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Evidence Project Final Report

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Project identification

1. Defra Project code: WU0132
2. Project title: Sustainable water for livestock
3. Contractor organisation(s): ADAS UK Ltd
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6. It is Defra's intention to publish this form.
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Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.

Direct access to water courses for livestock drinking may be restricted in the future as a result of the Water Framework Directive and associated daughter directives requiring more stringent water quality standards. The complete or partial fencing off of riverbanks controls livestock access to these water courses, reducing bank erosion of sediment, together with manure and urine inputs into such water bodies, and the associated pathogenic load. Alternative water provision will need to be made for such livestock, in a manner which is sustainable and minimises impacts on the environment (e.g. by maintaining summer flows in rivers). In addition to drinking water, livestock farms also have a significant requirement for non-potable water used for washing down buildings and equipment (e.g. milking parlours, hard standings). This is particularly relevant to livestock production in the south and eastern UK where climate change scenarios predict drier summers by 2020 with up to 20% less rainfall. Seasonally, this is a time of year when hotter weather causes a greater demand on water sources for livestock drinking requirements; and in some regions, such as Southern and Anglian, summer abstraction of surface waters would be considered unsustainable.

This project documents current drinking and service water by beef, dairy, sheep, poultry and pig livestock systems, and reviews novel methods for supplying livestock with natural water as an alternative to mains and borehole water. This review considered factors including reliability of supply; environmental sustainability; susceptibility to climate change; hygiene and legal issues; the quality of rainwater harvested from natural sources and the minimum acceptable quality of natural sources of drinking water for livestock. Specific assessments were made of the applicability of these techniques to the three Demonstration Test Catchments (DTCs). Project outputs were disseminated via a series of knowledge transfer events to livestock farmers and the wider stakeholder community.

The review firstly assessed the water requirements for water supply to livestock. Dairy and beef livestock production in the UK is estimated to consume 82 million m^3 of fresh water annually of which 79% can be attributed to drinking requirements, producing the greatest demand on water resources of all livestock sectors. Other UK sectors such as sheep have a much lower annual consumption of around 17 M m^3, also poultry at 12 M m^3 and pigs at 8 M m^3. The drinking water requirement of livestock is largely associated with the moisture content of feed available to animals. For grazing stock, weather conditions and consequently the dry matter content of herbage therefore have a considerable impact on the quantity of supplementary water required, with cattle fed mainly on a dry diet requiring up to twice as much drinking water than stock raised on a wet diet for example silage. For dairy cows, milk yield is the most significant contributor to the quantity of drinking water consumed, with c. 5 litres of fresh water required for every litre of milk yield. Current water requirements were found to be 104-122 litres/day (lactating) and 20-59 l/day (dry period) for dairy cattle; 25-45 l/day for beef cattle; 5-25 l/day for calves; 3.3-7.3 l/day for adult sheep; 0.09 l/day (pullet) and 0.20-0.22 l/day (laying hens); with pigs requiring 3-6 l/day (grower/finisher), 6-10 l/day (dry sow) and 15-30 l/day (farrowing sow).

Of the 184 million m^3 of water used by agriculture in England each year, the largest single proportion (41%) is used to provide livestock with drinking water (Defra, 2011). Around 79% of grazing livestock farms in England use mains water, while 60% have direct access to water courses and 23% use boreholes (Defra, 2011). Only 4% of farms in England use rainwater harvesting methods to provide drinking water to livestock (Defra, 2011). For grazing animals, there are alternatives to mains supply, in response to the fencing off of watercourses to improve water quality. Installing piped mains water directly to troughs or pasture pumps can be expensive where large areas of land are involved, but may be necessary if bank erosion and water contamination by livestock are to be avoided. More cost-effective systems may include the use of hydraulic ram pumps, pasture pumps, solar powered pumps, wind powered pumps, boreholes, and/or rainwater harvesting as potential alternative methods of supplying water to livestock instead of (or in addition to) mains supply. This report considers each of these methods, examining specific case study examples, and evaluating the cost-effectiveness, practicality and robustness of a range of alternative strategies covering a range of livestock farm types. Such activities will help constrain costs, increase water security, and encourage more sustainable provision of water for livestock.

Constraints on abstractions from boreholes could potentially limit the potential use of this resource, although at present abstractions below 20 m^3/day do not require a licence-and therefore this may be a viable option for small and medium sized farms located in groundwater areas. Although cheap, portable and durable, pasture pumps are not frost-hardy and only service around 20 animals each, so are unsuitable for extended season grazing systems, areas with sharp autumn or spring frosts, or large herds. They are unsuitable for sheep, goats or very young calves, but are capable of providing c. 7m vertical lift or 70m horizontal lift between water source (e.g. river) and the location water is provided. With pasture pumps, there may be issue of intake connected with cattle drinking in groups where lead animals achieve their required intake, whilst others move off with the herd before they have had sufficient water.

In contrast, hydraulic ram pumps are a more heavy duty alternative, operating on a clever engineering principle that only requires a 50cm drop in elevation between inlet and outlet points along a river stretch to provide up to 18m of vertical lift; a drop of 2m is sufficient to lift water 50m or more, although output falls as the delivery height increases. These pumps require no external power, being driven by the head of water from the river to the pump intake to drive the regular pulsing cycles. They work continuously provided the water source remains and are capable of operating when there is some sediment or debris in the water, and unlike some other techniques do not require frequent filter changes ("fit it and forget it"). However, they are more expensive to install and sited permanently. Solar powered (otherwise known as photovoltaic or PV) systems are viable in the UK, as was demonstrated in one of the project's dissemination workshops. They have very low maintenance and running costs, are suitable for all stock, and will pump water at a greater rate when solar radiation is higher i.e. in warm conditions when requirements will also be higher. However, whilst they work in cloudy conditions, they operate at low flow rates, usually require a buffer store to be provided, and an additional UV filter system is likely to be needed if water is stored more than a couple of weeks.

On some farms, roof water can be collected, purified and stored for use by livestock, thereby reducing consumption of and reliance on piped mains water. Water used for milk pre-cooling on dairy farms can also be stored then re-directed to livestock water troughs. This "rainwater harvesting" approach can reduce mains water requirements, whilst simultaneously providing water at a slightly higher temperature than mains water (which may be a benefit in the winter months). Such systems are a relatively low cost, reliable and reasonably low maintenance method, but require piping and storage of water from large roof areas. The potential for debris and bacteriological contamination (E. coli, salmonella) in roof water means that the use of first flush diverters is recommended to divert the first portion of the collected roof water to waste, as well as the need for UV filters or other systems to be installed (essential if water is to be used for drinking). The UV filters may require frequent changing, and the treated water should also be assessed for total dissolved solids (i.e. poultry are the most sensitive c. 3000 mg/l). Certain roof materials are unsuitable for this technique (e.g. bitumen, paint), and rainwater lacks some minerals which may be important for livestock if this is the only source of water used for drinking. Due to evaporative losses and the losses from the first flush diversion systems, rainwater harvesting methods tend to operate on an efficiency of around 80% of incident rainwater being stored for use.

Water can be pumped directly to a drinking trough or diverted to a storage tank. For storage tanks, water quality can be important, since bacterial loads can multiply rapidly away from sunlight in warm conditions. Water of good quality that has been filtered and passed through an ultra violet (UV) filter can be stored for around three weeks, but untreated water can become unsuitable after three days. Minimum acceptable quality of water is only an issue if it is to be used for drinking (rather than, for example, refrigeration), with poultry having amongst the lowest threshold of 3000 mg/l or less of total dissolved solids in potable water. Microbiological thresholds reported in the literature for potable water for livestock vary widely from <1 to <1000 faecal coliforms per 100ml water.

Boreholes provide the greatest volumes (4,000-20,000 m^3 p.a.) compared to pasture pumps (510 m^3 p.a.), the pv/wind and rainwater harvesting methods (1,040-1,325 m^3 p.a.) and ram pump method (most farm models deliver 750-2750 m^3 p.a., but far greater volumes are possible). Costs depend on the factors identified above, with capital costs of the order of £2,500-25,000 (borehole), £350 (pasture pump), £250-2500 (ram pump), £1,100 (pv/wind system), and from around £5,500 or more (rainwater harvesting). Considering both amortised capital and operating elements, then the resulting cost of the water supplied to livestock are typically of the order of £0.35-0.90 (borehole), £0.10-0.15 (pasture pump), £0.30-0.85 (ram pump), £0.30-0.40 (pv/wind pump), and £0.90 (rainwater harvesting). This compares to the current cost of mains-supplied water to agriculture which is £1.00-1.50 depending on region, although this is likely to rise in price and may be subject to restrictions in the future. In addition, mains systems run at a higher pressure than the systems studied and any leaks continue until discovered and remedied, resulting in potentially high costs for wasted water and repairs.

