional’ watercress growers are required to limit suspended solid concentrations in their discharge to 20mg/l (dried at 105 degrees centigrade). In addition, the discharge should not contain any solid matter arising from the culture of watercress having a size greater than 5mm in any two dimensions.

Data have been provided by the Environment Agency on compliance with these standards. These show generally very good compliance. In Dorset and Wiltshire, a total of 1,902 samples were analysed from watercress beds in 2004, of which only 32 (2%) failed to meet their standard for suspended solids. In Hampshire, 900 samples were taken between December 1999 and January

2004, of which 43 (5%) failed to meet their consent standard for suspended solids. Details of consent failures for watercress beds in Hampshire are shown in Table 5; some of these are serious, and it may be that other similar incidents went undetected.

Concern has been expressed by watercress growers and others over the lack of regulation of suspended-solid discharges from 'traditional' watercress growers. In Hampshire, water quality is not routinely monitored from these watercress beds, as their discharge consent does not have any condition for suspended solids. However, the traditional watercress growers are required by their consent to abide by a Code of Practice which includes notifying the Environment Agency, in writing, of an intention to clean out a bed, stating the date and time of the proposed operation. This requirement is not being widely complied with; indeed, the traditional grower interviewed as part of this study admitted that he never informs the EA of his intention to clean out a watercress bed. In the height of the growing season (mid March to mid July), traditional watercress growers may clean out and re-plant a bed every week. Given this frequency of bed cleaning, it may be impractical for traditional growers to inform the EA every time a bed is to be cleaned.

Table 5: Details of suspended-solid consent failures for watercress beds in Hampshire (Dec. 1999 - Jan. 2004) (data from the Environment Agency)

Location	Date	Suspended solids (>20mg/l)	Observations
Warnford W/Cress Beds Winch Rd	05/05/1999	52.9	cloudy, some watercress particles > 5 mm in any 2 dimensions
	21/09/2000	47.7	very high suspended solids and leaf matter
	12/03/2002	21.8	some solids
Warnford W/Cress Secretary Beds	19/04/2001	30.1	some solids, unusual odour in air
Vitacress Salads, Lippen Lane	20/01/2003	39.7	clear
	13/09/2004	58.1	
Nythe Watercress Beds	06/11/2002	48.9	cloudy
	11/12/2003	25.6	cloudy and some solids
Pinglestone Watercress Farm	27/03/2002	50.6	cloudy watercourse, solids in samples
	21/05/2004	25.1	
Fobdown Beds 16,17,18,19a&b	30/04/2003	65.5	clear, some solid matter present due to cross cutting earlier in water
Fobdown Upper Beds Stilling Pd	30/04/2003	21.3	clear
Fobdown Bottom End Stilling Pd	22/04/1999	69	cloudy, men working in cress beds with tractor
	31/05/2000	30.8	slightly cloudy (working on beds)
	29/04/2002	47.7	clear with some leaf matter
	15/08/2002	27.7	slightly cloudy
Drayton Beds Outlet 1	01/07/2002	25.9	cloudy, dam collapse
	06/11/2002	65.2	stream extremely cloudy
Manor Farm Cress Beds	16/03/1999	20.2	slight pale colour
	20/04/2000	29.2	slightly cloudy
	18/05/2000	31.6	working on cress beds, high suspended solids. Formal sample taken. Some water cress discharging under scum board.
	18/05/2000	48	high suspended solids (working on cress beds)
	31/05/2000	22.3	slightly cloudy (working on beds)
	10/07/2000	63	large particles of watercress passing discharge point, high in suspended solids
	10/07/2000	38.7	large particles of watercress passing discharge point. High suspended solids - formal sample taken.
	30/05/2002	21	clear

Maxwells Cress Beds	15/08/2002	25.2	cloudy
	03/09/2002	49	cloudy, lots of suspended solids
	15/10/2002	32.6	clear, some suspended solids
	21/05/2004	29.9	
Springvale Watercress Beds	28/04/1999	39.8	checking to see if the pond is preventing suspended solids and other associated pollutants leaving site and entering river water after cleaning of watercress beds
	03/11/1999	22.3	clear
	06/11/2002	689	extremely cloudy; work being carried out on settlement ponds
	24/04/2004	65.6	
Lower Bishops Sutton Outlet 1	24/03/1999	30.7	turbid
	22/04/1999	50.9	cloudy, men working in cress bed with tractors
	31/05/2000	57.5	high suspended solids with large particles present (formal sample taken)
	21/01/2002	42.4	cloudy
	26/02/2002	36.4	clear with slight white cloudiness in water course
St Mary Bourne W.F Viaduct Side	22/04/1999	152	very cloudy
	20/08/2001	26.5	
	27/03/2003	38.3	high suspended solids content (no loose plants, but leaf pieces in river)
	17/11/2003	27.9	fairly high suspended matter, though no loose plants
St Mary Bourne W.F Bourne Side	16/03/1999	45.7	slightly cloudy
	30/11/2004	39.6	
Abbotts Ann Watercress Farm	17/08/1999	26.5	clear
	30/05/2002	20.3	cloudy
	03/09/2002	22.8	matter slightly cloudy
	19/08/2004	21.4	

3.3 Impacts on invertebrate populations

3.3.1 The role of zinc

The Freshwater Biological Association (FBA) report to the Department of the Environment (Casey et al, 1988)[11] was one of the first publications to identify elevated levels of zinc in plants, suspended solids and sediments downstream of watercress beds and a positive correlation between zinc and organic matter. This report also recorded the absence of *Gammarus* from downstream of some watercress farms, but the cause of this was not established.

In 1990 the Water Research Council (WRc) was commissioned by the National Rivers Authority to investigate the role of zinc in the impact of watercress-bed effluent on populations of *Gammarus pulex*. This laboratory study investigated the response of *G. pulex* to sediments collected downstream of Abbotts Ann watercress farm in Hampshire. It concluded that the sediments were not directly toxic to *Gammarus* but that food palatability was reduced leading to behavioural responses such as avoidance, reduced feeding rate and increased swimming activity that may also lead to reduced fecundity and recruitment. WRc expected similar effects on all sediment types, as plants were still contaminated with zinc, even in more gravelly substrates.

Since the early 1990s, the Environment Agency has continued to monitor invertebrate populations downstream of watercress beds. The results of this are very variable. In Hampshire, a review of

[11] Casey, H., Ladle, M., Welton, J.S. and Smith, S.M. 1988. *Impact of watercress cultivation on river quality*. Unpublished report to the Department of the Environment

watercress farms in the county was carried out in 1999. This revealed a severe impact on the biological index downstream of St Mary Bourne and Abbotts Ann watercress beds. However, other watercress beds that were also known to use zinc did not show such an impact, for example at Manor Farm, Pinglestone, Fobdown and Springvale on the Itchen and at Warnford on the River Meon. Further surveys at St Mary Bourne have shown improvement at this site, whilst there is some evidence that the impact of the Abbotts Ann site has declined in recent years.

In Dorset and Wiltshire, severe impacts on populations of *G. pulex* and other invertebrates were associated with watercress farms in the early 1990s. However, more recent monitoring undertaken in 2004 suggests that many of these problems have been resolved, even if some issues remain. The following accounts provide a more detailed review of the results of invertebrate monitoring at watercress farms on chalk streams in Hampshire, Dorset and Wiltshire.

3.3.2 Impacts of watercress farms on invertebrate populations in Hampshire

In 1998, the Environment Agency reported that the discharge from St Mary Bourne had resulted in *'a marked reduction in biotic scores between the right and left branches of the Bourne Rivulet'.* In other words, the branch of the river unaffected by watercress discharge showed a much higher biotic score using two standard biological scoring methods.

The report goes on to state:-

'The impact of siltation was clearly evident. Elmidae (riffle beetles), a taxon sensitive to siltation, disappeared entirely, and given the riffle-run nature of the downstream sites an abundance of log 3 or more would be considered normal. Elmidae were found in log 2 abundance (2-11 individuals) at site 5 (2.9 km downstream) which is lower than would be expected for an undisturbed site. In addition, invertebrates adapted to silty environments (e.g. Valvatidae and Hydrobiidae) increased in abundance immediately downstream.

The water shrimp *Gammarus pulex* is particularly sensitive to zinc, used to control Crook Root Disease on watercress farms. The Environment Agency survey found a profound effect on *Gammarus pulex* at St Mary Bourne. A *G. pulex* abundance of log 4 or more is considered normal for riffle sites on a river of this type. The unaffected branch of the Bourne Rivulet had an abundance score of log 5 (1,001 – 10,000 individuals), whilst the branch affected by the watercress discharge had no *G. pulex*.

The Environment Agency report states:- *G. pulex showed some recovery downstream (log 2 at site 4 and log 3 at sites 3 and 5). However, at Hurstbourne Priors, which is routinely monitored, only one individual G. pulex was found in both spring and autumn samples. Thus St Mary Bourne cress farm is having a significant and deleterious impact some 2.9 km downstream.*

However, it should be noted that samples for this report were taken during a drought year.

In May 2004, Environment Agency monitoring at St Mary Bourne showed a clear impact on the invertebrate community downstream of the watercress farm, with increased abundance of indicators of organic pollution (Oligochaeta, Chironomidae, Glossiphoniidae, Erpobdellidae and Asellidae) and suppression of indicators of 'good water quality' (Elmidae and Gammaridae).

In October 2004, Vitacress commissioned their own monitoring of invertebrate populations associated with the St Mary Bourne watercress farm. These data have been analysed in relation to the 'indicators of organic pollution' and 'good water quality' identified by the Environment Agency. The results of this are shown in Figure 9, and tend to substantiate the results of the EA monitoring undertaken earlier in 2004. Indicators of pollution include Chironomidae*, Asellus aquaticus* and *Glossiphonia complanata*. Indicators of good water quality include *Elmis aenea* and *G.pulex*.

