OPTIMUM USE OF WATER FOR INDUSTRY AND AGRICULTURE: PHASE 3

Best Practice Manual

R&D Technical Report W6-056/TR2

Part A - Industrial Component*

B. Rees, F. Cessford, R. Connelly, J. Cowan and R. Bowell

Part B - Agricultural Component

E.K. Weatherhead, J.W. Knox, C.L. Twite and J. Morris

Research Contractors:
SRK Consulting*
in association with
Cranfield University at Silsoe

Publishing Organisation:
Environment Agency, Rio House, Waterside Drive, Aztec West, Almondsbury, Bristol
BS32 4UD
Tel: 01454 624400 Fax: 01454 624409
Website:www.environment-agency.co.uk

ISBN 1 84432 065 0

Dissemination status
Internal: Released to Regions
External: Public Domain

Statement of use
This report summarises the findings of research carried out to assess the reasonable water needs of agriculture and industry. The information within this document is for use by EA staff, particularly those involved with licence applications.

Key Words
Abstraction, agriculture, industrial, consumption, demand, efficiency, irrigation, licensing, water.

Research contractor
This document was produced under R&D Project W6-056 by:
SRK Consulting, Windsor Court, 1-3 Windsor Place, Cardiff CF10 3BX
Tel: 029 20348150 Fax: 029 20 348199 Project Manager: Dr R Bowell
in association with
Institute of Water & Environment, Cranfield University, Silsoe, Bedford, MK45 4DT
Tel: 01525 863336 Fax: 01525 863344

Environment Agency's Project Manager
The Environment Agency's Project Managers for R&D Project W6-056 were:
Bob Vaughan and Sarah Williams - Environment Agency, Wales

Further copies of this report are available from:
Environment Agency R&D Dissemination Centre, c/o
WRc, Frankland Road, Swindon, Wilts SN5 8YF

WRc

tel: 01793-865000 fax: 01793-514562 e-mail: publications@wrcplc.co.uk

CONTENTS

EXECUTIVE SUMMARY

PART A

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Background

The Water Resources Act (1991) and its preceding legislation provide the Environment Agency with the means to manage water resources through the licensing of abstractions. This research project provides information on the optimum water requirements of different agricultural and industrial practices, to complement existing data for public water supply. The data will enable Environment Agency licensing staff to audit abstraction licence applications more confidently. Additionally the data will assist the Environment Agency in promoting best practice water use amongst its customers and throughout the water industry.

Phase I of the study was completed in December 1998 (R&D Technical Report W157). Phase II was completed in March 2000 (R&D Technical Report W243). This Best Practice Manual, which combines the Agricultural and Industrial components, and the accompanying Technical Reports incorporate the findings of Phase III. The Agricultural and Industrial components have separate Technical Reports.

The Best Practice Manual reproduces the key tables and figures from the Technical Reports, and aims to provide a working document for day-to-day use by Agency licensing staff. The Best Practice Manual is split into two parts and has been re-formatted to enable future updates to be easily made. The Technical Reports provide a detailed account of the adopted methodology and background data, and act as reference documents.

The manual is seen as a working document and the new format will allow for updated and revised information to be readily incorporated as it becomes available.

Part A – Industrial

Water consumption figures were collected from a wide range of sources during Phases I and II that enabled look-up tables to be generated for a wide range of industrial processes. In Phase III, these tables have been updated and the range of industrial processes included has been expanded using data gathered from recently published literature and individual company assessments. In addition to water consumption data, the tables provide information on water use steps within each industrial process and the potential water saving initiatives that could be employed to optimise water use. The accompanying Technical Report also provides a methodology that enables an assessment of industrial effluent discharge.

Part B - Agriculture

The agronomic optima water requirements for a range of irrigation crops have been identified for varying agroclimatic conditions and soil types within England and Wales. The procedure has been validated against 14 benchmark farms, together with data from a further 11 benchmark farms involved in a complimentary Environment Agency funded project on trickle irrigation. The updated irrigation look up tables enable Environment Agency licensing staff to determine the dry year agronomic demand for the majority of crop types irrigated in England and Wales, based on seven agroclimatic zones and three soil classes.

Guidance is now included on crop suitability and typical crop rotations for irrigated outdoor cropping, for use in assessing whether the crop areas declared on abstraction licence applications are feasible and/or reasonable.

A methodology is now included to identify the typical ratio between agronomic and economic optima, by crop category. This will help to assess where the economic optimum is likely to be in relation to the agronomic optima, and to make suitable adjustments in calculating and setting licensed volumes.

Recommendations are now provided on how to set reasonable peak monthly, daily and hourly abstraction rates taking into account crop needs, equipment and water source.

Data (from Phase II) are presented on the irrigation needs for glasshouse production and on stock water requirements for cattle, pigs, sheep and poultry.

No allowance for assessing the impacts of climate change in setting abstraction licences is included. Some discussion of the issues and likely impacts is provided in the Technical Report.

PART A: INDUSTRIAL COMPONENT

THE OPTIMUM USE OF WATER FOR INDUSTRIAL PURPOSES

A1 INTRODUCTION AND HOW TO USE MANUAL

A1.1 Purpose of the Manual

Water is used by most industrial sites for a range of purposes, in addition to that required for domestic purposes. The Environment Agency initiated a research and development project to develop optimum water use values for different types of industry. This manual summarises the key findings to date of the Optimal Water Use Project.

The guideline values given in this report were derived from the following sources:

- results of a number of water surveys carried out as part of the project;
- results of a water use questionnaire sent out to selected industries;
- a literature review of documents identified by the Environment Agency and the consultants involved in the project.

Full details of the project and the derivation of the optimal water use values can be found in Environment Agency R&D Technical Report W6-056/TR.

A1.2 Purpose of the Manual

The main objective of the project was to develop values on optimal water use for a range of different industries. These values could be used in two ways. Firstly, they would be a useful tool for Environment Agency Abstraction Licensing Officers in determining new abstraction licence applications. Secondly, they can be used as a proactive tool to encourage industries to improve on water management.

Typical usage of water by an industrial site is likely to be greater than the theoretical minimum. The degree by which a particular site exceeds this minimum is usually determined by a number of variables (Section A1.3). The implementation of improved water management will be influenced by these variables and the cost of implementing water reduction measures as compared to the potential cost savings.