Selecting a suitable system, or combination of systems, for alternative provision of water to livestock is a site-specific decision, taking into account factors including type and location of available water sources, site location and conditions (slope, riparian features, access / remoteness), number and type of livestock, access to power (mains, solar, wind, riparian features), pumping system (height, distance, powered / manual), flexibility and portability, reliability and maintenance, the need for temporary or seasonal water storage, and the resulting assessment of cost / benefit and cost per animal.

In terms of capacity, boreholes provide the greatest volumes (4000-20000 m^3 p.a.) compared to the pv/wind and rainwater harvesting methods (1040-1325 m^3 p.a.) and ram pumps (750-2750 m^3 p.a.). Considering both capital and operating elements, then the resulting total cost of the alternative methods for supplying water to livestock are typically of the order of £0.35-0.90 (borehole), £0.10-0.15 (pasture pump), £0.30-0.50 (ram pump), £0.30-0.40 (pv/wind pump), and £0.90 (rainwater harvesting). This compares to the current cost of mains-supplied water to agriculture which is c. £1.00-1.50 depending on region, although this is likely to rise in price and may be subject to restrictions in the future. However, each method also has certain practical constraints: for example pasture pumps may be cheap and portable, but can freeze over-winter and are only able to service 15-20 cattle each.

Based on this assessment, and with specific reference to the DTCs as case study areas, alternative supply options to mains water are commercially attractive to farm enterprises, as well as increasing the resilience of such units by providing a robust, reliable secondary supply option which could prove increasingly important if, for example, further restrictions are imposed on abstraction licences in the future (e.g. seasonality and low flow issues; m^3/day limit etc) in response to long-term changes in UK climate. A series of workshops disseminated the detailed findings from this review and raised awareness of these supply options. Feedback indicated many farmers had not considered these alternative supply options, or were unsure where to obtain relevant information to help select the most appropriate system for their farm. Workshops were well received, attracting over 120 stakeholders including farmers (from small scale beef and sheep to national pig and poultry producers), agronomists, extension workers, and representatives from government agencies (Natural England, Environment Agency).

Project Report to Defra

8. As a guide this report should be no longer than 20 sides of A4. This report is to provide Defra with details of the outputs of the research project for internal purposes; to meet the terms of the contract; and to allow Defra

to publish details of the outputs to meet Environmental Information Regulation or Freedom of Information obligations. This short report to Defra does not preclude contractors from also seeking to publish a full, formal scientific report/paper in an appropriate scientific or other journal/publication. Indeed, Defra actively encourages such publications as part of the contract terms. The report to Defra should include:

- the objectives as set out in the contract;
- the extent to which the objectives set out in the contract have been met;
- details of methods used and the results obtained, including statistical analysis (if appropriate);
- a discussion of the results and their reliability;
- the main implications of the findings;
- possible future work; and
- any action resulting from the research (e.g. IP, Knowledge Exchange).

1.1 Introduction

Currently some farmers give livestock direct access to water courses for drinking, but these supplies may be restricted in the future as a result of the Water Framework Directive and associated daughter directives requiring more stringent water quality standards. The complete or partial fencing off of riverbanks controls livestock access to these water courses, reducing bank erosion of sediment, together with manure and urine inputs into such water bodies, and the associated pathogenic load. Alternative water provision will need to be provided for such livestock, in a manner which is sustainable and minimises impacts on the environment (e.g. by maintaining summer flows in rivers). In addition to the drinking water which all livestock require, livestock farms also have a significant requirement for non-potable water used for washing down buildings and equipment (e.g. milking parlours, farmyard hard standings) and for refrigerating milk.

A study by King et al (2006) estimated that livestock rearing in England accounted for 119 million m^3 $year^{-1}$, including both drinking and other related uses (e.g. washing, refrigeration). Cattle were found to use the most water, with a total requirement of 82 million m^3, followed by sheep at 17 million m^3, poultry at 12 million m^3 and pigs at 8 million m^3. The study showed that the washing water requirements were relatively low compared with the volumes required for drinking. Expressed as a percentage of total water, drinking water requirements were 79% for dairy cattle, 87-99% for different categories of pigs, >99% for sheep and 96-99% for poultry, respectively.

Given the volumes of water required to sustain livestock farming, there is a need to identify alternative sources and methods of providing both drinking water and non potable water to livestock farmers. The methods, sources and associated timings when water is sourced for livestock also has implications for the management of river systems, especially during summer months and in low flow conditions. This Defra project investigates sustainable ways of providing livestock with natural sources of quality potable water as an alternative to mains water. This includes novel ways of sustainably sourcing, storing, purifying, distributing and using water, as well as determining the minimum acceptable quality which can be used as drinking water for livestock.

For grazing animals, for example, a number of solutions are available, individually or in combination, including fencing off watercourses and installing piped mains water to troughs or pasture pumps. Providing this type of infrastructure, where there has been none previously, can be expensive where large areas of land are involved, but may be necessary if bank erosion and water contamination by livestock are to be avoided. On some farm types, roof water can be collected, purified and stored for use by livestock, thereby reducing consumption of and reliance on piped mains water. Water used for milk pre-cooling on dairy farms can also be stored then re-directed to livestock water troughs. This approach can reduce mains water requirements, whilst simultaneously providing water at a slightly higher temperature than mains water (which may be a benefit in the winter months). This project reviews such methods, examining specific case study examples, and evaluating the cost-effectiveness, practicality and robustness of a range of alternative strategies covering a range of livestock farm types. Such activities will help constrain costs, increase water security, and encourage more sustainable provision of water for livestock.

1.2 Objectives

The objectives of this project were to:

1. Build on the previous work (Sustainable Water Management programme: Defra projects WU0101 and WU0123) to determine, by reviewing available evidence, existing methods for supplying livestock with

natural water including a commentary on:

a. Current usage of drinking and service water by different livestock production systems (litres/head) and the potential for innovation in different livestock sectors (building upon the findings of WU0101
b. Extent of the uptake and use by livestock farmers of existing options
c. Reliability of supply
d. Environmental sustainability
e. Susceptibility to climate change and changes in legislation
f. Potential for wider application (building on WU0123)

2. Review novel ways of harvesting, storing, purifying, delivering and recycling natural water that is fit to drink to cattle, sheep, pigs and poultry on a whole farm basis.

3. Determine the costs of various options for harvesting, storing, purifying, delivering and recycling natural water

4. Determine the hygiene and legal issues likely to arise, the quality of rainwater harvested from a range of natural sources and the minimum acceptable quality of natural sources of drinking water for livestock.

5. Develop and execute appropriate knowledge transfer to livestock farmers and/or their representatives.

1.3 Approach

This work comprised a detailed literature review, supported by additional exercises exploring the hygiene issues, and abstraction licensing constraints on such methods. Specific case studies were considered in the demonstration test catchments (DTCs) using GIS methods and spatial data layers to consider the suitability of alternative methods of water supply to livestock instead of mains supply. The project fully engaged with industry stakeholders, which is demonstrated by the wide range of organisations associated with the final workshop events (see Chapter 4).

Chapter 2 focuses on the main literature review developed in this project. This covers the advantages, disadvantages, practical constraints and costs associated with alternative methods for supplying water to livestock. Case study examples are given based on discussions with industry representatives and suppliers/manufacturers. Unless otherwise stated, quoted prices were correct in 2011. This chapter relates to Objectives 1(b) and 2 above.

Chapter 3 contains a synthesis section which summarises the reliability, costs, operating capacity, advantages and disadvantages of different systems. This section concludes with guidance on the key criteria to consider when selecting a non-mains water supply system for livestock. This relates to Objectives (c) and 3 above.

Chapter 4 documents the Knowledge Transfer events which have been undertaken within this project. This relates to Objectives 1(f) and 5 above.

Further supporting detail is contained in a series of Appendices to this report:

- **Appendix 1.** Water requirements by different livestock types/ages
  This provides a set of reference tables summarising the most recent estimates of livestock requirements by type and age of animal (expands on information in Section 2.2). This relates to Objective 1(a) above.

- **Appendix 2.** Hygiene and legal issues associated with alternative methods for supply of water to livestock
  This provides an overview of the hygiene issues associated with provision of water to livestock, which are most pertinent with respect to rainwater harvesting (expands on information in Section 2.4.1). This relates to Objective (4) above.

- **Appendix 3.** Environmental sustainability of existing methods (including CAMS). This relates to Objectives 1(c) and 1(d) above.

- **Appendix 4.** Case study analysis of DTC areas
  This provides a GIS-based analysis of spatial datasets to support assessments of the potential suitability of different areas to alternative non-mains methods for supplying water to livestock. This relates to Objectives 1(d), 1(e) and 1(f) above.

2. Alternative methods of sustainable water supply to livestock

2. Review objective

In their 2006 review, King et al. estimated that livestock rearing accounted for over 119 million m^3 of fresh water annually in England including elements for drinking water intake, cleaning requirements, disease control and processing. At present common agricultural practice takes advantage of metered/non-metered mains water sources and both direct access to and abstraction from surface and groundwater sources to cater for livestock requirements. The main driver for water saving in livestock production focuses on Environmental protection, regulated by the EU Water Framework Directive and enforced by the Environment Agency (Thompson et al, 2007). This requires all water sources to reach good ecological status by 2015 and also outlines the potential damage to both ground and surface water sources caused by over abstraction (Environment Agency, 2007).