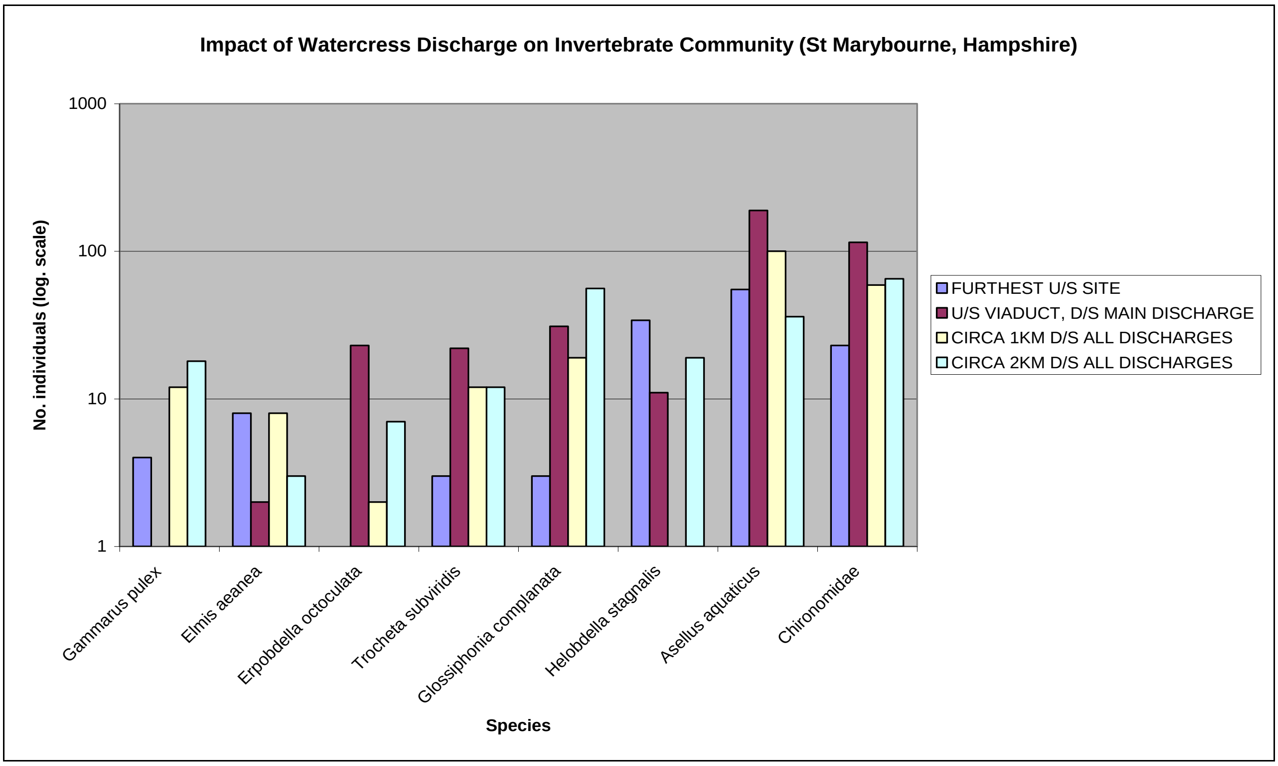


Figure 9: Results of invertebrate monitoring undertaken by Environ on behalf of Vitacress at St Mary Bourne watercress farm, Hampshire (October 2004)

Further monitoring of the aquatic invertebrates at St Mary Bourne was undertaken by the Environment Agency in 2005, 2006 and 2007. The 2007 monitoring report (Medgett, 2007) concluded that despite improvements to the operating regime of the watercress farm and dredging to remove silt downstream of the discharge, there continues to be:

'a measurable negative impact on the macro-invertebrate communities within the Bourne. Invertebrates generally associated with organic pollution proliferate in the Eastern Arm and to a lesser degree at The Island. This was largely attributed to the accumulations of organically rich silt that have built up in the eastern channel after it was dredged. However, there were other changes in the fauna that indicate that sediment deposition is not the only causal factor. For example, riffle beetles (Elmidae) continue to be virtually excluded from the eastern arm and further downstream despite suitable habitat.'

However, the report goes on to state:

'There were, nevertheless, welcome signs of an improvement in some important, and pollution sensitive, groups. Generally, this started to be seen in 2006 and continued in 2007. It was most obvious in the eastern arm of the Bourne and to a lesser degree at The Island. This ties in well with the time that Vitacress changed the composition of their salad-wash water and ceased to discharge this and sediment tank effluent, directly into the eastern arm of the Bourne. It appears that these changes have enabled a few groups of organisms that are more pollution-sensitive to colonise this stretch of the Bourne (Ephemerellidae, Baetidae and caddis fly larvae). The most striking improvement was in Gammaridae, which in 2007 were found in abundance at Iron Bridge and were also making a good recovery in the eastern arm and at the Island. Undoubtedly the high flows experienced in 2007 would tend to favour pollution-sensitive organisms. However, the scale of the upturn implicates an improvement in water quality over and above that which could be explained by the simple greater dilution of pollutants afforded by higher flows. Therefore, the operational changes made by Vitacress Salads seem to have benefited the fauna of the Bourne Rivulet. This has meant that a more typical chalk-stream fauna is beginning to develop below their site. The extent of the impact is still measurable 1.9 km downstream but it is less marked than historically.'

Results from the Environment Agency monitoring at St Mary Bourne are shown in Appendix 4.

During 2006, the impact of the watercress production and salad washing and packaging operation on the invertebrate fauna of the Bourne Rivulet at St Mary Bourne was also the subject of a comprehensive study undertaken by Clare Marsden (Marsden, 2006). This investigated the toxicity and chemical composition of the effluents discharged from the site, using a combination of approaches including biotic surveys, caged exposure, avoidance assays and chemical analyses. This study was able to show that the primary contributor to the impact on the invertebrate fauna of the Bourne Rivulet was the settlement-tank effluent, specifically BOD, COD (and possibly organic chloramines) associated with sodium metabisulphite used in dechlorination of the salad washing. Despite the suspension of chlorine use in the salad washing in July 2006, the salad-wash effluent remained a significant cause of invertebrate toxicity. Marsden concludes "The chemical cause of this toxicity has not been conclusively identified, although PETIC, BOD and aluminium have all been proposed. Three 'lesser' contributors to the impact were identified: sediment metal accumulations from various sources; ammonia/nitrite from the watercress liquid fertilizer; and sediment from the salad-wash effluent, watercress operations and road drain."

At Abbotts Ann, the Environment Agency reported a similar impact on invertebrate communities in 1998 and found that this watercress farm was having a significant impact some 700m downstream. Their report concluded that:-

'Abbotts Ann Cress Farm continues to have a significant effect on the ecology of the Pilhill Brook. The macro invertebrate communities have changed in response to toxic pollutants and siltation. Siltation may have been compounded by low flows, but an effect on G. pulex in response to toxic pollutants is evident.'

The most recent monitoring data from Abbotts Ann suggest that the invertebrate populations downstream of this watercress farm are now recovering.

The Environment Agency undertook invertebrate sampling above and below 8 'traditional' farms in Hampshire in 2008. There appeared to be no adverse impact from the watercress farm discharges (Miller, G, unpublished report).

3.3.3 Impacts of watercress farms on invertebrate populations in Dorset and Wiltshire

In Dorset and Wiltshire, there have also been concerns over the impact of watercress farms on invertebrate populations. In 1992, the Environment Agency reported the results of invertebrate surveys undertaken in the spring and autumn of that year. It found that five taxa predicted to occur by RIVPACS (a computer package designed to model river invertebrate communities) were absent below watercress-farm discharges in a number of cases. Of these *Gammarus pulex, Elmis aeanea, Baetis rhodani* and *Pisidium* spp. were regarded as being otherwise 'virtually ubiquitous in chalk-stream communities'.

The report goes on to state that *Gammarus pulex* was recorded below the vast majority of watercress farms, but that there was '*a significant reduction in abundance between upstream and downstream sites in most cases*'.

Additional surveys were undertaken by the Environment Agency in 1995 and 1997-1998. The 1995 survey concluded that problems relating to the absence or presence in much reduced numbers of *G. pulex* in the River Ebble (tributary of the River Avon) have been evident since 1989 and clearly implicated the discharges from the two watercress farms that were present in the valley at that time. One of these has since closed. The 1997-98 survey also found depleted *Gammarus* populations below a number of watercress beds in Dorset and Wiltshire.

Further monitoring of *G. pulex* at a number of sites in Dorset and Wiltshire was undertaken by the Environment Agency in the autumn and winter of 2004. This survey was done as a scoping exercise to identify those watercress farms where more detailed survey might be required to investigate possible impacts on invertebrate communities. The survey found much improved populations of *Gammarus* on the Ebble, and it was concluded that the remaining watercress farm could no longer be implicated in having an impact on this species (pers comm. Mitch Perkins, EA). It also found apparently improved conditions on the Bere Stream (tributary of the River Piddle). The survey suggested that problems may exist at two sites on the River Frome and its tributaries. The Environment Agency is undertaking further surveys to investigate this.

3.3.4 Declining use of zinc in watercress production

The use of zinc has been implicated in the observed changes to aquatic invertebrate communities downstream of watercress beds - in particular the depletion of *G. pulex* populations. However, no conclusive information has been produced to demonstrate a causal link between zinc use and effects on invertebrate populations. Nevertheless, the use of zinc in watercress production has been substantially reduced in recent years. For instance, no zinc has been used at St Mary Bourne since 2002, whilst at Doddings watercress beds in Dorset none has been used in the last four years. This reduction in use is partly due to the change in production pattern to a summer crop, reducing the emphasis on winter production when Crook Root (the disease zinc is used to control) is most prevalent. The regular cleaning and replacement of the beds on conventional and organic watercress farms reduces the build-up of Crook Root in the beds. Interestingly, the 'traditional' watercress growers, who replace their beds only once a year, do not use zinc and claim that their beds are full of *Gammarus* as a consequence.