However, in relatively recent times many companies have created significant reductions in their consumption of water by applying a systematic waste minimisation approach, and reductions of 50% are not uncommon. Other companies have altered existing systems so that although water consumption has not decreased, other improvements in water management have been obtained, for example reduced discharge.

These companies have achieved optimal water use in cost-effective ways that have sometimes reset the benchmarks for their industry. As technology improves and further developments are made, the benchmarks may change again. Therefore, it is impossible to accurately predict the absolute optimal water usage and this manual will need to be regularly reviewed and updated as further information is obtained.

A1.3 Layout of the Manual

Table 1 lists the different types of industries covered by this manual and their industrial classification in terms of SIC and the Environment Agency National Abstraction Licence Database.

Table 1 Industrial classification and references

INDUSTRY TYPE	SIC CODE	NALD ABBREVIATION
BEVERAGES	203, 208, 514	FAD
BREWING	208	BRW
BRICK PRODUCTION	325	CON
CEMENT AND CONCRETE PRODUCTS	327	CON
CERAMICS AND POTTERY MANUFACTURE	326	MIN
CHEMICALS – SPECIALITY SECTOR	281 - 289	CHE
CHIPBOARD AND MEDIUM DENSITY FIBREBOARD MANUFACTURE (MDF)	249	CON
COAL MINING	122 - 124	EXT
TOILETRIES, COSMETICS AND CLEANING AGENTS MANUFACTURE	284	OTI
ELECTRONIC ASSEMBLIES	361 - 369	MCH
GLASS AND FIBREGLASS PRODUCTION	322, 329	CON
FISH PROCESSING	209	FAD
FOOD PROCESSING - DAIRY PRODUCE	202	FAD
FOOD PROCESSING - FLOUR AND CORN PRODUCTS	204, 205	FAD
FOOD PROCESSING - FRUITS AND VEGETABLES	203	FAD
FOOD PROCESSING – SUGAR REFINING	206	FAD
FOOD PROCESSING - MULTI PRODUCT CONFECTIONERY PLANT	206	FAD
FOOD PROCESSING - MISCELLANEOUS	20	FAD
FRESH RED MEAT PRODUCTION	201	SLA

INDUSTRY TYPE	SIC CODE	NALD ABBREVIATION
GOLF COURSES	799	GOF
HOSPITALS	806	HOS
LAUNDRY	721	LAU
LEAD ACID BATTERY PRODUCTION	362	MTL
LEATHER TANNING	311	TXT
LEISURE PARKS	799	HOL
LIGHT INDUSTRIAL ESTATE WATER CONSUMPTION	VARIOUS	OTI
METAL FINISHING	347	MTL
METAL PROCESSING	331 - 339	MTL
PLASTICS MANUFACTURE	282	CHE
POULTRY PROCESSING	251	SLA
POWER GENERATION	491	ELC
PUBLIC SERVICES	701, 806, 82	PAD
PULP AND PAPERMAKING	261, 262, 263	PAP
QUARRIES	142, 144	EXT
SEMICONDUCTOR WAFER FABRICATION	367	MCH
STEEL MANUFACTURE	331	MTL
TEXTILE MANUFACTURE	221 - 229	TXT
VEHICLE MANUFACTURE	371	TRA
WALLCOVERINGS	267	OTI
WASTE INCINERATION	496	REF

The Standard Industrial Classification (SIC) code or range of codes for each industry is given in brackets after the title of each section. For consistency, each industry section has been broken down into the same subsections. The subsection headings used and the information contained in each subsection are described below.

Type of industry and main products

This subsection briefly outlines the type of industry covered and what the main products are.

Processing steps

The key steps or activities that take place within the industry will be bulleted, where known. In some cases the source of information (see References below) may not provide much detail and the processing steps may not be given or may only be given for certain types of products. This sub-section can be significantly expanded as additional information becomes available.

Water use steps

Water use steps are listed as bullet points. As with the processing steps, detail on water uses may not be well documented and continued review will be necessary. In some cases, the supporting information provides a breakdown of the percentage of the total for each use. Where this information is available, the percentages have been given in brackets after each use.

Water may be lost from the system as part of the product, through leakage of the water supply infrastructure, seepage into the ground and through evaporation. Other losses may exist for certain industries. These losses are not specifically mentioned as water use steps, but will need to be considered when looking at particular sites.

Optimal water use

This subsection provides a lookup table detailing the findings to date of the project. In most cases the optimal water use has been presented as the Specific Water Consumption (SWC). This is generally a measure of how much water is consumed with respect to the product generated. Units may vary depending on the nature of the industry. For example, concrete will be measured in tonnes and metal plating and tanning in square metres. In some cases, the water consumption may be compared to raw product processed rather than final product. It is not always clear in the source references, so it has been assumed that values relate to final product unless specifically stated.

There is a clear distinction between water usage and water consumption, with the first often being significantly higher. For example, a paper mill can recycle significant quantities, thus reducing consumption. For the purposes of this document, water consumption has been used rather than water use. A total SWC for a site can be derived by taking the total volume of water from all sources (mains, borehole, stream etc) and dividing by the total production. However, in some cases, information is available on the SWC for certain products, processes or sources of supply. Where these breakdowns are available they have been included in the lookup table. Some references are not specific about how the number quoted was derived and this can make interpretation difficult.

In some sections, a 'best practice' value has been given. This value is indicative of SWC or SWD after a company has undergone a water management improvement programme. Best practice is considered to be a continual improvement management system that monitors water management and compares the results to the industry benchmark and to its own targets for improvement.

The quality of the data shown within the look up tables varies from well researched, published, industry benchmarks to limited data supplied directly from one company. In all cases, specific references have been provided as superscripted numbers that provide a cross-reference to the source of the data as given in the reference subsection (see below).

Variables affecting optimal water use

In developing optimal water use values it is critical to understand some of the factors that contribute to variability within the industry, or even in the same factory. For each industry type, some of the variables have been identified. The list is not exhaustive and other variables that may be impacting on water use include the following:

- the availability of water (particularly where subject to drought restrictions);
- the cost of water;
- commitment of top management;
- seasonality arising from rainfall, customer demand or other criteria;
- scale of production;
- production rate inefficiencies through bottlenecking or use utilities;
- process technology;
- frequency of product or brand changes;
- wash-down practices;
- location.