Promoting sustainable agricultural production and the efficient use of water within livestock systems is also vital for agriculture, allowing the industry to move forward with regards to profitability and productivity, whilst protecting the security of a finite resource. This is particularly relevant to livestock production in the south and eastern regions of the UK where climate change scenarios predict drier summers by 2020 with up to 20% less rainfall (Environment Agency, 2007). Seasonally, this is a time of year when hotter weather causes a greater demand on water sources for livestock drinking requirements; and in some regions, such as Southern and Anglian, summer abstraction of surface waters would be considered unsustainable (Thompson et al, 2007).

This section highlights the options for water supply in relation to livestock requirements, focussing on both well-established systems, adopted throughout livestock production in the UK and new emerging technologies which provide the potential to improve water-use efficiency and, therefore, sustainability of natural sources.

2.1 Scope of review

This review identifies alternative novel methods for supplying livestock with natural water (surface, ground and rain) covering the capture of water at source, its distribution, storage and purification. The review concentrates on the requirements and the options for supply. Previous studies, surveys and case studies on water auditing are identified and interrogated for methods to supply water to livestock (Swanson, 2007). This includes pasture pumps (e.g. solar, wind, ram), solar powered troughs, the provision of managed access to surface water, methods of rainwater harvesting, water recirculation, filtration and purification equipment and the use of grey water for non sanitary applications. Sources also include the case studies cited in EA guidance documents (Metcalfe *et al.,* 2010; Dairy Co, 2009, 2010; NFU 2006; DEFRA 2007).

This review covers across all major livestock sectors and factors affecting the uptake of different methods on farms, and the level of technology and sophistication being used. Examples of methods are identified and considered with regard to their limitations, and the capability to meet different use requirement. The review included establishing contact with suppliers and manufacturers of equipment to obtain up-to-date information on costs and an understanding of prevailing trends in equipment use, as well as dialogue with industry bodies to determine attitudes towards different drinking water and process water supply.

International research and appropriate case studies have been selected from drought affected technologically advanced areas including California (Christian-Smith *et al.*, 2010), Australia and Israel (OECD, 2010). This ranged from simple water collection case studies to the addition of advanced water treatment for technical water required for high health status stock and processes. The costs of system components and level of costs for complete systems are derived from literature and industry case studies. Volumes of supply are allocated for calculation of cost per functional unit and evaluation of simple payback.

2.2 Livestock requirements for water

The most recent Defra survey data suggests that of the 184 million m^3 of water used in agriculture each year in England, the largest single proportion (41%) is used to provide livestock with drinking water, with 79% of grazing livestock farms using mains water, while 60% have direct access to water courses, and 23% have boreholes (Defra, 2011). Only 4% of farms in England currently use rainwater harvesting methods to provide drinking water to livestock (Defra, 2011).

The drinking water requirement of livestock is largely associated with the moisture content of feed available to animals. For grazing stock, weather conditions and consequently the dry matter content of herbage therefore have a considerable impact on the quantity of supplementary water required (King et al, 2006). This is highlighted by The Milk Development Council (2007) which suggests that cattle fed mainly on a dry diet require up to twice as much drinking water than stock raised on a wet diet for example silage. For dairy cows, milk yield is the most significant contributor to the quantity of drinking water consumed, with MDC (2007) suggesting that for every kg of milk yield a total of 5 litres of fresh water intake is required. Literature cites a wide range of values: a summary of typical water use requirements is shown in Table 2.1a and further information is included in Appendix 1 of this report.

Table 2.1a Overview of typical water use requirements by livestock (see Appendix 1 for further details)

Livestock type	**Litres/day**
Dairy cow	104-122 (lactating)
	20-59 (dry period)
Beef cow	25-45
Calf	5-25
Sheep	3.3-7.3
Pig	6-10 (dry sow)
	15-30 (farrowing sow)
	3-6 (grower/finisher)
Poultry	0.09 (pullet)
	0.20 (broiler / caged layer)
	0.22 (non-caged layer)

2.3 Drinking water sources

Conventional sources of fresh water for livestock production include abstraction from surface sources such as rivers, ponds & reservoirs and groundwater sources including borehole abstraction and springs. However, mains water deriving from public supply is the most common source used across livestock production for both drinking and washing requirements of stock. Water surveys completed by 146 dairy farmers across the UK provide an insight into the sources from which fresh water for production derives. This can be seen in Table 2.1 summarised by Dairy Co (2009). It should be noted that percentages do not add up to 100% because some farmers utilise more than one source of fresh water (Dairy Co, 2009).

Table 2.1b Freshwater sources for dairy production - survey results (Source: DairyCo)

Water source	**% of farmers using source**
Collection of roof water	15
Spring	32
Borehole	36
Mains – non metered	22
Mains – metered	75

2.3.1 Mains water

The use of mains supplied water for livestock drinking has numerous advantages over abstraction from ground and surface sources. Reliability of supply throughout the year being the most prominent reason for mains use, especially in regions where summer abstraction from ground & surface sources may be restricted due to catchment sustainability issues exacerbated by dry weather periods (Thompson et al, 2007). The ability to transport mains water over great distances to grazing animals is a distinct advantage, in comparison to abstraction systems operating at lower pressures. This is particularly pertinent in upland livestock production systems where remoteness of grazing animals such as sheep requires a reliable high pressure supply. However, periods of drought can threaten mains pressure, directly impacting on the supply of upland areas, and therefore an alternative emergency water supply option is always advisable (HCC, 2008). When leaks occur, they can go undetected for long periods resulting in costly waste and repairs.

Widespread use of mains water supply can be seen in intensively reared livestock production systems. This is often seen in the pig and poultry industries, as there is the guarantee of good quality water supply, the need for good biosecurity, and it is easier to supply indoor livestock with mains water for which the supply often runs in close proximity to housing. The dairy industry is also a prominent user of mains source water as wash down requirements for dairy parlours require water quality to meet the standards of Food Hygiene Regulations (2006) through annual inspection, which can be guaranteed through mains use (Environment Agency, 2009).

It is important to recognise however, that mains supply is originally abstracted from a surface water or groundwater source before being treated to a tertiary level to meet potable water standards. This exerts not only the pressure of abstraction from the natural source, but also large quantities of energy concerned with pumping and treatment. For livestock drinking purposes, The Dairy Assured Scheme requires water to be 'fresh and clean', although not specifically potable (MDC, 2007). It is, therefore, preferable to use untreated abstracted ground or surface water for livestock drinking where source quality is high and the quantity required can be abstracted sustainably. Although this may not be the main driver for livestock farmers to utilise natural sources, the cost of mains supply at around £1 - £1.50/m^3 promotes a strong economic incentive to investigate alternatives.

2.3.2 Groundwater abstraction

The potential abstraction of groundwater for livestock production in the UK is largely dependent on the hydrogeological properties of the catchment from which a water source is required. This is usually defined by Catchment Abstraction Management Strategies (CAMS), which quantify the sensitivity of a ground/surface water resource to abstraction (Environment Agency, 2007). Dependent on livestock numbers abstraction as a primary source for drinking and wash water requirements may require a licence granted by the Environment Agency if quantity removed exceeds 20m^3 per day (Environment Agency, 2008). It is often therefore common practice for a combination of sources to be used on single farms to keep abstraction quantity below the 20m^3 threshold limit and eliminate the cost and control associated with licence acquisition (HCC, 2008). As a guide, a dairy herd of around 100 cows is likely to require around 20m^3 water per day.

Table 2.2 Cost analysis example for borehole system (source: MDC)

Item	**Estimated cost** for abstractions of 4,000m^3 to 20,000m^3/yr
<u>Capital/one-off item cost</u>	
Geologists' report	£500 - £1,000
Abstraction licence fee application	£135
Admin fee	£150-£350
Advertising cost	£500-£1,500
Test bore	£500-£1,000
Main borehole	£5,000-£10,000
Bore hole pump	£500-£1,000
Pump shed	£150-£500
Electrics, tanks, pumps, pressure vessels, pipe work, filters etc	£2,000-£5,000
Total estimated range in capital or one-off costs	£9,035-£19,585
<u>Annual running costs</u>	
Annualised capital costs	£675-£1,500
EA abstraction license fees	Over 25 years @ 7% APR (If required £170 to £2500)
Borehole maintenance/service cost	£250-£,1000
Labour costs	£50-£150
Electricity costs	£250-£750
Total annual running costs	£1,395-£5,900
£/m^3 range	£0.19-£0.38

Groundwater extracted from aquifers, along with springs where groundwater reaches a natural discharge point at the surface, often provides a source of clean drinking water for livestock. When source quality is high, purification prior to consumption is not required and can provide the security of having an on-site supply of fresh water for both livestock and farm buildings (MDC, 2007). Boreholes, drilled directly into the aquifer discharge point, provide a means of bringing groundwater to the surface where it can be pumped to a surface store or directly to troughs/stock tanks for livestock consumption. The process of borehole installation, however, can be an expensive process requiring a geologists report, the physical drilling & installation and associated annual maintenance costs (MDC, 2007). Table 2.2 provides an example of cost analysis provided by The Milk Development Council (2007).