3.4 *Gammarus* depletion and the impacts of mustard oils

The monitoring of invertebrate populations downstream of watercress beds has shown depletion of *G. pulex* populations and an increase in the number of species associated with silt and sediment at a number sites. This appears to be related to sediment deposition and to some unspecified toxic effects, possibly involving zinc.

More recently it has been suggested that the natural mustard oils that are present in watercress may be released during its harvest and have a deterrent effect on *Gammarus*. Watercress stores phenylethyl glucosinolate, which is hydrolised to 2-phenethyl isothiocyanate (PEITC) when the plant tissues are bruised or damaged. Watercress is the richest natural source of PEITC, which gives it its unique peppery flavour. Work in the USA has shown that *Gammarus pseudolimnaeus* and other aquatic invertebrates have a strong aversion to feeding on the leaves of healthy watercress, but that this aversion is not shown to unhealthy yellow leaves or when the enzyme that hydrolises the glucosinolate is denatured by heating.

A 1999 survey of operational practice on watercress farms commissioned by the Environment Agency and undertaken by Michael Payne for Sue Fewings[12] concluded that:-

'The evidence available gives reason to believe that PEITC, which is produced by healthy watercress leaves when damaged, results in avoidance behaviour by Gammarus pseudolimnaeus at least so far as feeding is concerned and possibly more generally. The hypothesis that the maceration of quantities of healthy watercress tissue causing a release of PEITC at watercress farms could cause Gammarus to be absent for distances downstream of farms is worthy of investigation. The effect at some farms rather than others may be a concentration function relating to the scale and nature of watercress production at the farm in relation to the dilution available in the receiving water'.

These effects were observed in laboratory conditions in high concentrations of crushed and rolled watercress in a study undertaken for Vitacress Salads in 2005[13].

Clare Marsden also considered the effect of PEITC on *Gammarus* and concluded that as the watercress harvesting machine crushes only a small proportion of plants and that watercress

[12] Fewings, S. 1999. Survey of Operational Practice on Watercress Farms in Hampshire. Collaborative Project of The Environment Agency, Horticultural Development Council and Watercress Growers Association
[13] Worgan, AP & Tyrell, R. 2005. Monitoring behavioural responses of Gammarus pulex to watercress oils.

plants are cropped above the water's surface, only small quantities of PEITC would end up in the effluent discharge. In addition, she suggested that if watercress harvesting was releasing PEITC at concentrations sufficient to cause an invertebrate impact, there would be a strong smell of PEITC associated with harvesting – which there is not. As a consequence, she concluded that:
"Overall, PEITC resulting from the harvesting process, seems an unlikely culprit for the invertebrate impact in the East rivulet."

However, she also concluded that:-

"PEITC derived from the salad wash is more likely. Approximately 40% of the washed salad is watercress or rocket, both of which release PEITC. Considering the large quantities of salad washed combined with the high sap content of the salad wash effluent and the strong smell of PEITC, it is highly plausible that PEITC is a major contributor to the mortality detected in the East rivulet."

3.5 Impacts of watercress farming on fish

The effects of watercress farms on fish communities has not been well studied. However, the Environment Agency has undertaken surveys of fish downstream of the St Mary Bourne watercress farm. The first of these was undertaken in November 2004 and concluded that there was no evidence of an adverse effect either on the numbers or biomass of brown trout (*Salmo trutta*) from the watercress farm's discharge to the Bourne Rivulet.

A second more comprehensive survey was undertaken at St Mary Bourne by the Environment Agency in the autumn of 2006 (Longley, 2007). This sampled six sites using electro-fishing methods to estimate populations of brown trout and record the presence of other species (see Appendix 4 for a map showing the location of survey sites). Six species of fish were caught, including brown trout, brook lamprey (*Lampetra planeri*) and bullhead (*Cottus gobio*). Both brook lamprey and bullhead are listed on Annex II of the EU Habitats Directive and are an interest feature of the River Test SSSI (Table 7).

	Brown trout *Salmo trutta*	**Eel** *Anguilla anguilla*	**Bullhead** *Cottus gobio*	**Grayling** *Thymallus thymallus*	**Brook lamprey** *Lampetra planeri*	**Three spined stickleback** *Gasterosteus aculeatus*
Eastern Fork	■	■	■			
Western Fork	■	■	■			■
D/s Parallel		■				
Island	■	■	■		■	
D/s Ironbridge	■	■	■			
Hurstbourne Priors	■	■	■	■	■	

Table 6: Summary of species identified during the 2007 electro-fishing survey downstream of St Mary Bourne watercress farm

The survey concluded that the distribution, density and biomass of brown trout in general and juvenile trout in particular do not suggest an effect from the watercress farm's effluent. It found that sites closest to the discharge supported brown trout populations which compared favourably with those downstream.

The density of bullhead observed in the Eastern Fork (immediately downstream of the watercress farm) was the lowest observed. Bullhead densities were also low at Hurstbourne Priors and d/s of Ironbridge but relatively higher at both the Island and Western Fork sites. The low densities of this species observed in the channel downstream of the watercress farm in this and the 2004 survey may be due to sampling effects. But the relatively sedentary nature of the bullhead and its preference *Gammarus* and *Asellus* in winter, means that it may indicate environmental effects not apparent from the brown trout data.

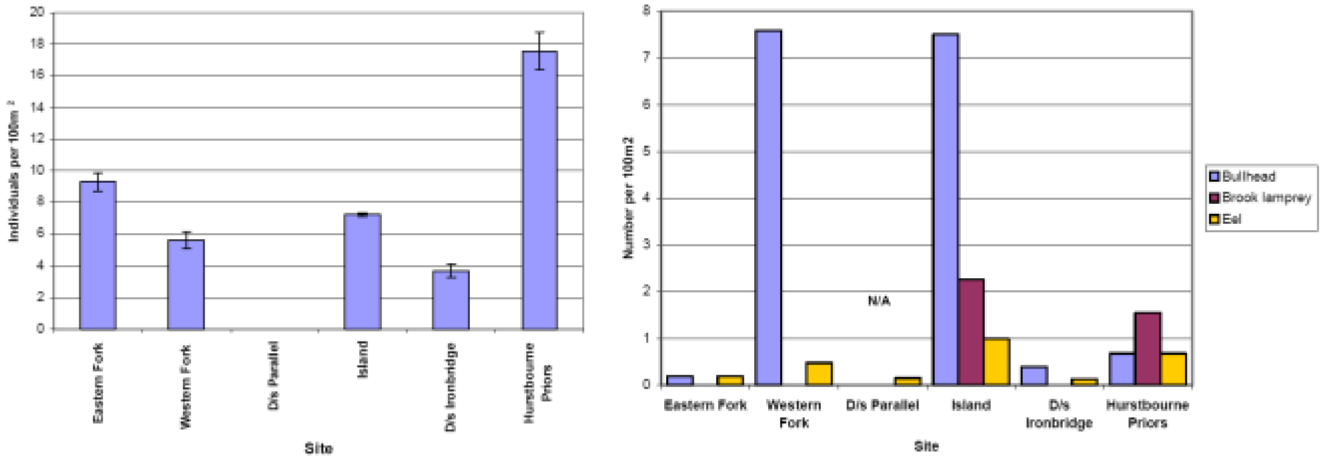


Figure 10: Densities of brown trout (left) and other species (right) associated with the St Mary Bourne watercress beds

3.6 Impacts of watercress farming on bird populations

Hampshire watercress beds were known to provide an important habitat for breeding and wintering wetland birds. In summer, the watercress beds in the Itchen valley were used by nesting waders, and redshank (*Tringa totanus*) in particular. These birds used to nest mainly in the floodplain grasslands adjacent to the watercress beds and use the beds for feeding, although there are a few reports of birds actually nesting within the watercress beds themselves (Charles Cuthbert pers. comm.). The birds fed on invertebrates within the watercress beds during the spring and early summer. In referring to the decline of breeding redshank in the Hampshire river valleys, the *Birds of Hampshire*[7] states that this was due to the progressive drainage and improvement of many of the meadows but that this was '*exacerbated by other factors such as the increased use of chemicals in watercress beds (a favoured feeding habitat)*'. It seems more likely that the decline in use of the watercress beds by redshank in the breeding season, if indeed it is different from the decline in redshank breeding numbers on flood plain grassland, could have been caused by a switch in emphasis from winter to summer watercress production, and the disturbance associated with frequent cleaning and replanting of watercress beds in the spring and early summer.

In addition to their use by breeding birds, watercress beds in Hampshire were once used by significant flocks of water pipits (*Anthus spinoletta*). Water pipits are uncommon wintering birds in Britain, confined to south and south-east England. The British wintering population has been estimated at only 100 birds, although this is probably an under-estimate. Between 30 and 35 birds wintered on Hampshire's watercress beds until the mid 1980s, but since then numbers have been much reduced. In a survey of 21 watercress farms in 1989/90, only one bird was found, at Alresford (Pain, 1990). The reasons for lower numbers are not clear, and may be due to factors clearly divorced from watercress production. In Dorset, water pipits still visit watercress beds in cold winters (George Green, pers. comm.), and there is less evidence of a decline in numbers.