Possible optimisation measures

Many of the sources of information referenced contain case studies where optimisation measures have been implemented, leading to improved water management and cost savings. Where such measures have been identified, they are listed. To avoid repetition, measures that would apply in almost all industries are not included. Some of the general measures that apply to all sites are given below.

References

This sub-section details the sources of information used to determine all of the above results. Each reference is allocated a number and this number is used in the preceding subsections to identify individual sources of information. As the manual is reviewed and updated, additional references can be added.

Many of the publications referenced in this document offer excellent information on water reuse and reduction strategies for industry. The following publications are recommended for further reading.

- Cutting Water and Effluent Costs, IChemE, 1995
- Water Use and Reuse, IChemE, 1994
- Envirowise (previously Environmental Technology Best Practice Programme) publications. A full list of publications is available from the Envirowise Helpline, Tel No. 0800 585794 and www.envirowise.gov.uk

Water efficiency measure	Typical cost	Typical payback period	Example of initiatives
Good Housekeeping	No – Low cost	Immediate	• Appropriate storage and containment of potentially contaminating solids and/or liquids to minimise risk of spills and the need for washdown • A system to identify accidental discharges or spills and to quickly remedy problems should they arise • Routine inspection of water transport and storage systems to identify and repair leaks • Flow rate controls on equipment that requires regular or continuous supplies of water • Optimal wash down facilities with equipment fitted with automatic shutoff valves and high pressure or low volume controls, as necessary • Regular planned maintenance of systems and calibration of monitoring equipment
Management	Low – minimal cost	Immediate	• A detailed understanding of the water system on site • Availability of a water mass balance or possibly a water and salt mass balance • A monitoring programme, that considers both quality and quantity and is not restricted to the inlet and outlet to the site (in other words that monitoring within the process also occurs) • A system to set targets for water consumption, use and discharge (possibly as part of an environmental management system such as ISO 14001) • Regular assessment of monitoring data to determine progress against targets as well as to assess compliance with legal limits • A review of process scheduling to ensure optimal water use and production • Regular staff training and awareness campaigns focussed on water issues
Reuse	Low – medium cost	Less than 1 year	• Reuse of washdown water • Rain water harvesting
Recycle	Medium cost	1- 2 years	• Recycle water after treatment
Redesign	High cost	> 3 years	• Closed loop systems • Effluent treatment

A1.4 How to Use the Manual

An Environment Agency officer or a specific company can use this manual to compare water use with what is considered optimal. In this way, a company can be assessed as to whether it is operating at acceptable water use efficiency enabling new licences to be assessed on the basis of 'reasonable need'. The manual will also provide background guidance on the types of processes taking place within the industry to provide a better understanding of why and how water is used.

The cautions to be taken when applying the values and some examples of how to use the manual are given below.

A1.4.1 Cautions

For the assessment of 'reasonable need' to succeed, it is critical that the approach undertaken to derive the benchmark values used for comparison is first fully appreciated. The advance of process technology influences current industrial best practice, and therefore water use. As a result, the continual re-appraisal and update of the data contained in the manual is needed.

The depth of detail of the information sources and the number of different sources varies between industrial sectors. Where only one or two sources of information are used, caution should be taken applying the benchmark and further research and monitoring should be done to determine their validity.

As discussed in Section 1.2 above, there are a number of variables that affect optimal water use within an industry sector. When determining an application or making comparisons with other industries it is important to consider these variables. Discussions with the site representatives may help to explain why the optimal water use for a specific site is so different from the value given in the manual.

A1.4.2 Examples of how to use the look up tables

Two examples of how to use the industry look up tables are given below.

a) Soft drink manufacturer

A proposed site intends to produce soft drinks and requires water for the factory at 700 000 m^3/year.

Information Required:

Question	Answer
Which type of soft drinks are to be produced?	Carbonates
What is the yearly manufacturing capacity of the site, in terms of volume of drink produced?	500 000 m^3
What are the variables affecting the site?	Relatively small process with a number of different products being generated

Calculations:

From Section 2 of the manual, the 'best practice' figure for water consumption is 1 m^3 /m^3 and the average is 2.3 m^3 /m^3. Therefore, 1 multiplied by 500 000 gives a 'best practice' value for the proposed site of 500,000 m^3/year, with the average being 2.3 multiplied by 500 000 to give 1 150 000 m^3 /year.

Conclusions:

The site's request for 700 000 m^3/year of water falls between the average and the best practice values of 500 000 and 1 150 000 m^3 /year. As the site is relatively small and generates a number of different products, the amount of water needed is likely to be higher with more frequent vessel washing required as the product changes are made. The difference between what has been applied for and the best practice is therefore reasonable.

b) Red meat abattoir

An abattoir has proposed constructing a new facility to process cattle and requests an additional 600 000 m^3/year of water.

Information Required:

Question	Answer
What is the product?	Red meat
What is increase in production capacity?	1000 cattle units per day, 5 days per week
What are the variables?	Seasonal variability, boning operations, by-product processing, on-site vehicle washing

Calculations:

From Section A20 the 'best practice' for water consumption from reference 1 is 1.1 m^3/cattle unit. Reference 2 gives a value of up to 1000 litres/cattle unit or 1 m^3/cattle unit.

Five days a week coverts to 280 days a year and 280,000 cattle per year. At 600 000 m^3/year, the site is proposing to use approximately 2 m^3/cattle unit. This is almost double the suggested consumption so the variables need to be considered. With boning, by-product processing and vehicle washing the 'best practice' SWC may be re-assessed at a slightly higher rate (for example 1.4 m^3/cattle unit), to allow for additional water use. This gives a total water use, under strictly managed conditions, of about 390 000 m^3/year.

Conclusions:

The reason for the high water requirement must therefore be further considered in association with the company and may require a detailed review of the proposed new process. It is expected that a medium sized abattoir processing 1000 cattle units per day will experience water use inefficiencies with variable daily production levels, as well as start-up inefficiencies.

Under the circumstances an initial allocation of 500 000 m^3/a would be reasonable, with an expectation that water management measures, determined by the Environment Agency in conjunction with the company, would be implemented to reduce the annual consumption to 400 000 m^3/a within an agreed time period.