Uptake of groundwater use in livestock production in the UK is therefore a function of availability of the resource on farm, and the costs associated with accessing and delivering the source to livestock. BPex (2010) report an increase in applications relating to borehole abstraction for pig production as the source can provide both security of supply and abstraction within the 20m^3 permit threshold has the potential to satisfy the requirements of a 2,000 head finishing unit. Its uptake, however, should be governed by the sustainability of the groundwater source and the implications of its use on water security and quality.

From consultancy experience the costs described by the Milk Development Council (2007) adapted in Table 2.3 appear to be at the high end of expectations and whilst may be relevant to larger scale deep installations, may not be applicable to systems with smaller stock numbers and less extensive drilling requirements. For example a 100 cow herd is unlikely to require an abstraction licence if borehole water is solely used for stock drinking, as annual consumption would be less than 5,000 m^3 and daily abstraction of 20 m^3 equates to 7300 m^3/yr. Systems are available at lower cost subject to depth of water, from 30m to over 90m, the latter being exceptional with average costs of £5,500 in total. It would be wise to have a no water, no fee clause in the drilling contract. Details of typical costs for an example 200 cow herd requiring around 7000 m^3/per annum are shown in Table 2.3, but these costs will vary on a site by site basis - particularly with regard to geology and location.

Table 2.3 Example costs for farm with borehole and mains electric pump or wind/solar pump

Item	£	£
	Borehole no water, no fee	Borehole, wind turbine, solar panel, batteries & pump
Main borehole	2,500	2,500
Bore hole pump	500	
Pump shed	500	
Electrics, tanks, pumps, pressure vessels, pipe work, filters etc	2,000	
Carriage		70
Install		150
Total estimated range in capital or one off costs	5,500	2,850
Amortisation capital costs (20 yrs @ 7%)	**517**	268
EA abstraction license fees		
Borehole maintenance/service cost 5%	125	143
No. turbines required for 100cows		4
Labour costs	150	
Electricity costs	150	
Total annual running costs	425	
Total costs	942	1,214
£/m^3 range	**0.22**	**0.29**

2.3.3 Surface water abstraction

Surface water sources such as rivers, ponds and lakes are also used as a source of drinking water for livestock production. Although increasingly uncommon, a small proportion of farmers allow cattle and sheep grazing in close proximity to fresh running water to drink freely from the source. As a practice this is actively discouraged, as access of livestock to the water exerts extensive pressure on river banks causing erosion, sediment loading of watercourses and often nutrient enrichment and contamination with biological contaminants resulting from animals accessing and excreting directly into water (Anon, 1998).

The susceptibility of surface water to pollution means that its use for livestock drinking will require testing before intake is allowed, as diseases such as Salmonella and E-coli can pose significant risk to livestock health (Environment Agency, 2009). In addition foot rot, leg injuries and death by drowning are also risk factors which need to be taken into account when considering direct livestock drinking from surface waters (HCC, 2008). Fencing off surface water sources from grazing livestock and abstraction for supply and storage is a safer and environmentally responsible method of satisfying the requirements of livestock, and in some locations and times may be required by law due to SSSI status and/or cross compliance issues (HCC, 2008). However abstraction from surface sources as an alternative to direct drinking still needs to take into account the sustainability of supply. Reduced flows caused by over-abstraction directly impacts both chemical and physical properties of the water course causing decreased dilution of pollutants, changes in the kinetic characteristics of the water and decreased available habitat due to volume and temperature variation (Lord et al, 2007). In addition, the effect of stock no longer grazing fenced off stream banks should be considered in terms of maintenance requirements.

2.4 Water re-use

2.4.1 Rainwater harvesting

2.4.1.1 Overview of system

Rainwater harvesting systems provide an alternative method of fresh water collection and reuse for agricultural production, which in recent years has become a more common practice, as the importance of improving resource efficiency in agriculture has been established. In some cases this may be via prescribed planning agreements as detailed by Elliott *et al* (2005) and further highlighted by Whitehead et al (2009) who state that one rainwater harvesting supplier suggested that 15% of domestic sales were influenced by planning requirements.

The process of rainwater harvesting prevents evaporation and the return flow to surface and ground water sources through runoff and percolation, which is often a concern associated with installing systems on a large scale. However, the quantity of water collected in relation to catchment size, and in general the close proximity of applied use to original collection point makes the impact on catchment sensitivity negligible in comparison to surface and groundwater abstraction (Environment Agency, 2009). In fact, most harvested water is used and returned to the system on site with little loss.

Its application as an on-site water supply is dependent on both annual catchment rainfall (in terms of quantity and timing), and on the ability of systems to collect an adequate quantity (influenced by roof area, slope and construction material, and the design features of the system itself).

The roof area forms the surface that will collect and channel rainwater to the storage tank; this is likely to be site-specific and dependent on both livestock numbers and stocking density (Whitehead et al, 2009). The ability of this surface to channel rain water and the flow rate at which this will occur is determined by the run-off coefficient, which is influenced by factors such as; surface wetting, evaporation, ponding in depressions, and the type of material of which the surface is constructed (Whitehead et al, 2009). For example, a coefficient value of 0 would mean that no run-off occurs whilst a value of 1 would mean that all the rain falling on the roof is translated into effective run-off. Legget et al. (2001) provides examples of runoff coefficients for different roof types as shown in Table 2.4.

Table 2.4 Common roof coefficients (Taken from Whitehead et al (2009), adapted from Leggett et al. (2001)

Roof type	Coefficient		
	High	**Expected**	**Low**
Pitched roof tiles	0.90	0.85	0.75
Flat roof, smooth surface	0.60	0.55	0.50
Flat roof with gravel layer or thin turf (<150mm)	0.50	0.45	0.40
Corrugated metal roof cladding	0.95	0.90	0.80
Corrugated composite sheet roof cladding	0.90	0.85	0.75

Filter efficiency is also an important factor concerned with the potential collectable volume of systems. Often filters designed for collecting rainwater will reject the first flush and also include a feature which allows self-cleaning by rejecting a proportion of the flow. The efficiency of high quality filters is typically around 90%, although this figure is variable and will be determined by individual manufacturers or suppliers of rainwater harvesting components (Whitehead et al, 2009).

Finally the amount of rainfall available for collection is often the key factor which governs the feasibility of system installation and the overall success of the system in achieving its target harvest volume. It is therefore important that the rainfall data used during preliminary investigations into system installation is as accurate as possible. Since rainfall patterns very from region to region, the rainfall data should relate to the area of concern (Whitehead et al, 2009). Potential collectable rainfall can be expressed by the equation below (Environment Agency, 2007):

Potential collectable rainfall (l) =
Roof area (m^2) x run off coefficient x filter efficiency factor x annual rainfall (mm)

2.4.1.2 Economics of system installation

Method and quantity of rainfall which can be collected successfully is therefore largely dependent on the design and construction of buildings already present on-farm, and modifications to guttering and surface runoff channels required to maximise harvest yield. In general, a system which is incorporated into the design phase of a building, prior to construction, will be cheaper in terms of capital investment and payback period will be shorter due to higher annual yield reducing the need to rely on mains supply and surface/groundwater abstraction at a higher cost.

System costs vary greatly depending on the requirements of individual systems: the design and cost of extensive systems will depend on the combination and quality of individual components used and the scale of maintenance required for the system to operate effectively (Table 2.6). Typically a rainwater harvesting system draining to an above ground tank with a pumped system and automatic control to applications, could cost around £10 per m^2 of roof surface area (Whitehead et al, 2009). In general agricultural systems typically have a better payback than domestic systems due to the higher water gathering capability from large roofs and the higher demand for water for various uses within agricultural premises.

Table 2.5 Compilation of rainwater harvesting components (source: Whitehead et al., 2009)

Group	Item	Cost	Installation
Storage	Circular above ground tank (per m^3)	£25-£60	£10-£30
	Roof for tanks (per m^2)	£50 -£140	£20-£40
	Algae cover	£14-£35	£1
	Below ground poly tank (per m^3)	£80 - 100	£45
Pumps	Submersible pump 4-8 l min^{-1}	£1000 -£1300	£ 250
	Submersible pump small 2 l min^{-1}	£250	£ 250
	100µ pump inlet screen	£40	-
Filter	Inlet Cartridge Filter 200 -700 (per m^2 roof area)	£160- £700	£50
	Delivery pipe filters	£50	£15
	Delivery side Self flushing filter	£530	£50
	Sand filters 6m^3 h^{-1}	£400	£ 200
	Siphons surface skimming	£80	£10
Controls	Control units	£180 - £250	£250

Economic benefits are provided not only with regards to a reduction in mains water use and associated sewerage costs, but also in a decrease in water running across yards and entering slurry and dirty water storage, thereby reducing the size of storage facility required and the costs and energy associated with dirty water disposal (Environment Agency, 2009). The Environment Agency (2008b) report showed that by collecting and diverting rainwater from a 180 head cattle house in the Devon area during the winter months could lead to a £10,000 saving due to the avoidance of spreading an entire slurry pit to land the following spring.