Another characteristic wintering bird of watercress beds is the green sandpiper (*Tringa ochropus)*. The wintering population of green sandpipers in Britain is estimated at between 500 and 1,000 birds. Numbers wintering on watercress beds in England have not been surveyed, but there are regular reports from watercress beds in Dorset and Hampshire. The *Birds of Hampshire*[14] refers to counts of 8-17 birds being made from '*Old Alresford, Bighton Lane, Bishops Sutton, Western Court, Quidhampton, Southington and Mapledurwell watercress beds*'. Several of these watercress farms are no longer operational. However, there is a general concern that numbers of wintering green sandpipers using the remaining beds have also declined, in line with the decline in water pipit numbers (Jess Pain, pers. comm.).

3.7 Abstraction

Water used to irrigate watercress beds in chalk-river catchments is abstracted from aquifers under licence from the Environment Agency. The volume of water abstracted can be very considerable; for example, the total licensed daily abstraction for watercress production in Hampshire is 259,639m^3. By volume, 47% of the licensed abstraction is in the Test catchment, 42% in the Itchen catchment and 11% in the Meon catchment. There are, however, significant differences between licensed volumes and those actually abstracted. Measurement of abstractions has shown that the larger licensed abstractions are generally under used, whilst some of the smaller ones are over abstracted.

Licence conditions for watercress growers are that abstraction is non-consumptive, requiring at least 95% of water to be returned locally. On a catchment scale, watercress licences have a small impact on overall water resources. However, site-specific data and investigations have shown that large watercress beds have the potential to alter river flow regimes. This can be illustrated by investigations at two watercress beds in the upper Test catchment. At Abbotts Ann watercress farm, investigations were undertaken by the Environment Agency in the summer of 1997. The pumped boreholes were turned off for one hour, and river flows and groundwater levels monitored before, during and after this event. The results showed that, in summer months, flows from the cress beds can represent over 90% of total flow in the Pilhill Brook downstream of Abbots Ann. It also appears that the abstractions cause reduced flow immediately upstream of the beds for a distance of about 1 km. Both of these effects represent changes to the natural flow regime of the river.

Investigations were undertaken at St Mary Bourne in July 2004, when the pumped boreholes were turned off for a 2-3 hour period to allow monitoring of river flows and groundwater levels. The results of this test and collation of other flow-gauging data at the site suggest that, in exceptional summer conditions, flow from the watercress bed can represent over 90% of total flow in the Bourne Rivulet downstream of the beds. Drawdown in groundwater level at the beds was about 60 centimetres, and around 15 centimetres in a borehole 200m from the beds.

The naturally high groundwater levels result in flows in the Bourne Rivulet accreting upstream of the watercress beds. The drawdown effects of the watercress bed abstraction may mean the rate of flow accretion is lower than would occur if the cress-bed abstraction was not there. As a consequence there may be some local reduction in flows immediately upstream of the beds.

A characteristic feature of chalk streams is that they have an ephemeral upper section known as a 'winterbourne' that flows for only part of the year, when groundwater levels break through the bed of the stream channel. This generally occurs in late autumn or early winter, but varies considerably between years. Flow may persist into mid summer and then cease as groundwater levels subside. Winterbournes typically have a distinctive flora and associated fauna adapted to these ephemeral flows. In common with many watercress beds, those at Abbotts Ann and St Mary Bourne are at the head of the perennial flow section of the watercourse. The construction of boreholes and pumping at watercress beds creates something of a stepwise change in river flow above and below the beds. Upstream, there may be some draw-down of ground water, so that the length of time the

[14] Clark, J M & Eyre, J A. 1993. *Birds of Hampshire*. Hampshire Ornithological Society.

winterbourne sections flow may be reduced. Downstream of the watercress beds, flows are significantly increased by the discharge from the watercress beds.

The ecological consequence of this change is that the period for which the winterbourne sections upstream of the watercress beds flow may be reduced by a few weeks each year. This could have implications for the winterbourne vegetation communities that are able to develop. Equally, the augmented flows downstream of watercress beds are likely to sustain flora and fauna, which would occur further downstream in more natural conditions. For these and related reasons, English Nature resisted the use of supplementary borehole flows to compensate for abstraction from the River Till in Wiltshire (David Withrington, pers comm). However, the impacts of specific abstractions need to be assessed in relation to their local circumstances.

4 Regulatory regime

4.1 Discharge consents

4.1.1 Control of silt

The Environment Agency has produced water quality consenting guidance for watercress bed discharges. Discharge consents are issued in accordance with this guidance. The following account summarises the guidance.

Control of silt from intensive (conventional) watercress beds

a) Where the entire flow from the site can be passed through a settlement lagoon or other treatment plant, the level of suspended solid in the final effluent must not exceed 20mg/litre at any time. It is recognised that site layout may preclude the provision of a full-flow facility, and in this situation the Agency will grant an interim consent, pending improvements to provide a standard of protection equivalent to that provided under (a).

b) Daily bed-cleaning operations shall be concluded within a two-hour period notified and agreed with the EA. All effluent from beds being cleaned will be passed through a lagoon or other treatment plant, the effluent from which shall not contain suspended solid at concentrations in excess of 100mg/litre. The discharge shall be permitted for the specific period during the working day to coincide with bed-cleaning operations. Thereafter, no bed-cleaning operations shall take place.

c) It is recognised that exceptional precipitation will create increased levels of sediment in bed effluent, and a condition is applied to take account of exceptional rainfall.

Control of silt from traditional watercress beds

The Environment Agency guidance defines 'traditional' growers as those who replant their beds no more than once a year between the beginning of June and the end of September.

Solids released from traditional watercress beds are controlled under a Code of Practice. This states:-

Code of Practice for control of silt from traditional growers

Growers will ensure that bed cleaning incorporates the following precautions for the Minimisation of silt discharge:-

a) Isolation of the inflow from the carrier and allowing the bed to drain

b) After removal of the crop stubble, all remaining silt and humus material to be swept up, collected and removed off site.

c) After replanting, reinstate flow gradually.

d) Prior notification to the local EA office (pollution control sections) of bed cleaning.

Although traditional growers are only permitted to clean out each bed once a year, in the height of the growing season (March-July) a small watercress farm of 12 or so beds is likely to be cleaning out a bed almost every week.

4.1.2 Control of pesticides

The application of pesticides by watercress growers is carried out in accordance with '*Protecting our Water, Soil and Air: A Code of Good Agricultural Practice for farmers, growers and land managers* (Defra, 2006) and the *Code of Practice for using plant protection products* (Defra, 2006).

Following tests carried out in Hampshire, the watercress industry was given approval for ‘off-label’ use of a number of pesticide formulations.

Fungicides are applied to the compost material in which seedlings are grown. Tests have shown there is no release of these materials when used under the terms of the Codes of Practice.

- Etridiazole
- Benomyl
- Fubol 58 WP
- propamocarb hydrochloride
- fosetyl aluminium

Insecticide were used to remove beetles and other insects from the crop. They are no longer used following pressure from the supermarket chains, the lapsing of the off-label approval for dimethoate and the withdrawal of malathion as a plant product by the EU in 2008.

4.1.3 Control of chlorine and pH

Cut watercress is often washed on site in a hypochlorite solution to meet public health requirements and to improve marketability. To ensure chlorine is not discharged to the river, a consent limit of zero free chlorine is applied to all consented discharges. This is commonly achieved by treating washing water with sodium metabisulphite. However, the impacts of this treatment on river ecology can be very significant as has been shown by the research undertaken by Clare Marsden at St Mary Bourne (Marsden, 2006). There is a strong case for the phasing out of all chlorine treatment in watercress and associated salad processing plants on chalk rivers.

Salmonid waters EQS for pH is between 6 and 9. Consents for watercress discharge are set at this standard. Monitoring indicates that these standards are very rarely if ever breached.

4.1.4 Control of zinc

In response to concerns over the effect of zinc on *Gammarus* populations, a consent level of <75µg/l has been set on all discharges. This equates to the Salmonid waters EQS for zinc. However, effective control of Crook Root (the disease which zinc is used to control in watercress) is effective at just 50µg/l. The Environment Agency’s consenting guidance also states that zinc at concentrations in the water column below the EQS level can be absorbed onto sediment and become sufficiently enriched to deter *Gammarus*. The guidance also suggests that zinc should only be added during the period September to May, when Crook Root is particularly prevalent.