A2 BEVERAGES (SIC codes : 203, 208, 514)

A2.1 Type of Industry and Main Products

The beverage industry in the UK will include (but is not limited to):

- bottled water (514);
- fruit juices (203);
- carbonated soft drinks (208);
- juice concentrates (208);
- wine (208).

A2.2 Processing Steps [1, 2, 3]

Type	Process steps
Bottled Water	• Purification, if necessary • Filling of containers
Fruit Juice	• Blending of juice concentrates, as described below, with water • Filling of containers
Carbonated Soft Drinks	• Formulation of syrups • Blending of syrups with water • Carbonation • Filling of bottles or cans
Juice Concentrate	• Fruit are brushed to remove dirt and washed • The outer layer may be removed in a scarifier • The juice is extracted • Pulp and peel are pressed and disposed of • Oils are recovered in an essential oils line • The juice is heated, de-pulped by centrifuge and then concentrated in an evaporator • Filling of containers
Wine	• Destalking and crushing • Separation • Fermentation • Filtration • Blending • Stabilisation • Filtration • Bottling or packaging

A2.3 Water Use Steps[1]

Type	Water use steps
Bottled water	• Rinsing (2%) • In product (30%) • Equipment preparation (67%) • Domestic use (1%)
Fruit Juice	• In product (27%) • Equipment preparation (51%) • Floor washing (3%) • Boiler water (11%) • Pasteurizers (4%) • Cooling water (4%)
Carbonated soft drinks	• Rinsing of containers (4%) • In product (78%) • Equipment preparation (3%) • Floor washing (1%) • Boiler water (4%) • Pasteurizers (6%) • Domestic use (3%) • Other uses (1%)
Juice Concentrate	• None currently identified
Wine	• In product • Cooling • Equipment preparation • Vessel washing

A2.4 Optimal Water Use

Values for the SWC are in m^3 of supply water/m^3 of product, unless otherwise stated.

Type of beverage	Units of SWC	SWC (Specific Water Consumption)	
		Average / Range	Best practice
Bottled Water	m^3/m^3	1.6 [1]	-
Fruit Juice	m^3/m^3	3.5 [1] – 14.5 [2 3]	2 [1] – 3.0* [2 3]
Carbonated Soft Drinks	m^3/m^3	2.3 [1] – 4.0 [2 3]	1 [1] – 3 [2 3]
Carbonated Soft Drinks	m^3/m^3	2.5[6]	-
Juice Concentrate	m^3/t oranges	0.55 [2 3]	-
Wine	m^3/t grapes	0.7 – 3.8** [5]	-

* Assumes re-circulation of cooling water

** Water consumption is compared to tonnage or raw product rather than volume of final product.

A2.5 Variables Affecting Optimal Water Use

- Type of beverage being produced (see ranges given above);
- Higher production may have higher (or lower) SWC;

A2.6 Possible Optimisation Measures

- Cleaning-in-place (CIP) (installed at 44% of soft drinks sites [1]);
- Control of flow rates (implemented at 30% of sites [1]);
- Air cleaning of packaging;
- Recirculation of pasteurizer waste water;
- Recirculation of vessel wash water (reuse of final CIP rinse as first rinse in next cycle).

A2.7 References

1. Environmental Technology Best Practice Programme, (1998), Water Use in the Soft Drinks Industry, Guide EG126.

2. Rinse Water Recovery, Beverage World International, March/April 1996. p42-44.

3. Food Factories – Process, Equipment, Costs. Alfred Bartholomai.VCH. Jan-88.

4. IK Mathieson, JW Knox, EK Weatherhead, J. Morris, DO Jones, AJ Yates, N Williams. Optimum Use of Water for Industry and Agriculture. Phase II Technical Report W243.

5. Steffen, Robertson & Kirsten Inc, Consulting Engineers, (1993), Water and Waste-Water Management in the Wine Industry (Natsurv 14), prepared for the Water Research Commission, WRC Project No 145, TT 51/90.

6. Phase 2 – Company B Audit.

A3 BREWING (SIC code : 208)

A3.1 Type of Industry and Main Products

Breweries generate an alcoholic and often carbonated beverage from a number of ingredients including barley, maize and sorghum. The main product is beer, but powder malt may also be generated.

A3.2 Processing Steps

- Malting – steeping the grain in water, germinating the grain, drying and airing (this is often done at a different site to the brewery);
- Milling and mashing – the basic raw materials are mixed in a mash tun to produce sweet wort;
- Boiling – the sweet wort is mixed with hops and boiled in a copper kettle and clarified;
- Fermentation – yeast is added;
- Storage and maturation;
- Fining and filtration – finings are added to aid flocculation and the settled material is filtered off;
- Packaging and pasteurisation– beer is put into kegs, bottles or cans.

A3.3 Water Use Steps

- Product generation;
- Wash down of vessels and pipelines;
- Product chase through pipelines;
- Cooling and steam generation;
- Filter plate or candle wash;
- Bottle or cask washing;
- Vehicle washing;
- Domestic.

A3.4 Optimal Water Use

Reference	Units	SWC (Specific Water Consumption) Average / Range	SWC (Specific Water Consumption) Best practice
Breweries	m^3/m^3	5 – 15 [1,2]	5 [1,2]
Small breweries (up to 4000m^3/week)	m^3/m^3	8.5[3]	4[3]
Large breweries (4000 - 10000m^3/week)	m^3/m^3	5.8[3]	4[3]
Malt breweries	m^3/m^3	5.5 – 8.8[*4]	5[*4]
Brew house (milling through to fermentation)	m^3/m^3	1.4 – 3[4]	-
Cellars (storage and filtration)	m^3/m^3	1 – 1.5[4]	-
Packaging and pasteurisation	m^3/m^3	0.7 – 1.9[4]	-
Utilities (domestic and boilers)	m^3/m^3	0.7 – 1.9[4]	-
Sorghum breweries	m^3/m^3	3.4[5]	2[5]

* The reference gives a target specific pollution load of kg Chemical Oxygen Demand per m^3 of beer as 7.5 kg COD/m^3

A3.5 Variables Affecting Optimal Water Use

- Age of the brewery with older breweries often being more water inefficient;
- Size of brewery with smaller breweries having higher SWC that larger breweries;
- Variety of products – if a wider range of products is generated the SWC is likely to be higher;
- Use of wet or dry mills.