The storage and transport of collected water in a harvesting system also has a significant bearing on the cost of installation and operation, the energy efficiency, and therefore on the sustainability performance of such methods of fresh water supply. Over ground and underground storage tanks brought from new have a high capital cost and energy expenditure concerned with manufacture and installation, and so where possible storage tanks should be reused from a previous application and modified to fit the purpose. The transport of water from the collection area to storage area and from storage area to point of use can also create a large energy demand, especially if utilising electrical or fuel-powered pumps which have high a energy consumption and associated annual running costs. It is therefore advisable to utilise gravity fed systems wherever possible, together with renewable energy sources such as solar and wind to power pumps (discussed in detail in Section 2.5).

Table 2.6 Typical costs associated with the development of a rainwater harvesting system. Content derived from Effective Use of Water on Dairy Farms (MDC, 2007) and Rainwater Harvesting: An on-farm Guide (Environment Agency, 2009)

Typical one off items	Estimated cost
Alteration of gutters and down pipes	£15-£30/m
Filters for down pipes	£25-£150
Laying and diverting rainwater pipes to rainwater store	£25-£35/m run
Rainwater store tanks	
Recycled container with lid (6m^3)	£145
Filters prior to storage	
Cross flow	£500-£2,500
Vortex	£500-£2,000
Cartridge	£160-£700
Fine mesh	£40
Sand	£400
Pump	£250-£750
Typical annual running costs	**Estimated cost**
Cleaning gutters & downpipes annually	£50
Pump running cost	10p-30p/m^3
Annual maintenance contract (filter & pump service + repair)	£250

An additional factor in rainwater harvesting is the storage period: the longer it is, then the more complex the equipment required. For a building 30m x 20m (area 600m^2) in a region with 1050 mm annual rainfall, net collection per annum would be some 440m^3 at a value of around £440. The aim would be to collect high rainfall events (over 25mm), where a 50mm precipitation would provide sufficient water for three days. Above this, water may need circulating and cleaning in addition to the filtering and UV treatments.

Table 2.7 Typical rainwater catchment system

Rainwater capture system	£
Galv. steel tank 30 m^3	2,673
Pipes & gutters	250
Filter	80
Pumps	250
Pipes	1,000
Header tank	150
UV filters	964
New bulbs	62
Total investment cost	5,429
Amortisation cost (20 yrs @7%)	94
Annual amortised cost	510
Electricity £/yr	96
Annual cost	607
£/m^3 (incl. maintenance)	**1.20**

OCMIS Ltd of Somerset suggest that an above ground galvanised corrugated steel tank with lid of 30 m^3, plastic lined, requiring a simple mesh filter with pumps etc. would involve a total capital cost of some £5,250 plus maintenance of £250/annum. The resulting system is simple, has a life of 20 years or more, and a cost of around £1/m^3. Clearly, this is close to the likely current cost of mains water, but it would break even and act as a buffer in times of shortage and become increasingly cost-effective as water charges increase as is likely in the future. An overview of the typical costs of a rainwater harvesting system are shown in Table 2.7, which contains values based on an example 600m^2 roof area, 1050 mm annual rainfall, and assumed 90% efficiency.

2.4.1.3 Rainwater harvesting for livestock drinking

Rainwater can be used for a variety of activities concerned with livestock production, the most common of which is yard and selective building wash down for cattle, pig and sheep production - which only requires preliminary filtration to remove large foreign bodies (MDC, 2007). For collected rainwater to be used for livestock drinking, secondary filtration and treatment is advisable. As mentioned previously, legislation does not prescribe that water for livestock drinking must be of potable standard; however rainwater contamination from wild bird faeces and vermin excretion is common and, therefore, risk of disease in animals should be minimised through precautionary sterilisation (MDC, 2007).

This is especially relevant to intensive livestock production, such as poultry units where disease spread would be rapid. Outbreaks of avian influenza in recent years, and its potential to mutate and spread to humans may rule out using rainwater for such stock drinking (Environment Agency, 2009). Water used for washing milk lines,, udder or hand washing must be of potable quality.

When considering the water requirements of livestock, such as dairy cattle, it is apparent that in most cases rainwater harvesting systems are unlikely to have the capacity to *totally* satisfy the day to day requirements of animals. For this reason rainwater systems are commonly used in conjunction with mains or abstracted ground/surface water as a secondary source. Using mains water to supplement this will require a 'top-up' arrangement compliant with the Water Supply Regulations (1999) to ensure that non-potable water does not contaminate the mains supply, and this will involve the correct placement of stop valves, metres and the use of appropriate piping to minimise risk (MDC, 2007).

2.4.1.4 Chemical, hygiene and legal aspects

Rainwater harvesting has been practised in arid or semi-arid climates for many centuries for human drinking and other uses, but only recently have there been published studies on the microbiological and chemical contamination of rainwater, and the effects of local atmospheric conditions and sources of airborne contamination.

Rainwater is relatively free from impurities except those picked up by rain from the atmosphere, but the quality of rainwater may deteriorate during harvesting, storage and use. Wind-blown dirt, leaves, faecal droppings from birds and animals, insects and other debris on the catchment areas can be sources of contamination of rainwater, leading to health risks for livestock. However, risks from these hazards can be minimized by good design and maintenance.

Water is an essential component which is involved in all basic physiological functions of animals. However, it is important to note that water, relative to other nutrients, is consumed in considerably larger quantities. Therefore, water availability and quality are extremely important for animal health and productivity. Considering that water is consumed in such large quantities, if water is of poor quality, there is an increased risk that water contaminants could reach a level that may be harmful to the animal and may cause disease or leave residues harmful to those consuming products of animal origin.

Rainwater also lacks minerals, and some, such as calcium, magnesium, iron and fluoride, are considered essential for health. Although most essential nutrients are derived from an animal's diet, the lack of minerals, especially calcium and magnesium, should be considered if rainwater is the only source of water available to livestock.

Rainwater is generally slightly acidic and low in dissolved minerals; and as a result it is relatively aggressive. Rainwater can therefore dissolve heavy metals and other impurities from materials of the catchment and storage tank. In most cases, chemical concentrations in rainwater which has been analysed have been shown to be within acceptable limits. However, elevated levels of zinc and lead have been reported in samples of stored rainwater, and this could be from leaching from metallic roofs and storage tanks or possibly from atmospheric pollution.

There have been many studies on the potential impact of high levels of certain chemicals on livestock health but the literature search has revealed no widespread incidents of harm to livestock from drinking rainwater.

Microbial contamination of collected rainwater indicated by coliforms or *E. coli* is quite common, particularly in samples collected shortly after rainfall. Pathogens such as *Cryptosporidium*, *Giardia*, *Campylobacter*, *Vibrio*, *Salmonella*, *Shigella* and *Pseudomonas* have also been detected in rainwater. However, the occurrence of pathogens is generally lower in rainwater than in unprotected surface waters, and the presence of non-bacterial pathogens, in particular, can be minimized.

Higher microbial concentrations are generally found in the first flush of rainwater, and the level of contamination reduces as the rain continues. However there have been no documented livestock disease outbreaks attributed to contaminated rainwater, although some studies showed reduced consumption, and hence effects on productivity, thought to be caused by bad odour or taste. A system is therefore recommended to divert the contaminated first flow of rainwater from roof surfaces. Some manual and automatic devices are available to divert the first flush of rainwater.

There are no specific legal requirements concerning quality of livestock drinking water. Since 1 January 2006 the hygiene of food production throughout the EU has been covered by EC Regulation 852/2004 *on the hygiene of foodstuffs*. This regulation does not make specific reference to livestock drinking water. Annex I concerns primary production and includes a requirement for animal keepers *"to use potable water, or clean water, whenever necessary to prevent contamination"*. Clean water is defined in the regulations as "*water that does not contain micro-organisms or harmful substances in quantities capable of directly or indirectly affecting the health quality of food."* This was interpreted by FSA to mean that livestock drinking water should be protected from contamination and keepers should not knowingly permit animals to drink from a contaminated source. There are no published UK standards setting out the microbiological or chemical quality of water to be used for livestock drinking although standards have been published in other countries such as Canada, USA, and jointly by Australia and New Zealand.

Further details on the hygiene and legal issues associated with rainwater harvesting are included in Appendix 2.