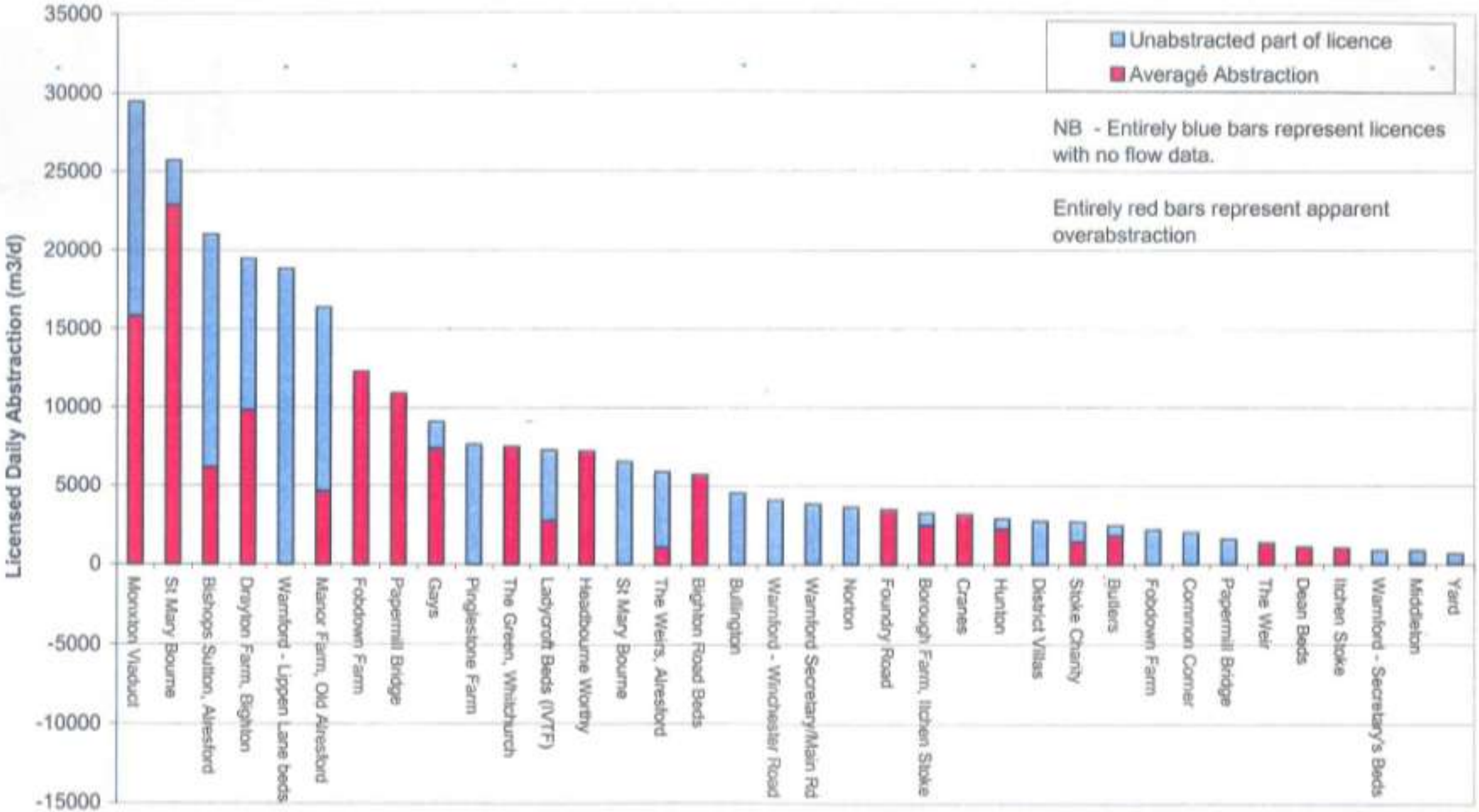
The monitoring data from Hampshire, Dorset and Wiltshire suggest that zinc concentrations in excess of the permitted level were one of the most frequent causes of samples failing permit levels with 66 samples (3%) failing in Dorset and Wiltshire in 2004 and 17 samples (2%) failing in Hampshire between January 1999 and December 2003. The Environment Agency data suggest that most failures are only marginal. However, there is evidence that some watercress beds have repeat failures with up to 14 (32%) of failed samples in one year. This suggests that control of zinc application has not always been carefully adhered to in some watercress beds.

4.2 Abstraction licences

Licences are issued by the Environment Agency for the abstraction of water for irrigation of watercress beds. Abstraction is either from artesian boreholes, pumped boreholes or natural springs. Licence holders are required to make an annual return to the Agency of the volume of water abstracted under their licence. In the case of the large pumped abstractions, such as that at St Mary Bourne, this is calculated by multiplying the running times of each pump by the pumping rate. All watercress abstraction licences require at least 95% of water to be returned locally.

Figure 11 illustrates the volumes of water abstracted by watercress abstraction licence holders in Hampshire. It should be noted that some of these licensed abstractions are no longer used to irrigate watercress beds, for example those at Papermill Bridge.

Figure 11: Usage of abstraction licences at Watercress Beds in Hampshire



5 Towards an environmental Code of Practice for watercress operations

5.1 Scope

The Watercress Growers Association, affiliated to the National Farmers Union, has embarked upon the production of an Environmental Code of Practice. The Environment Agency and Natural England, as the two principal environmental regulators of watercress operations, are participating in the development of the Code of Practice and intend to incorporate parts of it in their consenting systems. The regulators would also like the Code to apply to 'traditional' growers and any other growers who are not currently members of the Association.

5.2 Content

The Code seeks to cover the following key environmental issues:-

- Abstraction of water
- Use of fertilisers
- Use of pesticides
- Discharges of water
- Design and management of settlement lagoons
- Storage of oil, fertiliser and chemicals
- Waste management
- Wildlife management and pest control
- Record keeping

It would also be timely to include an overall sustainability audit to consider wider environmental implications of watercress farms: transport, packaging and waste stream management, energy use and CO_2 emissions and possibly exported impacts from winter 'offshore' watercress production.

5.3 Water use and sustainability

There is a large variation in the amounts of water abstracted for use at different watercress farms (see Figure 11 for licensed abstractions in Hampshire). Ideally, there should be only minimal abstractions from groundwater in the headwaters of chalk river SSSIs, even if they are described as 'non-consumptive' with most of the water discharged to the river. It is desirable to identify best practice in the efficiency of water use in watercress operations, including re-circulating abstracted water through the beds. This would also be a valuable contribution to sustainability. In developing best practice in sustainability overall, it would be sensible to utilise the expertise of the Business and Biodiversity workstream of the England Biodiversity Strategy.

5.4 Suspended solids

These can be generated through the management of beds, particularly bed cleaning and harvesting the crop, as well as through washing operations. The design and operation of settlement tanks and lagoons are obviously crucial to preventing solids from discharging to chalk rivers. The levels of suspended solids measured by the Environment Agency have generally been within the consented concentrations (<20mg/l). However, on a few occasions on a number of watercress farms, levels have been alarmingly high (see Table 5). It is clear that practices need to be improved in these areas of operation, eg improved supervision of contractors, better design and increased extent of settlement lagoons.

5.5 Nutrient concentrations

It is more efficient to control levels of phosphate at the input end, rather than installing effluent treatment. This means accurate dosing of fertiliser matched to the needs of the crop and in ways which will be most effectively taken up by the crop.

Although the emphasis should be on better targeting of nutrient inputs, there is also a role for ancillary treatments. These may include:

- Development of reed beds or other wetland wildlife habitats through which water from the watercress farm can be discharged.
- Increased size and improved design of settlement lagoons capable of accepting all discharge water from the watercress beds.
- Use of no-fertiliser (sacrificial) watercress beds through which normal discharge can be channelled.

Measures to control nutrient inputs – and discharges – will need to take account of any elevated levels of phosphate in the inflow or pumped water supplies to the beds. For example, this is a particular problem on the Bere Stream in Dorset, where there are high phosphate levels in the stream above the watercress farm. These may be due to diffuse pollution from a number of sources, which also need to be controlled.

Research being undertaken by the Horticultural Development Company should contribute significantly to the development of this section of the Code of Practice.

5.6 Toxic discharges

The reduced use and phasing out of insecticides have helped to reduce concerns in this area. However, applications of zinc are still a potential cause for concern. Recent elevated ammonia levels have been recorded by the Environment Agency in discharge water. The causes of these should be identified and good operating practice included in the Code. Further work may be needed to quantify the impact of PEITC on invertebrate populations downstream of cress farms and investigate methods of reducing any impacts.

6 Research and monitoring

6.1 Research

References have been made in this report to research which has been undertaken and that might be needed in future. In the latter category, is a more systematic evaluation of the effects of PEITC in watercress oils on invertebrate populations (Section 3.4); more efficient water use in growing and washing operations; and design and operation of settlement tanks and lagoons (Section 2.5). Research is underway into the impact of different phosphate application regimes on the discharge of total reactive phosphate (TRP) to rivers. The data obtained will determine optimum rates of phosphate fertiliser for maximum economic return, while producing the lowest possible levels of TRP in discharge waters. Information from this research will be incorporated into the Code of Practice.

6.2 Monitoring and investigations

Monitoring for toxic substances, suspended solids and nutrients should continue below conventional and organic watercress farms and should be extended to ‘traditional’ operations. (The Environment Agency undertook invertebrate sampling above and below traditional’ farms in Hampshire in 2008.) Further biological monitoring should be targeted at sites where problems are perceived and linked to investigations to better define the extent, sources and causes of the problems.

6.3 Comparative studies of the effects of different watercress production systems

There is a need to consider monitoring and research to further investigate the comparative ecological effects of traditional, organic and conventional water cress production. In particular:-

- Comparison of water quality discharges from traditional, organic and conventional watercress producers, in particular those discharging to chalk river SSSI.
- Comparison of invertebrate communities associated with different production systems.
- Investigation of invertebrate and in particular *Gammarus pulex* populations within watercress beds operated under different production regimes through a year.
- Monitoring of fish populations downstream of watercress beds and use by fish of settlement lagoons of different design.
- The value of watercress beds for breeding and wintering wetland birds.