A3.6 Possible Optimisation Measures

Reference 3 provides detailed recommendations on how water management at a brewery can be optimised, including:

- Mapping of water supply network;
- Leak detection systems;
- Reduced boiling time of wort;
- Heat exchangers automation and optimisation;
- Cask and bottle washing optimisation (reuse of final wash for earlier stages);
- Cleaning in place optimisation;
- Pasteurizer water recycle [4].

A3.7 References

1. Private Communication with Allied Domecq.

2. IK Mathieson, JW Knox, EK Weatherhead, J. Morris, DO Jones, AJ Yates, N Williams. Optimum Use of Water for Industry and Agriculture. Phase II Technical Report W243.

3. Environmental Technology Best Practice Programme, (1998), Reducing Water and Effluent Costs in Breweries, Guide GG135 (also Final Results GC 21 and GC41).

4. Binnie & Partners, Consulting Engineers, (1986), Water and Waste-Water Management in the Malt Brewing Industry, (Natsurv 1), prepared for the Water Research Commission, WRC Project No 145, TT 29/87.

5. Steffen, Robertson & Kirsten Inc, Consulting Engineers, (1989), Water and Waste-Water Management in the Sorghum Malt and Beer Industries (Natsurv 5), prepared for the Water Research Commission, WRC Project No 145, TT 39/89.

A4 BRICK PRODUCTION (SIC code : 325)

A4.1 Type of Industry and Main Products

Bricks can come in a variety of forms depending on the type of material used in production and the finishing process.

A4.2 Processing Steps

- Grinding natural clays;
- Mixing into a marl by the addition of water - the exact composition of the marl determines the type of brick;
- Moulding;
- Firing;
- Finishing.

A4.3 Water Use Steps

- Mixing - a typical range is 15% to 30% w/w (weight / weight) for the water content of the marl;
- Domestic.

A4.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption) Range
Bricks	m^3/t bricks	15 - 30[1]

A4.5 Variables Affecting Optimal Water Use

- Type of brick;
- Type of finishing applied – grinding of bricks may require additional water.

A4.6 Possible Optimisation Measures

Monitoring of actual usage versus production to ensure water use is as close to the theoretical minimum (marl water content specification) as possible.

A4.7 References

1. Private communication from Ibstock.

A5 CEMENT AND CONCRETE PRODUCTS (SIC code : 327)

A5.1 Type of Industry and Main Products

Concrete is formulated by blending suitable proportions of cement, sand, aggregate and water. The concrete can then be mixed with other materials such as glass, slag and additional aggregate to produce concrete blocks or slabs.

A5.2 Processing Steps

Cement is manufactured using both wet and dry manufacturing processes:

- Wet process
  - Raw materials including limestone, iron oxide, sandstone and ash are mixed with water and fed to ball mills to form a slurry;
  - The slurry is fed to a kiln where it is dried, calcined and then further heated to form clinker;
  - The kilns are fired with pulverised coal or coke and/or oil
- Dry process
  - The primary materials are blended and fed directly to the roller mill;
  - The blended materials are sent to a direct fired kiln to be transformed into clinker;
  - The resulting clinker from either process is mixed with small quantities of gypsum and then ground in ball mills to form cement;

Production of concrete blocks or slabs can involve the following:

- Mixing of concrete and other material;
- Pressing and moulding;
- Curing in kilns or under ambient conditions;
- Finishing (such as grinding or shot blasting).

A5.3 Water Use Steps

- Cement production
  - Product water;
  - Cooling water;
  - Wash water (mixing vessels, floors).

- Block or slab production
  - Product water;
  - Cooling water;
  - Wash water (product, floors, mixing vessels);
  - Grinding water.
- Dust control
- Wheel washing
- Domestic use

A5.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption)
Cement Manufacture	kg/kg clinker kg/kg raw materials	Cooling Water- 0.41[1, 2, 3] Product Water - 0.325[1, 2, 3]
Concrete Products	m^3/t product	1[1, 2, 3]
Concrete Blocks	m^3/200 blocks	1[1, 2, 3]
Reinforced Concrete	m^3/m^3 dry concrete	0.63[1, 2, 3]
Concrete slab production[4]	m^3/t	0.04 – 0.4[4]

A5.5 Variables Affecting Optimal Water Use

- Type of product being produced with some products requiring more water in the manufacture;
- The amount of water expressed by different types of press during block production can vary dramatically;
- Finishing off required (grinding and polishing requires water while shot blasting does not);
- Number and duration of production shifts.

A5.6 Possible Optimisation Measures

- Recirculation of wash water and recovered water from the production process after settlement or filtration;
- Containment of storm water runoff or roof drainage for use in the process.

A5.7 References

1. Castle Cement, EPA Authorisation Application. AI2813.

2. A. C. Twort, R. C. Hoather, F. M. Law. Water Supply. Edward Arnold(Publishers) Ltd.

3. IK Mathieson, JW Knox, EK Weatherhead, J. Morris, DO Jones, AJ Yates, N Williams. Optimum Use of Water for Industry and Agriculture. Phase II Technical Report W243.

4. Phase 3 – Company B survey.

A6 CERAMICS AND POTTERY MANUFACTURE (SIC code : 326)

A6.1 Type of Industry and Main Products

Clay and other materials are used to produce earthenware, pottery or china products.

A6.2 Processing Steps

- Porcelain [1, 2]

  - Raw materials are mixed with water and then passed over a magnetic separator, screened and stored.

  - Most of the water is removed using a filter press. All the entrained air is removed in the pug mill, assisted by vacuum and slicing knives.

  - The prepared clay is formed into blanks in a hydraulic press or by hot-pressing in a suitable mould.

  - The blanks are preliminarily dried, trimmed, finally completely dried and then coated with the required glazing material.

  - The vitrification of the body and glaze is carried out in tunnel kilns.

A6.3 Water Use Steps

- Equipment cooling, e.g. kilns, vacuum pumps and compressors;
- Product finishing;
- Glaze preparation;
- Equipment washing;
- Domestic.