2.4.2 Plate cooler water re-use

Plate coolers are used in dairy parlours to reduce the temperature of milk before it enters storage. This is achieved by circulating water through a system which surrounds pipes containing the flow of milk. As prescribed in the previous section, water for this use must be potable and therefore mains supply is commonly utilised. Most systems consume around 2-3 litres of water for every litre of milk cooled, which the Environment Agency (2007) report to be similar to the drinking water requirements of dairy cattle. For example, a dairy herd of 150 cows which yields around 22 litres of milk per cow will require a total daily plate cooler water quantity of 9900 litres and daily drinking water requirements will be around 10500 litres (Environment Agency, 2007).

From this perspective, it is essential that an appropriate method of water re-use is established in order to prevent large quantities of mains water from being wasted on a daily basis. Using plate cooler water for livestock drinking is one way in which this can be achieved, as once water has circulated through the cooler it can either be stored in a tank with sufficient capacity or distributed directly to troughs for stock drinking. Evidence suggests that an added benefit may be that the water exiting the plate cooling system is warm and preferable to cattle over colder sources, especially in cooler months. However, it should be noted that warm water also increases the risk of bacterial growth, and therefore should not be stored for extended periods in troughs (MDC, 2007).

An alternative to reusing plate water for livestock drinking involves directing exit water to storage or to hot water tanks for use in parlour wash down. Obviously this is dependent on the size and layout of the parlour, and additional water may be required. Alternatively it may be that plate cooling produces a larger amount of water than required for wash down, which means a further reuse must be established in order to prevent waste (MDC, 2007). A problem often encountered with reusing plate cooler water for wash down involves the timing concerned with water exiting the cooler in relation to when it is required for use in parlour wash down. For example, cooler water which is added to hot water tanks for heating prior to wash down often causes a general decrease in temperature of the tank water, and so water used for wash down may be less effective as a cleaning solvent and a greater quantity may have to be used (MDC, 2007).

2.5 Water purification

For the use of all non-mains water for livestock drinking intake the quality of water must be established prior to consumption to ensure that the source is 'clean and fresh'. Although some non-mains water may be suitable for livestock drinking, without the need to treat before use, it is vital that contaminated or potentially contaminated water is purified to a suitable standard to prevent the risk of disease.

There are various options which allow for the purification of water for livestock intake and dairy wash down on site. Ultraviolet (UV) sterilisation is a common non-chemical method which is largely employed alongside rainwater harvesting systems to remove pathogens from stored water, utilising a series of additional filters and a UV unit. The process allows water to be treated quickly at a relatively small cost due to low capital investment, estimated at £360 for an 8l/min system and £710 for 54l/min equivalent (Environment Agency, 2009). Obviously the size of system and capital investment is dependent on the water requirements of stock, however running costs are likely to be similar for most systems, involving the replacement of UV bulbs & filters annually and the cost of electricity consumed by the unit. On a 100 cow herd, a UV filter would cost around £1,000 together with around £65 for annual replacement of UV tubes and electricity costs of some £100 p.a.. UV bulbs and filters, operate continuously to prevent contamination in the event of reflux.

The use of reed beds to treat waste waters to both secondary and tertiary standard is also a common method of purification employed across the USA and Europe since the 1980s (Sun et al, 1997). Horizontal and down flow systems use a combination of physiochemical and biological processes to breakdown organic fractions in water and therefore reduce the BOD and COD, allowing it to outlet to either surface water courses or percolate back to groundwater source. Water which exits the system has the potential to be used for livestock water requirements, such as yard wash down, decreasing reliance on further abstraction and mains supply. However before use as a drinking water source it is advisable to test the quality to ensure the process is working correctly and the output is pathogen free.

In recent years research on the application of reed bed systems to provide a solution to the on-farm treatment of concentrated dirty water such as slurry and milk contaminated waste has been conducted in the UK. It has been found that reed bed systems have the potential to significantly reduce the BOD and COD of concentrated waste water, however not to a standard which would allow its discharge into surface water sources or use for livestock drinking (Sun et al, 1997). Further development of horizontal and down flow systems to allow the treatment of dirty water deriving from agricultural use to a tertiary standard would drastically reduce both the energy and cost associated with commercial waste water treatment and further allow water to be directly reused on site. Further details of the hygiene aspects associated with provision of water to livestock are considered in Section 2 of this report.

2.6 Distribution of water to livestock

One of the main factors when considering an appropriate source of water for livestock drinking and wash requirements is the ease at which abstracted or collected water can be distributed to livestock. As a rule, livestock should be taken as close to the water source as possible to limit the need to pump water over great distances. However, upland stock or remotely grazing animals may require water to be delivered to them to satisfy requirements. This can present both high cost and energy consumption associated with pump electricity or fuel consumption and pipe installation. The following section provides an insight into available technology for water distribution from source to stock or point of use.

2.6.1 Solar & wind powered pumps

Solar pumps provide an alternative method of transporting water a short distance, from either source or storage, to livestock troughs, utilising electricity generated by photovoltaic cells. The system which conveniently works best on sunny days when drinking requirements of livestock will be higher does not require an additional mains power supply. Provision therefore needs to be made for days where cloud cover reduces efficiency and thereby constrains the quantity of water pumped (HCC, 2008). This may be in the form of an external power supply or the ability to pump and store enough water to last for three to four days to satisfy stock requirements when there is sufficient sunlight to power the pump (HCC, 2008).

Swanson (2007) provides an analysis of two solar powered pump systems, both supplied by Windsund International Ltd for which pumping capacity has been calculated based on installation in Southern England. A summary is provided in Table 2.8.

Table 2.8 Summary costs of two alternative solar powered pump systems

	System 1	**System 2**
	1 x Solar Panel - KC80 rated at 80Wp	1 x Solar Panel - KC60 rated at 60Wp
	1 x Inverter unit (400W output at 230v AC)	1 x Pump: 12v DC
	1 x Pump: 230v AC single phase	1 x Solar Panel mounting frame / pole
	1 x Solar Panel mounting frame or pole	1 x Deep Cycle Battery 220Ah
	1 x Deep Cycle Battery 220Ah	1 x Set of cabling
	1 x Set of cabling	1 x Pump float switch and fittings
	1 x Pump float switch and fittings	
Capacity	Max. 550 litres per hour	Max. 550 litres per hour
Full capacity period	April – September	February - October
Cost	£1,758 + VAT	£1,490 + VAT

Wind powered pumps similarly offer a renewable method of providing the energy required to distribute water to livestock. In areas which receive sufficient wind, a turbine can be installed which generates electricity to power an electric submersible pump for water redistribution. These systems have the ability to transport large volumes of water over small head distances, often to storage tanks at the surface of boreholes or from source to trough. Conventional mechanical systems utilise the rotary movement of a multi-bladed fan-like rotor to drive a reciprocating pump through reduction gearing. Design of the system allows it to operate at much lower cut in speeds of around 3m/s (Carbon Trust, 2008) and pump greater distances in comparison to electric turbines, which is more appropriate for areas which receive light winds (Fraenkel et al, 1998).

In the UK, regional wind speed can be extremely variable, and the choice of wind pump system must reflect the conditions in which it is to be used and the water requirements of the stock for which it will supply. For this reason the application of wind pumps to provide a suitable method of water distribution must take into account weather patterns experienced at catchment scale. Again, as with solar pumps, the installation of such a system should allow a guarantee that there will always be sufficient water to meet livestock requirements, and this can be ensured by fitting a backup power source to the pump or allowing additional storage capacity for days where wind speed is insufficient.

A costing was provided by Amos pumps for a 400l/hr output using a combined wind/solar pump using 2 x 135Amp hour batteries to drive a 24v DC 100mm pump complete with tower, ground anchors and installation @ £2,850 plus VAT (see borehole section). The equipment has few working parts and is capable of a life of over 20 years, with the only likely maintenance being battery replacement. The cost can be as low as £0.40p/m^3 water and supplies sufficient water for 31 cows per unit.

2.6.2 Hydro ram pumps

Hydraulic ram pumps utilise the velocity generated by the gravitational fall of water through a pulse valve to drive water into a pressurised air cylinder, which then forces water from source to storage area or to troughs through a 'rising main'. The design of the system allows water to be pumped over great distances with minimal fall required; for example, with a 0.5m gravitational fall water can be raised around 18m (Swanson, 2007). The distance that water can be transported increases as a function of fall height, and, therefore, there are examples of ram pump installations where water is pumped to over 5km in distance from its source and 300m in height (Swanson, 2007). The main application of ram pumps involves the distribution of flowing or still surface water sources such as rivers and lakes, as the waste water which continues to flow through the pulse valve can be returned to the source downstream. However, this may present an issue with regards to providing water of a suitable quality for livestock drinking requirements, therefore a 'compound' ram can be installed which uses the velocity of a stream source to pump water from an alternative source such as pure groundwater to the water store or trough (Swanson, 2007).