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Appendix 1 Soluble reactive phosphorus concentrations recorded from watercress farm discharges

A. Monitoring in Dorset and Wiltshire. Feb. 2003 – Dec.2004 (Environment Agency)

Description	mean	max	min	samples
Tincleton west watercress beds 1	0.261	0.989	0.020	10
Waddock Cross cress settlement lagoon	0.244	0.491	0.106	10
Holwell cress Cranborne	0.239	0.689	0.080	11
Tincleton east watercress beds 1	0.210	0.702	0.080	11
Warmwell watercress farm A	0.173	0.292	0.040	9
Watercress beds, Ludwell	0.122	0.272	0.040	15
Hill Deverill watercress west outlet	0.089	0.171	0.040	14
Hill Deverill watercress north outlet	0.079	0.258	0.020	25
Doddings farm watercress B2	0.078	0.330	0.020	11
Doddings cress settlement pond A1	0.067	0.136	0.020	10
Lower Magiston watercress farm B	0.055	0.152	0.020	10
Hill Deverill watercress east outlet	0.051	0.100	0.030	15
West End cress beds Spetsbury	0.050	0.050	0.050	4
Lower Magiston watercress farm C	0.048	0.070	0.030	9
Southbrook cress settlement	0.033	0.070	0.020	11
Brockhill watercress farm B & C 1	0.032	0.060	0.020	12
Southbrook cress bed 1	0.030	0.060	0.020	13
Roke cress settlement (Hollybush)	0.029	0.040	0.020	10
Brockhill watercress farm A1	0.029	0.050	0.020	12
Broadchalke cress	0.027	0.060	0.020	14
Ilsington cress settlement outlet	0.020	0.020	0.020	9

B. Monitoring in Hampshire. Jan. 1999 – Dec. 2004 (data from the Environment Agency)

Description	mean	max	min	samples
Springvale Watercress Beds (R. Itchen)	0.269	1.390	0.040	30
St Mary Bourne W.F Bourne Side (Bourne/R. Test)	0.183	0.862	0.020	33
Manor Farm Cress Beds (R. Arle/Itchen)	0.163	0.511	0.050	29
Nythe Watercress Beds (R. Arle/Itchen)	0.132	0.816	0.020	29
Drayton Beds Outlet 1 (R. Arle/Itchen)	0.128	0.799	0.040	29
Pinglestone Watercress Farm (R. Arle/Itchen)	0.118	0.724	0.020	29
St Mary Bourne W.F Viaduct Side (Bourne/R. Test)	0.112	0.337	0.020	31
Lower Bishops Sutton Outlet 1 (R. Arle/Itchen)	0.099	0.272	0.020	29
Fobdown Beds 16,17,18,19a&B (Candover/Itchen)	0.098	0.770	0.020	29
Abbotts Ann Watercress Farm (R. Test)	0.098	0.601	0.029	28
Fobdown Bottom End Stilling Pd (Candover/Itchen)	0.092	0.353	0.020	28
Maxwells Cress Beds (R. Arle/Itchen)	0.091	0.319	0.020	29
Fobdown Upper Beds Stilling Pd (Candover/Itchen)	0.072	0.250	0.020	29
Warnford W/Cress Beds (R. Meon)	0.062	0.257	0.020	29
Warnford W/Cres Secretary Beds (R. Meon)	0.053	0.150	0.020	30
Vitacress Salads, Lippen Lane (R. Meon)	0.046	0.140	0.020	29

Appendix 2 Operating procedure for the settlement tanks at St Mary Bourne (Vitacress)

SOP SMB FARM

Ensure settling tank has capacity to receive dirty water and that tank drains are closed.

Identify discharge course for bed to be cleaned down or any other operation causing dirty water discharge.

Minimise clean water entering same discharge flow by reducing pumps/diverting flows.

Wash bed down using sufficient water/tractor or roller or rake to move all the sediment into discharge course.

Start pumps in sumo to drain system – check they are all working.

Divert discharge course to sump just before dirty water reaches sluice. This operation invariably needs 2 people to co-ordinate efficiently.

Once the last of the dirty water has entered the discharge flow follow it to sluice. When the water is clear then the flow can be diverted directly to the watercourse. Record the date and time on the sheets and sign off to confirm.

The dirty water in the main holding tank can only be released when the discharge is less than 20mg/L. This process takes a minimum of three hours.

Check the Hercules filter is in operation before releasing settled water from the tank. The long pipe should be released before the short to prevent silt being lifted back into suspension.

An initial slug of dirty water will be apparent at the Hercules filter. This is sediment falling into the 6" drain pipe and collecting n the "A" carrier and is released every time the system is drained. We are currently seeking to eliminate this.

The discharge should be checked on every release.

Check tank periodically for sediment level.

Arrange tanker to clean out when sediment level approaches the lowest discharge level. This is now automatically triggered by the sludge blanket installation. — Co Field

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We the undersigned have read and understood the procedures outlined above and agree to work within the guidelines.

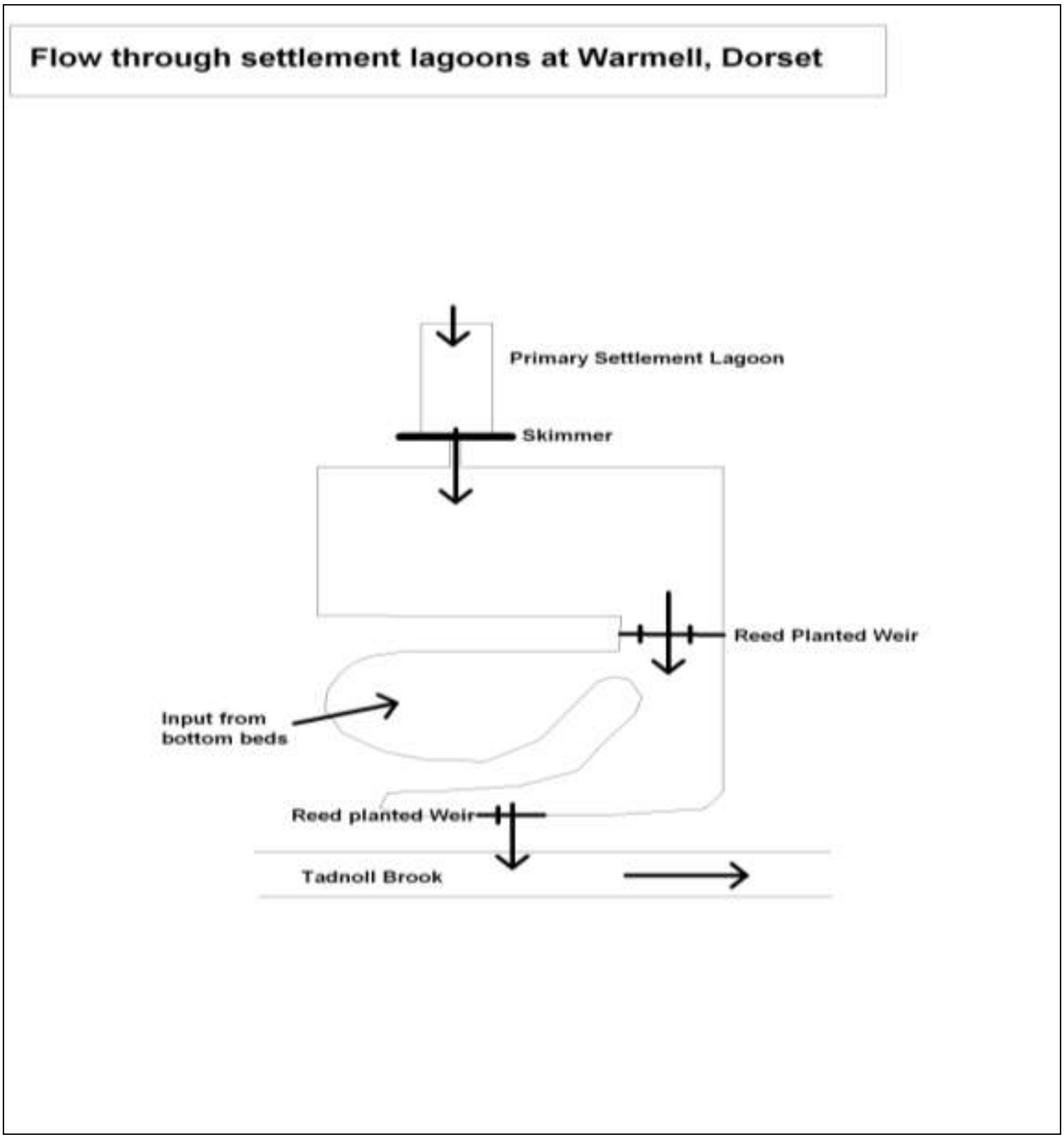
Signed...H T Hardy............................16/7/04.........

Signed...P B Cook.............................16 - 7 - 04.......

Signed...[signature]..........................16/7/04............

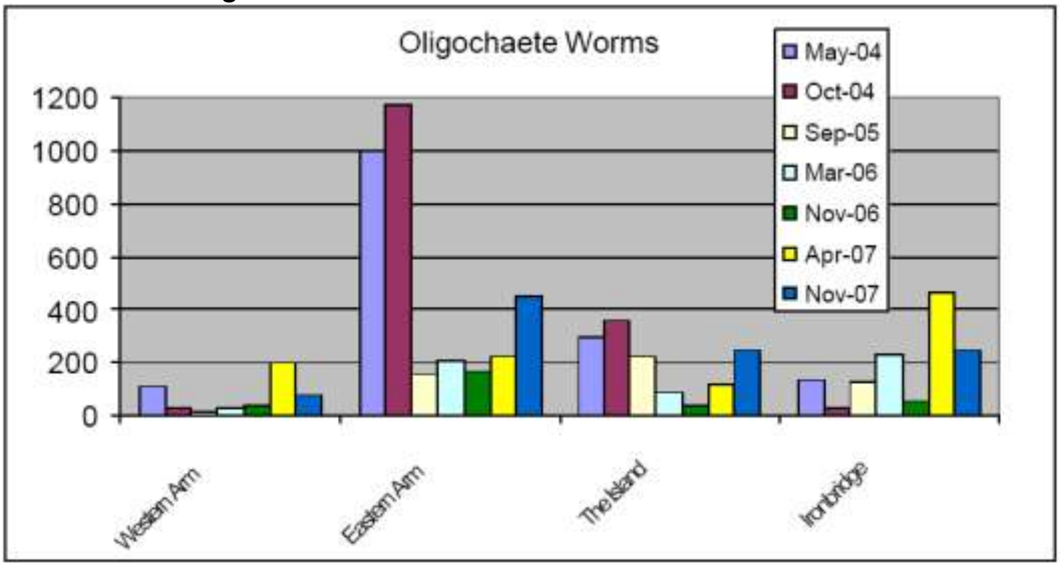
Signed...[signature]..........................16.7.04............