A6.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption) Range	SWC (Specific Water Consumption) Average*
Ceramic white ware	m^3/t	15 –20[1, 2]	1.6[1, 2]
Sanitary ware	m^3/t	6 - 15[1, 2]	2.36[1, 2]
Stone ware	m^3/t	2 -10[1, 2]	2[1, 2]
Glazed tile	m^3/m^2	0.5 - 8[1, 2]	0.04[1, 2]
Fine porcelain	m^3/t	5.5 - 14.0[1, 2]	

* Average values take into account the closed cooling water cycle and the fact that demand for water used for auxiliary needs is met by the water reclaimed from the purified industrial wastes.

A6.5 Variables Affecting Optimal Water Use

- Type of product and the finishing off required.

A6.6 Possible Optimisation Measures

- Re-circulating cooling water;
- Reuse of reclaimed water from industrial wastes;
- Reuse of filter press effluent;
- Fully closed water cycle

A6.7 References

1. Private Communication with Mike Dutton, Spode Potteries.
2. Application of water cycles in the ceramic industry. Krolikowski, A. Environment Protection Engineering, 1979. 5. No.3 243-253.

A7 CHEMICALS – SPECIALITY SECTOR (SIC codes : 281 - 289)

A7.1 Type of Industry and Main Products

This is a diverse industry producing items ranging from simple acids and alkalis to complex pharmaceuticals.

A7.2 Processing Steps

The speciality chemicals sector is too varied to enter into a discussion of processing steps within this document.

A7.3 Water Use Steps

- Cooling;
- Steam production;
- Raw material to product;
- Reagent make-up;
- Product washing;
- Plant and vessel washing;
- Effluent dilution;
- Air pollution control;
- Domestic uses.

A7.4 Optimal Water Use

SWC for some types of specialist chemicals are given below

Product Type		Units	SWC (Specific Water Consumption) Typical/Range
Resins, adhesives, detergents, disinfectants, photographic solutions		m^3/t	<1.0[1, 2]
Sulphonic Acids, detergents, rubbers, resins, pigments, salts		m^3/t	1 - 2[1, 2]
Silicones, Polyacrylics, water treatment chemicals, chelating agents, surfactants, amine products, synthetic organic polymers, sulphonic acids, esters, imides, anhydrides, quaternaries, alkyl ethers, salts, soaps		m^3/t	2 - 5[1, 2]
Brightening agents, dyes, biocides, herbicides, insecticides, phosphates, pharmaceutical, intermediates, polyacrylics, amine products, esters, soaps		m^3/t	5 - 10[1, 2]
Esters biocides, fungicide intermediates, mercaptan gas, odorants, carbonates, thioglycollates, thioureas		m^3/t	10 - 50[1, 2]
Pharmaceutical intermediates, acrylates, amine products		m^3/t	50 - 100[1, 2]
Liquid Crystals, buffer solutions, pigments, chlorine and bromine products [1, 2]		m^3/t	>100[1, 2]
Chloro-alkali industry	Amalgam, diaphragm and membrane processes	m^3/t	1 – 2.8[3]
	Brine re-circulation process	m^3/t	2 – 2.5[3]
	Waste brine process	m^3/t	10[3]

A7.5 Variables Affecting Optimal Water Use

The chemical industry is considered to be a case where benchmarking is often impracticable because there are so many variables. The most significant of these will be the type of process being used. Each site, and in fact each process, will need to be considered on an individual basis.

A7.6 Possible Optimisation Measures

Opportunities to reduce water use are similar for associated industries, such as Plastics manufacture (see report index).

Measures for water use reductions may be split into three distinct areas; good housekeeping, water management and reuse, recycle and redesign. The table lists those measures that have been successfully implemented and the corresponding reductions in water use.

Type of measure	Measures Introduced [1, 2]	Reduction in water use (%)
Good housekeeping measures	Improved pipework to reduce leaks	10
	Good housekeeping, taps on hoses, etc	8
	Better housekeeping to avoid cleaning	3
	Storm water prevented from entering effluent system	7
	Leak detection and reduction	30
	Flow restrictors on vessel cooling lines	5
Water management techniques	Metering individual product areas and setting reduction targets	30
	A management system including production scheduling, improvements in plant wash-downs and use of trigger hoses	50
Reuse, recycle and redesign	Cooling water re-use	21
	Installation of cooling tower	50
	Improved cooling tower efficiency	50
	Re-use of wash water for batch dilution	25
	Installation of pressure washers for cleaning blending tanks	5
	Recirculation of water in liquid ring vacuum pumps	50
	Replacement of water seal vacuum pumps with dry versions	24
	Installation of air chillers	5
	Reduction in process water wastage	5
	Water minimisation project	20
	Modernisation of manufacturing facilities	38
	Improvements in process efficiency	5

A7.7 References

1. Water Use in the Manufacture of Speciality Chemicals. Guide EG105. ETBPP.

2. IK Mathieson, JW Knox, EK Weatherhead, J. Morris, DO Jones, AJ Yates, N Williams. Optimum Use of Water for Industry and Agriculture. Phase II Technical Report W243.

3. European Integrated Pollution Prevention and Control Bureau, (2000), Reference Document on Best Available Techniques for the Chloro-Alkali Manufacturing Industry, pp 34 - 36, October 2000.

A8 CHIPBOARD AND MEDIUM DENSITY FIBREBOARD MANUFACTURE (MDF) (SIC code : 249)

A8.1 Type of Industry and Main Products

Logs and waste wood are shredded and mixed with resin (urea, formaldehyde) and 'pressed' into board. The precise size of the wood particles and the amount of resin used, determine the type of board.

MDF can be coated with melamine to give a finished board for the manufacture of furniture, kitchen units etc.

A8.2 Processing Steps

The significant process stages are:

- Formaldehyde production (IPC regulated);
- Chip drying;
- Board pressing;
- Board sawing;
- Melamine coating.

A8.3 Water Use Steps

- Formaldehyde plant;
- Steam system;
- Cooling;
- Wash down;
- Resin manufacture;
- Abatement equipment (dust control).

A8.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption) Range	SWC (Specific Water Consumption) Best Practice
Chipboard	m^3/t board	0.23-7.2*[1-4]	0.23[1-4]
MDF	m^3/t board	0.31-7.2[1-4]	0.31[1-4]

* The higher figure of 7.2m^3/tonne is for the manufacturing plant with once-through use or minimal reuse of water. The lower value of 0.23 m^3/tonne is for a plant intentionally striving to minimise water usage, and at present represents UK 'best available' value for water consumption.