Both systems do not require a power source and only minimal maintenance is needed as in general the pumps have no metal moving parts (Swanson, 2007). For this reason ram pumps offer an energy efficient low cost method of delivering water to livestock and are highly suitable for adoption in pastoral agriculture systems. A range of ram pumps are available which provide the appropriate pumping capacity required on farm. As a case study example, a hydraulic ram pump at Penhein Farm, Chepstow is considered in Table 2.9.

Table 2.9 Case study example - cost to install a hydraulic ram pump system (adapted from Swanson (2007))

Capital cost of pump	£500
Installation cost	£1,000
Installation time	3 days
Volume of water delivered	11,365l/day
Distance water delivered to	70m
Use of water	100 cows, 200+ sheep, pigs, farm buildings

According to trade information (Green and Carter), an engineered solution (all metal, weighing some 100kg) can pump to 1:30, that is 30 times the head delivering 7,500l/day at a cost of £2,500 plus VAT. These pumps are virtually maintenance-free and have been known to work continuously for many years. They are often used in remote areas in the UK and overseas where the only check is to see if the water is being delivered to where it is required (Table 2.10). Costs shown are for pump and installation although infrastructure costs for delivery will include a buffer tank/reservoir and piping subject to site, which will add to the cost.

Table 2.10 Hydro ram pump systems

	Flow rate	
	Light plastic & metal	**Heavy duty all metal**
l/min	1.50	5.25
l/day	2,160	7,560
m^3 pa	788	2,759
Use l/day/hd (suckler)	45	46
Beef cows supplied/pump	48	164
Use l/day/hd (dairy)	75	76
Dairy cows supplied/pump	29	99
Cost £/unit	250	2,500
Amortised (20yrs @ 7%)	23.5	235
Cost £/m^3	0.03	0.09

2.7 Water intake methods

Traditionally, the supply of drinking water to larger stock, such as cattle, sheep and pigs, is achieved through the use of troughs which allow large quantities of water to be stored at any one time. Typically, such systems can receive fresh water from all clean sources, as long as enough water can be delivered to satisfy the requirements of stock and the flow rate of incoming water can be controlled. This is often achieved using a combination of storage tanks and ball cock valves which control the re-fill rate and prevent trough overflow.

Maintaining high water quality in troughs is a priority and therefore regular cleaning is essential. This process, however, has the potential to cause large quantities of waste water (in some cases up to 2,270l per trough (Thompson et al, 2007)), as they are emptied,. The use of bowser tanks to fill troughs when needed is often employed as a measure to prevent poor water quality as water is stored in an enclosed environment, preventing contamination and is fed into troughs via a trickle system to keep them well stocked.

Wastage can also be generated through poor maintenance of equipment or damage due to vandalism and freezing weather conditions. Long lengths of pipe, used to transport water from source to storage and troughs, can often burst or leak resulting in wasted leaking water (if isolation valves are not fitted) and could also result in livestock not receiving their required water intake. This is a particular problem for upland farms and remote grazing stock such as sheep. Broken ball valves, or those set at an incorrect level in relation to trough height, can often cause water to overflow. This not only causes a problem in terms of waste, but ground surrounding the trough can become waterlogged, causing poaching and potentially leading to significant chronic diffuse water pollution (Environment Agency, 2007). It is estimated that a leaking ball valve in a trough can contribute to up to 150m^3 of waste annually, while a fractured valve can result in annual losses of up to 2,000m^3 (Environment Agency, 2007).

2.7.1 Alternative intake methods for cattle

Pasture pumps (also known as nose pumps) provide an alternative method of supplying cattle with drinking water. The system involves a lever operated piston and diaphragm which when activated by the nose of a cow delivers up to 0.5 litres of water into a bowl underneath (Swanson, 2007). As no external power source is required and the delivery of water is solely based on the mechanical action of the lever, practical limits include a lift of just 6m and horizontal distance of 60m (Thompson et al, 2007). For this reason pasture pumps are often used to supply cattle which are grazing in close proximity to source - for example next to rivers which have been fenced off.

There are both advantages and disadvantages to introducing a system for livestock drinking. Firstly pasture pumps allow supply to stock in remote locations without the need to consume the energy associated with electrical/diesel pump use, while by eliminating the need for long pipes the risk of leakage is reduced which leads to increased water efficiency (Thompson et al, 2007). An added benefit to the use of nose pumps is the ability to provide an alternative to allowing cattle to drink directly from water courses such as rivers, preventing bank erosion and/or biological contamination of surface waters from livestock (e.g. cryptosporidium spp.).

The capital cost of a pasture pump is relatively low; Swanson (2007) reports that the unit cost is around £295 with a further £125 required for additional installation costs including piping, and one pump can provide enough water to meet the requirements of 20-30 beef cows or 10 dairy cows (Thompson et al, 2007). However communication with farmers who have practical experience of livestock drinking from pasture pumps recommend that as many units as economically viable should be installed to prevent livestock from queuing for water, with less confident stock not achieving the required intake. Example costs associated with a pasture pump are shown in Table 2.11.

Each pump should be mounted on a properly constructed hardstanding. For Catchment Sensitive Farming grant aid, the hardstanding should consist of a minimum area around the pasture pump of 1 m x 1 m, excavated to a minimum depth of 150 mm or down to a naturally occurring hard surface. Hardcore should be well compacted on a geotextile liner by rolling to a minimum depth of 150 mm. The hardstanding area should be edged with preserved timber (not smaller than 150 mm x 50 mm) so as to prevent the movement of hardcore. The cost of each is estimated at approximately £100 (excluding VAT).

Table 2.11 Cost of pasture pump per 15 animals

	£
Cost not including VAT	240
Base for fixing	100
Pipes & fittings	20
Total cost	360
Amortised 10 yrs @ 7%	142
Amortised annual cost	51.12
Animals supplied/pump	15
Daily req. per head litres	70
Daily use	1050
Annual use cu m	383.25
Annual cost £/cu m	0.13

2.7.2 Alternative intake methods for pigs

Monoflow nipple type drinkers have for a long time been the conventional method of delivering drinking water to pigs, especially those housed indoors. This system however has the potential to create large volumes of waste water through both recreational play of pigs with the drinkers and the tendency of stock to drink from a side angle causing spillage (Thompson et al, 2007). Although BPex (2010) report that in general, pig farmers need to be sure that stock are receiving enough water and spillage can be a sign that this is occurring, large scale wastage is an issue with regards to sustainability and cost.

Studies have shown that the installation of bite type drinkers can reduce wastage by up to 10% for indoor pigs, saving costs associated with quantity of mains supply used and slurry produced therefore cost of spreading to land (Thompson et al, 2007). For outdoor pigs the use of shallow troughs and bowls can help to reduce waste. It is also possible to modify drinking bowls to become lever activated, in a similar method to pasture pumps, so that water is only used when required (Thompson et al, 2007).

2.7.3 Alternative intake methods for sheep

As with all livestock, the drinking water requirement of sheep is largely dependent on the dry matter content of their diet along with other influences on metabolism such as weight and pregnancy. Non-pregnant ewes in the UK often require little additional fresh water to that metabolised through grazing pasture, however it is important that all livestock have access to a suitable fresh water source. Traditionally this is provided to sheep via direct access to water courses or troughs which allow drinking as and when required. As stock drinking from rivers and streams is actively discouraged (Environment Agency, 2008b), an alternative intake method is favourable and this can be achieved through a modified pasture pump, activated by the weight of the animal which triggers a diaphragm (Thompson et al, 2007). However, this system is fairly uncommon with limited current uptake, as most farmers prefer to ensure access to water through trough drinking.

2.7.4 Alternative intake methods for poultry

Intensive poultry systems traditionally use suspended bell drinkers to provide water for intake of stock; however, these systems have the capacity to create large volumes of waste due to spillage. This is not only an issue with regards to water efficiency but also due to the impact of water on floor litter. When wet this litter produces ammonia – a source of odour with the potential to burn poultry in direct contact. Cup drinkers which use mini float valves to ensure that the unit is always full provide a far more stable option, reducing the incidence of spillage and therefore wastage of water provided drinking. Similarly, poultry quill and nipple drinkers provide a favourable alternative to bell drinkers; however these may not be suitable for larger birds such as turkeys that do require bell drinkers (Thompson, 2007).

All systems require regular sterilisation at high pressure particularly the lines feeding the drinker from which poultry take in water. Water hardness from mains supply can be a source of calcium carbonate build up which prevents drinkers refilling at the required rate, while iron contained in abstracted groundwater can also accumulate over time and cause partial blockages. Problems such as these can be avoided by using shallow bowls and troughs for drinking where possible - such as outdoors where the lower stock density is likely to reduce spillage and associated waste.

3. Synthesis

A variety of alternative methods to mains water exist for supplying water to livestock. These alternatives may become increasingly attractive options:

- if mains supply becomes increasingly expensive or restricted,
- if abstraction licences are difficult to obtain or renew,
- if future climate change promotes the need for farm businesses to increase their resilience to prolonged drought periods
- or if measures are taken on a farm to reduce diffuse pollution from land to water (such as fencing off river banks to reduce bank erosion from direct cattle access)

Systems considered in this review include boreholes, wind pumps, solar powered pumps, rainwater harvesting, pasture pumps and ram pumps. The relative reliability of these alternative systems are shown in Table 3.1 and a summary showing cost and supply capacity of each method are presented in Table 3.2.