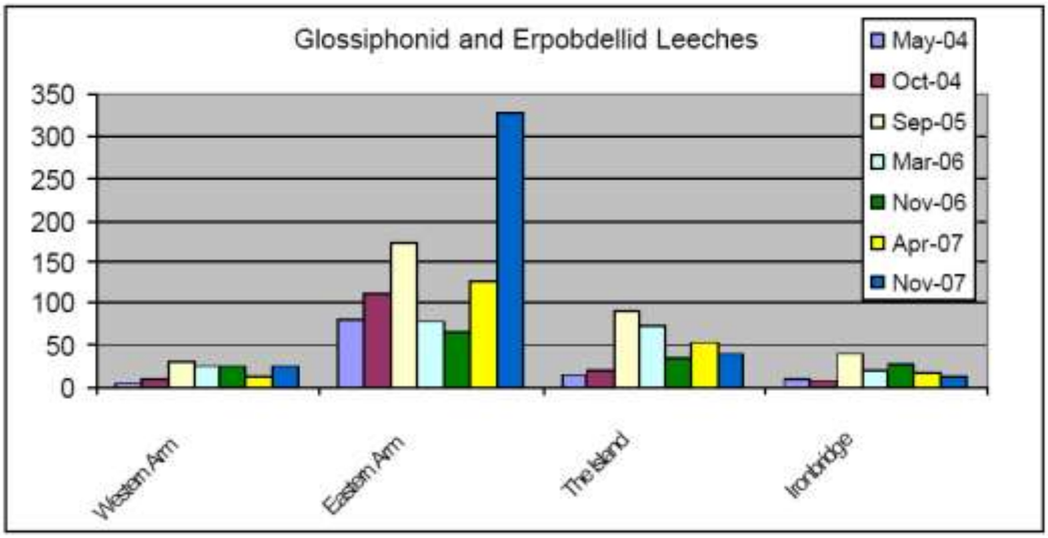
Appendix 3 Design of settlement lagoons operated by The Watercress Company

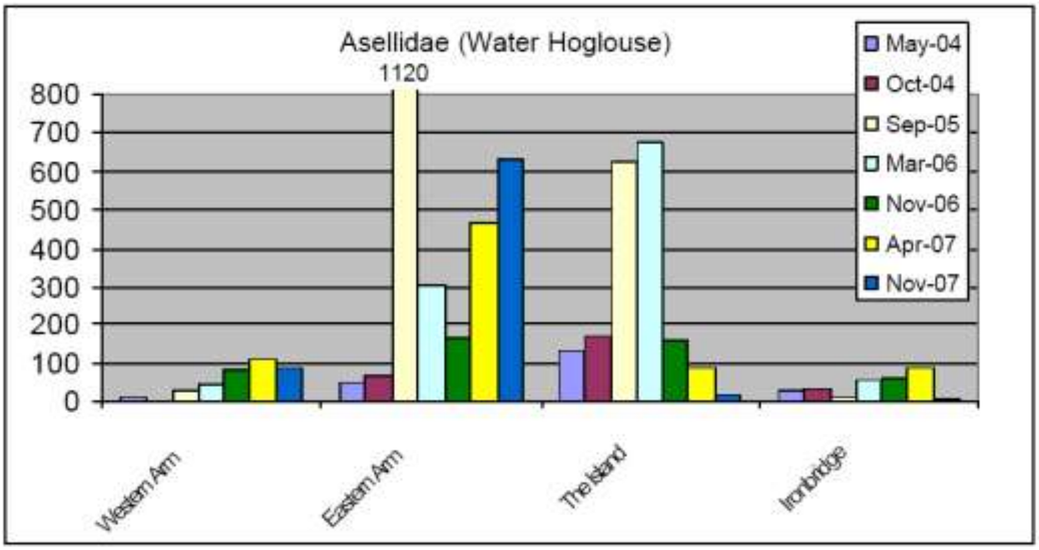


Appendix 4 Invertebrate populations downstream of St Mary Bourne, 2004-2007

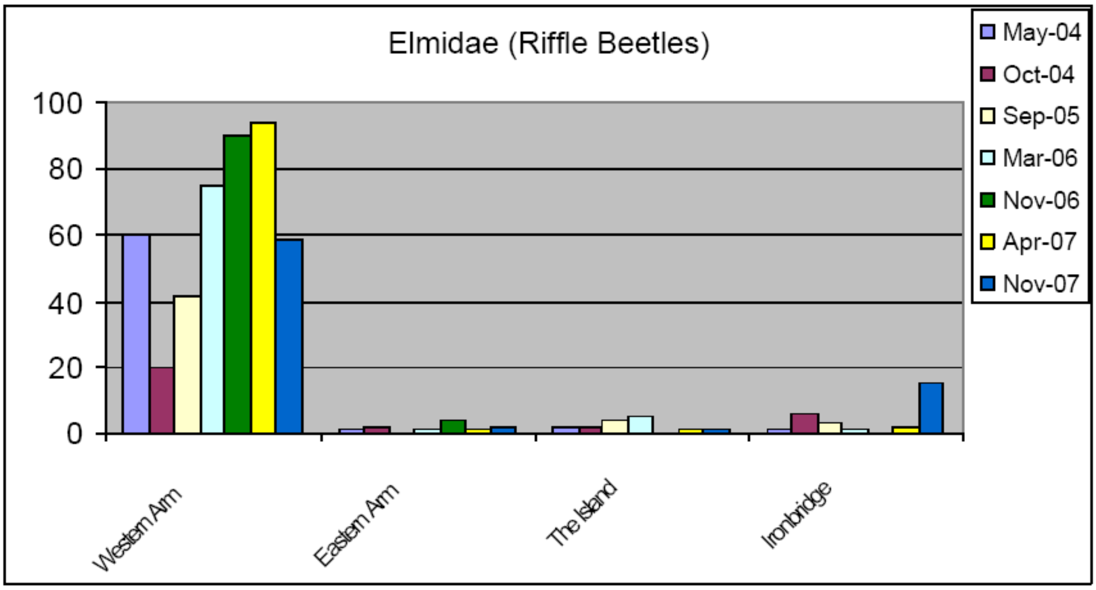
Indicators of Organic Pollution

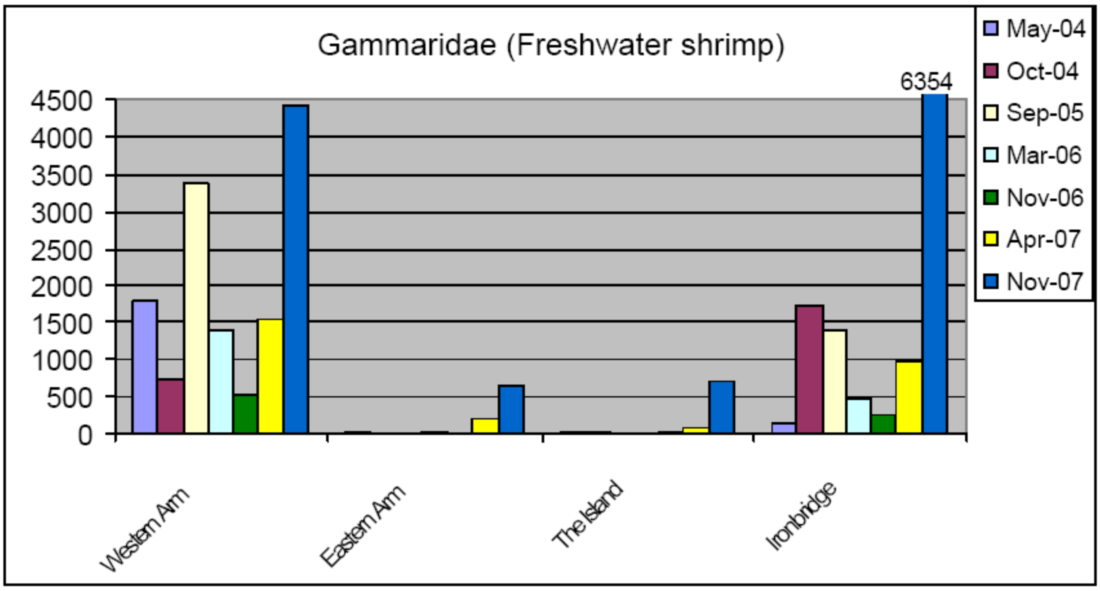


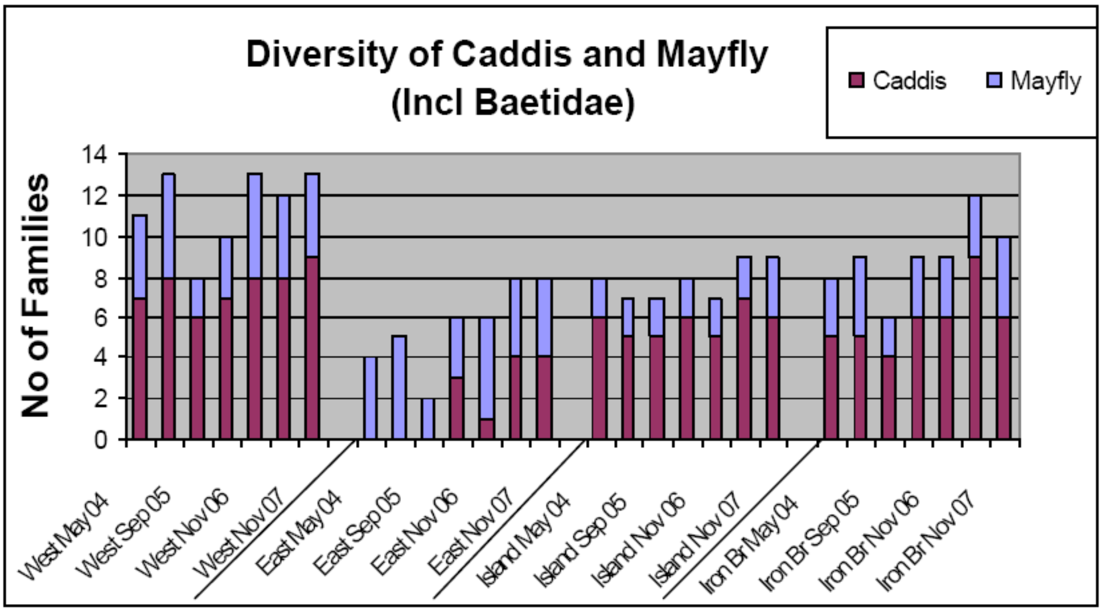




Indicators of Good Water Quality







Appendix 5 Model consents for watercress discharges

ANNEX B - WATERCRESS BED - INTENSIVE - LONG-TERM CONSENT

MODEL CONSENT CONDITIONS

Application No…………

SCHEDULE

Construction

The outlet shall be constructed and maintained in accordance with the plan numbered**…….**submitted by the Applicant.