A8.5 Variables Affecting Optimal Water Use

- None currently identified

A8.6 Possible Optimisation Measures

- Significant reuse of water is inherent in the process and the potential for further reductions depends upon process development of the existing systems.

- The best practical environmental option for reduction of water usage can be a balance between less water but greater energy consumption.

A8.7 References

1. Dee Catchment Waste Minimisation Report, October 1997, The Environment Agency (Telephone 01248 670770).

2. Private Communication From Kronospan.

3. Wenita Forest Products, Resource Consent Application

   http://www.es.co.nz/information/planc8.html.

4. IK Mathieson, JW Knox, EK Weatherhead, J. Morris, DO Jones, AJ Yates, N Williams. Optimum Use of Water for Industry and Agriculture. Phase II Technical Report W243.

A9 COAL MINING (SIC code : 122 - 124)

A9.1 Type of Industry and Main Products

The primary purpose of coal mining is to produce bituminous coal, anthracite, and lignite. A variety of processing options exist for coal, for example briquettes. There are also a number of ways the coal may be packaged depending on the intended market.

A9.2 Processing Steps

The nature of the mine and mining techniques will depend on a number of factors, but the depth and extent of the coal seam primarily determines the processing technique selected. Processing options include:

- extraction of material from open pits or underground operations;
- cleaning (washing) and preparation (classification) of material;
- processing to form briquettes;
- packaging.

A9.3 Water Use Steps

Depending upon the geographical location, the depth of mine and other features, it may be necessary to abstract water or dewater operations to prevent flooding. Therefore, a mine may be a net 'producer' of water for discharge to a suitable location. Some of the major water uses include:

- coal washing;
- coal classification;
- dust suppression;
- vehicle washing;
- domestic.

A9.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption) Average / Range	SWC (Specific Water Consumption) Best practice
Underground mining	m^3/t	0.33 - 0.45[1]	-
Open cast	m^3/t	0.11[1]	-

A9.5 Variables Affecting Optimal Water Use

- Type of mine;
- Quality of the deposits;
- Product quality required;
- Local geology and hydrogeology.

A9.6 Possible Optimisation Measures

- Understanding of water system (mapped network and detailed water balance);
- Separation of clean and dirty water streams;
- Treatment (such as settling or filtration) of wash water to enable reuse.

A9.7 References

1. IK Mathieson, JW Knox, EK Weatherhead, J. Morris, DO Jones, AJ Yates, N Williams. Optimum Use of Water for Industry and Agriculture. Phase II Technical Report W243.

A10 COSMETICS, TOILETRIES AND CLEANING AGENTS MANUFACTURE (SIC code : 284)

A10.1 Type of Industry and Main Products

As with the chemical industry, a broad range of products can be generated from many different ingredients. Products include: soap, cosmetics, detergents and polish.

A10.2 Processing Steps

Standard steps in the manufacture of cosmetics and toiletries are:

- mixing of ingredients, either in cold or hot form;
- filling;
- packaging manufacture (sites may import packaging or containers from other sources).

A10.3 Water Use Steps

- Total water use can be broken down as follows:
- Bulk manufacturing and plastics (61 %);
- Production (filling) (14 %);
- Warehouse – (12 %);
- Domestic – (13 %).

A10.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption)
Typical consumption	m^3/t	4.18[1]

A10.5 Variables Affecting Optimal Water Use

- Production of packaging on or off site;
- Manufacturing technique;
- Type of packaging.

A10.6 Possible Optimisation Measures

- Efficient use of water for cleaning;
- Steam condensate recovery.

A10.7 References

1. Think Act Change, Water and Wastes. The Body Shop. http://www.think-act-change.com/environment/act/act9.html.

A11 ELECTRONIC ASSEMBLIES (SIC code : 361 - 369)

A11.1 Type of Industry and Main Products

The industry produces a wide range of products including computers, peripherals, photocopiers, communications equipment, information storage, measurement instruments, and laser devices.

A11.2 Processing Steps

- Individual unit processes are product specific.

A11.3 Water Use Steps

- Wash water
- Domestic

A11.4 Optimal Water Use

Water consumption (m^3/Std hr/m^2) is normalised against standard hours worked (Std hr) and/or production floorspace (m^2). Data is product specific. The table below highlights the types of products with low, medium and high SWC [1].

Type	Units	SWC (Specific Water Consumption)
Low Consumption		
• Photocopiers • Domestic appliances • Computers • Data storage devices	m^3/Std hr/m^2	0.02[1]
Medium consumption		
• Digital test equipment • Instruments	m^3/Std hr/m^2	0.02[1] and < 30[1]
High consumption		
• Clean room operations for example manufacturing of laser devices	m^3/Std hr/m^2	30+[1]

A11.5 Variables Affecting Optimal Water Use

- None currently identified.

A11.6 Possible Optimisation Measures

- None currently identified.

A11.7 References

1. Rank Xerox. Environmental Statement. Mitcheldean Manufacturing Operations.

2. Private Communication with Zoe Jackson, Hewlett Packard, Health, Safety and Environment Department.

A12 FIBREGLASS AND GLASS PRODUCTION (SIC codes : 322 AND 329)

A12.1 Type of Industry and Main Products

Glass is made from silica and is used extensively for both the domestic and industrial market. The method of production can give it a variety of properties. Glass fibre is usually wound before forming into the final product that can be insulation or chopped strand mats. These products are manufactured to a wide range of specifications.

A12.2 Processing Steps

- Fibre glass
  - Glass is melted in a furnace.
  - The glass is then extruded into fibres.
  - The fibres are then coated with a range of binding agents.

Processes for glass will vary depending on the end product desired.

A12.3 Water Use Steps

- Plant wash down;
- Cooling;
- Pollution abatement (dust control);
- Production of binding agents (fibreglass);
- Domestic.

A12.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption) Best practice	SWC (Specific Water Consumption) Range
Fibreglass	m^3/t	2.5[1, 2, 3]	10 - 20[1, 2, 3]
Soda-lime glass	m^3/t	4 - 9[4]	-
Lead crystal glass	m^3/t glass melted	3 - 70[4]	-
Glass wool	-	3 – 10*[4]	-
Stone wool	-	0.8 - 10[4]	-

* The water consumption is based on raw product rather than final product.