There is no single "best" solution for all situations – the most suitable and cost-effective non-mains water supply option will vary from site to site. Selection criteria for an individual site should consider:

- Type and location of available water sources
- Site location & conditions (remote, slope, riparian features)
- Number and type of livestock (which defines daily water requirements)
- Access to power (mains, solar, wind, livestock)
- Pumping system (height, distance, powered / manual)
- Flexibility and portability
- Reliability and maintenance

- Temporary or seasonal water storage
- Cost / benefit and cost / animal

Table 3.1 Reliability of supply of existing methods

System	Reliability of supply	Comments	Water quality
Borehole	Guaranteed availability provided aquifer if charged	Requires electricity, but could use solar or wind pump	As extracted, provided source is potable
Wind pump	Subject to wind provided water is in the source, low capacity compared with electric pump borehole	Virtually maintenance free – weakness is batteries	As in source – if surface water, may be subject to varying quality
Solar	Works even on cloudy days in winter an average of 9hrs/day. Lowe capacity compared with electric pump borehole	Virtually maintenance free – weakness is batteries	As above
Rainwater capture	Subject to rainfall, may be very unreliable in hot summers	Limited quantity by rainfall, evaporation from roofs in hot weather. Limited storage without extensive purification.	Unlikely to be potable due to bird droppings on roofs or vegetation caught in gutters etc.
RAM pumps	Works 24 hrs a day 365 days a year if water is in source	Virtually maintenance free.	Subject to surface water quality
Pasture pumps	As RAM pumps	Virtually maintenance free.	Subject to surface water quality

Table 3.2 Summary of water supply systems

Method	Typical total capital cost (£)	Amortised cost (£)	Running costs (£ p.a.)	Total annual costs (£)	Capacity (m^3 p.a.)	Cost (£/m^3) (annualis ed)	Comment
Borehole	2,500 to 20,000	525 to 2,000	425 to 1,800	£950 to £3,800	4,000 to 20,000	£0.22 to £0.88	Low cost version needs no licence, carried out on no water, no fee basis
Rainwater harvesting	5,500	520	200	£720	440	£1.18	Supplies 10% of need @ 1050mm pa. Storage for >3 days is more expensive Saves slurry storage costs (£1,150), mains water & spreading costs
Solar/wind pump	£3,100	£300	£150	£450	1,325	£0.34	4 units required for a 100 cow herd. Preferably close to troughs and source, can supply to 2m to 3m head Batteries only maintenance issue.
Ram pump	£250 to £2,500	£25 to £250	£50	£75 to £300	750 to 2750	£0.3 to £0.50	Costs are for surface installation. Add £500 to £1,000 if installed on concrete plinth or in concrete lined pit. Maintenance @ £50 to visit and check.
Pasture pump	£360	£55	£50	£105	511	£0.10 to £0.15	Costs include installation @ £100 for concrete plinth. Maintenance @ £50 to visit and check. One unit per 15 or 20 head.

A summary of the pros and cons of the alternative non-mains water supply systems are shown in Table 3.3.

Table 3.3 Summary of characteristics of water supply systems

Method	Borehole	Rainwater harvesting	Solar/wind pump	Ram pump	Pasture pump
Constraints	Up to 20 m^3/day free	1050mm rainfall produces 0.85m^3 per m^2 roof p.a.: 15% loss	Up to 20 m^3/day free	Up to 20 m^3/day free	Up to 20 m^3/day free
		Cost £/m^3 depends on rainfall – higher cost in low rainfall areas			One pasture pump per 15 to 20 head
Pros					
	Avoids energy cost of treated mains water	Avoids energy cost of treated mains water	Avoids energy cost of treated mains water	Avoids energy cost of treated mains water	Avoids energy cost of treated mains water
		Reduces surface water demand	Continuous supply regardless of sunshine strength or wind speed.	Needs little attention once installed	Needs little attention once installed
				Able to pump significant distances from source if head available	
Cons	Requires aquifer – engage contractor on 'no water, no fee' basis	Limited potential even in 1000mm+ rainfall areas – need large roof area per head.	Limited capacity at moderate cost		
	Security of supply - water supply may be seasonal	Water most needed when least rainfall	Needs to be close to source and delivery	Needs to be close to source, but can deliver significant distance per unit of head	Needs to be close to source and delivery
	Needs energy to pump out – could use solar pump	Difficult to store for > a few days without incurring significantly high purification costs			

Considering these techniques in the context of the Case Study DTCs (Appendices 3 and 4), any farm holding wishing to apply for an abstraction licence in the Eden catchment is likely to be successful in obtaining a licence, although it may include restrictions for low flows (although the percentage time for resource availability for the area ranges between 70% and 95% annually indicating a frequent and reliable supply of water). However for the Hampshire Avon and the Wensum catchment water resource availability is significantly lower with both having WMRUs which are either over-licensed or over-abstracted (with the percentage time for resource availability for the area ranges between 50% at best down to under 30% - see Appendix 3). This will need further investigation and management by the Environment Agency through the RSA and RBMP programmes. As livestock holdings are considered to be 50% consumptive it suggests that obtaining a licence is not impossible but any licence issued is likely to have severe restrictions on when water is available for abstraction and this cold be a problem for a holding requiring resource availability all year round and more so in summer months when drinking water requirements are higher and the prohibitive conditions are at their most restrictive. A secondary source of water will need to be available in these circumstances – which would provide a viable justification for alternative water supply methods such as those reviewed above.

Based on this context, there is further potential for the alternative non-mains and non-borehole sources to be used to supply water to livestock in the three case study DTCs, although this potential varies from modest (Eden) to considerable (Avon and Wensum). Lower rainfall in the Wensum limits the potential value of rainwater harvesting, while the cold winters in the Eden may limit the potential for the use of pasture pumps (see Appendix 4).

6. Knowledge Exchange

6.1 Dissemination material

A series of flyers were developed highlighting three methods available to farmers as alternatives to surfacewater or groundwater abstractions. These flyers covered hydraulic ram pumps, pasture pumps, and solar powered (pv) pumps, and were used to raise awareness of both these methods and the workshop events. In all cases bar one, workshops were held on farms where one or more alternative methods for providing water to livestock were already successfully used in practice – with the host farmer serving as a valuable advocate of his chosen method and able to comment from experience on the advantages, disadvantages, and practicalities associated with his chosen system(s).

6.2 Stakeholder workshops

A series of stakeholder workshops were planned for the winter 2011/12 and spring 2012 periods. The focus in each event differed, depending on the regional climate, presence of surface and groundwater bodies, and typical livestock systems present in each area. The wider stakeholder community was involved in all events (see below).

- **Cumbria**

6 Dec 2011, Low Grounds Farm, Plumpton (in association with Livestock NorthWest, Cumbria Farmer Network, Environment Agency and Eblex)

- **Hampshire**

15 Mar 2012, Wherwell Pavilion, Wherwell (in association with Catchment Sensitive Farming and Environment Agency)

- **Norfolk**

25th April 2012, Park Farm, Swanton Morley (in association with the Wensum Alliance, Natural England, and Environment Agency)

- **Lancashire**

1 May 2012, Laund Farm, Bowland with Leagram, Chipping, Preston (in association with Livestock NorthWest, Reaseheath College, Myerscough College, Eblex, DairyCo and Cumbria Farmer Network)

- **Lancashire**

21-22 May 2012, Mariott Hotel, Chipping, Preston (in association with SAC)

- **Cheshire**

30 May 2011, Huntington Hall Farm, Chester CH3 6EA (in association with Livestock NorthWest, Reaseheath College, Myerscough College, Eblex, DairyCo and Cumbria Farmer Network)

Each event was typically attended by 20-40 people, including farmers, extension workers, land managers, agronomists, staff from government agencies (EA, NE) including those involved in granting and reviewing abstraction licenses and those involved in Catchment Sensitive Farming. The total direct audience reached by these events was therefore around 150 people, with additional indirect dissemination of results via publicity material, including flyers on the individual water supply methods.

Feedback received from participants attending these events was entirely positive. In particular, given rising costs of mains water, and the drought conditions present in much of England in winter 2011/12 when some of the workshops were held, then the need to build resilience into farm businesses to withstand such adverse conditions was also recognised as an important factor in support of these alternative methods for supplying water to livestock. Feedback indicated that prior to these workshops, many farmers were either unaware of the alternative options available for non-mains water supply, or were unsure where to obtain information to reach an impartial opinion of the most appropriate and cost-effective method for their individual farm businesses. Based on the assessments reported here, there is clearly considerable potential for wider adoption of these cost-effective technologies to provide more sustainable methods for water provision to livestock in the future.

References to published material

9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.

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Additional references are contained within the Appendices.