Use

The outlet at National Grid Reference………………..shall be used only for the discharge of watercress bed effluent.

Nature and composition

The effluent discharged to controlled waters shall at the specified sampling point comply with the following standard:

a) pH shall not be less than 6 or greater that 9;

b) free chlorine shall be absent, see Note 1;

c) total zinc concentration shall not exceed 75 µg/l;

d) suspended solids dried at 105 degrees Centigrade shall not exceed 20 mg/l except as the result of exceptional weather conditions defined as per Note 2.

The effluent discharged to controlled waters shall not contain any substance in a concentration such as will cause the waters to be poisonous or injurious to fish or their spawning grounds, spawn or food of fish.

Screening

The effluent discharged to controlled waters shall not contain any solid matter arising from the culture of watercress having a size greater that 5 millimetres in any two dimensions.

Sampling points

Facilities for the taking of samples by the Agency's officers shall be provided and maintained at the point marked " " indicated on the plan numbered………submitted with the application.

Other conditions

This consent is not to be taken as providing a statutory defence against any charge of pollution in respect of any constituent for which limits are not specified in the Schedule.

Intention to use any other prophylactic chemical or pesticide must be notified to the Agency in advance and a record kept of date and time of use and amount applied. As regards Zinc, a record must be kept of the date and time of application and the volume of stock concentrate applied. These records are to be made available to the Agency's officers on request.

Volume or rate of discharge (where applicable)

The volume of effluent discharged shall not exceed…..cubic metres in any period of 24 hours.

The rate of discharge of the effluent shall not exceed…litres per second.

Flow measurement (where applicable) and see Note 3

Flow measurement facilities affording visible display of instantaneous flow shall be provided and maintained at the point indicated on the plan numbered……submitted with the application.

Flow records to Agency specification shall be maintained and made available to the Agency's officers on request.

Note 1: Absence of free chlorine is defined as less than the lowest value obtainable using the DPD Comparator Test.

Note 2: Exceptional weather conditions is defined as a rainfall rate of 68mm in 72 hours.

Note 3: The extent of these conditions may be modified at the discretion of the Consenting Officer.

ANNEX D - WATERCRESS BED - TRADITIONAL OPERATION

MODEL CONSENT CONDITIONS

Application No……………

SCHEDULE

Construction

The outlet shall be constructed and maintained in accordance with the plan numbered submitted by the Applicant.

Use

The outlet at National Grid Reference………shall be used only for the discharge of watercress bed effluent.

Nature and composition

The effluent discharged to controlled waters shall at the specified sampling point comply with the following standard:

a) pH shall not be less than 6 or greater that 9;

b) free chlorine shall be absent;

c) total zinc concentration shall not exceed 75 µg/l;

The effluent discharged to controlled waters shall not contain any substance in a concentration such as will cause the waters to be poisonous or injurious to fish or their spawning grounds, spawn or food of fish.

Screening

The effluent discharged to controlled waters shall not contain any solid matter arising from the culture of watercress having a size greater that 5 millimetres in any two dimensions.

Sampling points

Facilities for the taking of samples by the Agency's officers shall be provided and maintained at the point marked " " indicated on the plan numbered………..submitted with the application.

Other conditions

Suspended solids: control during annual watercress bed cleaning shall be in accordance with the Code of Practice appended to this consent.

Appendix 6 Location, ownership and size (area) of watercress enterprises in the catchments of chalk rivers

The following tables summarise information on the location, ownership, size and type of watercress producer on chalk rivers in England. The first table provides information for watercress growers on SSSI chalk rivers, and the second on non-SSSI chalk rivers.

Watercress growers on SSSI chalk rivers

SSSI	Watercourse	Watercress Beds	Operator	Production system	grid ref.	Size hectares
tributary of River Frome	Tadnoll Brook	Warmwell Mill	The Watercress Company	conventional	SY 749873	1.3
tributary of River Frome	Tadnoll Brook	Warmwell Mill	The Watercress Company	organic	SY 749873	2.1
River Frome	River Frome	Tincleton (East)	The Watercress Company	conventional	SY 767917	0.4
River Frome	River Frome	Tincleton (West)	The Watercress Company	conventional	SY 766917	1.2
River Frome	River Frome	Ilsington	The Watercress Company	organic	SY 756916	0.8
River Frome	River Frome	Brockhill	The Watercress Company	organic	SY 837929	1.0
River Frome	River Frome	Waddock Cross	The Watercress Company Waddock, Dorchester, Dorset DT2 8QY	conventional	SY 795909	2.5
tributary of Moors River	River Crane	Holwell Watercress	Sun Salads, Cranborne, Wimborne, Dorset BH21 5QJ	conventional	SU 074124	3.2
Bere Stream	Bere Stream	Doddings	Vitacress	conventional	SY 852938	2.9
Bere Stream	Bere Stream	Manor Farm	Vitacress	organic	SY 847946	0.9
Bere Stream	Bere Stream	Holly Bush	Vitacress	organic	SY 839956	0.8
River Loddon	River Loddon	Black Dam, Basingstoke	Maple Leaf Watercress	traditional	SU 653520	?
River Loddon	River Lyde	Huish Farm, Mapledurwell	Maple Leaf Watercress	traditional	SU 672515	?
River Loddon	River Lyde	Andwell, Mapledurwell	Maple Leaf Watercress	traditional	SU 689522	?
tributary of Salisbury Avon	River Nadder	Ludwell Watercress	Sun Salads	conventional	ST 907225	2.0
tributary of Salisbury Avon	River Ebble	Chalke Valley Watercress	Fersit, Broadchalke, Salisbury, Wilts SP5 5HL	traditional	SU 031252	1.6

SSSI	Watercourse	Watercress Beds	Operator	Production system	grid ref.	Size hectares
tributary of Salisbury Avon	River Wyle	Stonewold Watercress	Hill Deverill, Warminster, Wilts BA12 7EF	organic	ST 869405	3.2
River Test	River Test	Home Beds and Crane's Beds	A.W. Biggs & Son, 2 District Villas, Longparish, Andover, Hants SP11 6QL	traditional	SU 444447 439422	0.8
tributary of the River Test	Bourne Rivulet	St Mary Bourne	Vitacress Ltd, Lower Link Fm, St Mary Bourne, Andover, Hants SP11 6DB	conventional	SU 430489	6.9
tributary of the River Test	Pilhill Brook	Abbotts Ann	Vitacress	conventional	SU 327438	3.2
River Test	River Dever	Bullington	The Watercress Company	traditional	SU 463413	0.6
River Test	River Dever	Norton	The Watercress Company	traditional	SU 466409	0.4
River Itchen	Cheriton Stream	Spring Gardens	Stoke Valley Watercress, 2 Church Cottages, Bishops Sutton, Alresford, Hants SO24 0AE	traditional	SU 577317	2.4
River Itchen	Candover Brook	Borough Farm		traditional	SU 569324	?
River Itchen	River Alre	Weir		traditional	SU 587333	?
River Itchen	River Itchen	Itchen Stoke		traditional	SU554 324	?
River Itchen	Arle	Drayton	The Watercress Company	conventional	SU594 333	3.8
River Itchen	Arle	Maxwells	The Watercress Company	conventional	SU 591334	1.2
River Itchen	Arle	Bishops Sutton	The Watercress Company	conventional	SU 604323	1.4
River Itchen	Headbourne Worthy Stream	Springvale	The Watercress Company	conventional	SU 486322	1.6
River Itchen	Candover Brook	Fobdown	Vitacress	conventional	SU 570338	2.4
River Itchen	River Arle	Pinglestone	Vitacress	conventional	SU 581330	1.6
	Total area hectares					**52.6 +**

Watercress growers on non-SSSI chalk rivers

Catchment	Watercourse	Watercress Bed	Operator or owner	Production system	grid ref.	Size hectares
River Stour	River Allen	Wimborne St Giles (recently opened)	Sun Salads	conventional	SU 024126	2
River Stour	River Stour	Spetsbury	Vitacress	organic	ST 908300	2
River Meon	River Meon	Warnford	Vitacress	conventional	SU 621230	1.2

River Blackwater	Sherfield Stream	Sunbeam Watercress	Mr Noble, Sherfield English, Romsey, Hants, SO51 6FJ	traditional	SU 292226	?
River Wey	Tilling Bourne	Kingfisher Watercress	R. Coe and Son, Abinger Hammer, Dorking, Surrey RH5 6RX	conventional	TQ 097473	0.2
Chichester Harbour	Ham Brook	Hairspring Watercress	Edward Scales, Mill Farm, Hambrook Hill South, Hambrook, Chichester, Sussex PO18 8UJ	traditional	SU 780059	1.6
	Total					**7 +**