A12.5 Variables Affecting Optimal Water Use

- The binding agents used;
- The final form of the product.

A12.6 Possible Optimisation Measures

- Efficient vessel clean down systems, e.g. use of spray balls;
- Longer campaigns for less frequent cleandown;
- Closed loop cooling circuits;
- Water consumption monitoring and management system

A12.7 References

1. Private Communication From Owens Corning.
2. Dee Catchment Waste Minimisation Report, October 1997, The Environment Agency (Telephone 01248 670770).
3. IK Mathieson, JW Knox, EK Weatherhead, J. Morris, DO Jones, AJ Yates, N Williams. Optimum Use of Water for Industry and Agriculture. Phase II Technical Report W243.
4. European Integrated Pollution Prevention and Control Bureau, (2000), Reference Document on Best Available Techniques for Glass Manufacturing Industry, October 2000.
5. Phase 2 – Company Water Audit.

A13 FISH PROCESSING (SIC code : 209)

A13.1 Type of Industry and Main Products

Fish processing will convert a range of raw materials in various forms (fresh or frozen) into a number of end products, including:

- whole fish for market (fresh and frozen);
- filleted and packaged fish for market;
- canned fish;
- fish meal.

A13.2 Processing Steps

The main processes involved in some types of fish processing are given below.

Type of fish	Processing steps
Tuna	Receiving, Thawing, Butchering, Pre-cook, Cleaning, Canning, Retorting, Labelling, Casing.
Shrimp	Receiving, Rock separation, Peeling, Cleaning, Inspection, Deveine, Grader, Packaging.
Other sea fish	• Live fish are received and dumped into holding tanks • Fish are stunned with low voltage electric shock and then conveyed to either ***dressing*** or ***filleting*** line. • ***Dressing*** consists of removing dorsal fin, beheading, evisceration, skinning, chilling, sorting, and freezing. • ***Filleting*** consists of beheading, slitting, skinning, trimming, refrigeration and or breading/coating.

No information was available on fresh water fish processing.

A13.3 Water Use Steps

- Holding/Thawing tanks (up to 30-40%);
- Butchering;
- Water Chilling;
- Water glazing;
- Cleaning;
- Cooking;
- Spray Cooling;

- Domestic.

A13.4 Optimal Water Use

Type of fish or process	Units	SWC (Specific Water Consumption) Average / Range	SWC (Specific Water Consumption) Best Practice
Tuna	m^3/t	10 - 20 [1,2]	<10 [1,2]
Other fish	m^3/t	17 [1,2]	3.72 [1,2]
Filleting	m^3/t	9 - 25 [1,2]	9 [1,2]
Herring	m^3/t	4 - 8 [1,2]	4 [1,2]
Shrimp	m^3/t	30 - 60 [1,2]	30 [1,2]
Fish meal	m^3/t	1-3 [1,2]	1 [1,2]
General	m^3/t	-	< 4 [3]
Canning	m^3/t	2 – 3 [4] (sea water only)	-
Fish-meal plant	m^3/t	0.84 [4] (fresh water only)	-
White fish	m^3/t	3 – 8 [4] (fresh water only)	-
Rock lobster or crayfish	m^3/t	24 [4] (sea water only)	-

A13.5 Variables Affecting Optimal Water Use

- Type of fish being processed;
- State of fish on arrival (fresh or frozen);
- Use of wet or dry off-loading;
- Final product e.g. fresh, cooked, frozen or canned.

A13.6 Possible Optimisation Measures

- Converting wet off-loading to dry off-loading;
- Elimination of the use of all flumes for in-plant transport of product;
- Air cooling to replace water cooling;
- Reduction of water use in the butchering area and in frequency of cleaning by using more efficient systems such as high pressure spring loaded hose nozzles, automatic cleaning brushes and biodegradable detergents;
- Pressure controls in water distribution lines to reduce use especially during clean-up operations;
- More efficient defrosting units;
- Dry filleting process.

A13.7 References

1. Pollution Control through Water Conservation and Wastewater Reuse in the Fish Processing Industry. Chandran Nair, Siamtec International Ltd. Wat Sci Tech Vol22 No9 p113-121. 1990.

2. Cleaner Production -Water Usage. Nord Food, Icelandic Fish Laboratories.

3. Environmental Technology Best Practice Programme, (1999), Cutting Water and Effluent Costs in Fish Processing, Final Results GC202.

4. Binnie & Partners (1986), Guide to Water and Waste-Water Management in the Pelagic Fishing Industry, prepared for the Water Research Commission, WRC Project No 97, TT 28/87.

A14 FOOD PROCESSING - DAIRY PRODUCE (SIC code : 202)

A14.1 Type of Industry and Main Products

The dairy industry is considered a complex industry due to the range of products that can be generated. Examples of products produced include milk, cheese, yoghurt, cream, ice cream, milk powder, butter and whey cream or powder (by-product).

A14.2 Processing Steps

Processing steps for some dairy products are detailed below.

Type of product	Processing steps
Milk	• Milk is transferred from road tankers through the milk meter, deaerator and plate cooler to the raw milk silos • The milk is cooled to 4°C • Standardisation, skimming and homogenisation occur next • Milk is pasteurised at 75°C for 20 seconds and then cooled again to 3°C • Deaeration occurs before it is bottled
Powdered Milk	• The milk is pasteurised, evaporated, spray dried and the resulting particles are collected in a bag filter
Blue cheese	• Milk and cream are blended and continuously injected with a mixture of selected bacteria to increase the acidity of the milk • The mix is pumped into pre-ripening tanks • Blue mould culture and rennet, which is needed to coagulate the milk into junket, are added, and the whole is agitated • The resulting curd is cut, fed into plastic blockforms and the whey is drained off • The cheese is cooled, immersed in brine, then lifted and sprayed with a mould • Ripening takes 12 to 14 days - the cheese is pierced with holes regularly to allow the mould to grow • Whey, from the cheese making process, may be further processed to extract fat (whey cream) or to generate whey powder
Cheese	• Milk and cream are blended and rennet which is needed to coagulate the milk into junket, are added, and the whole is agitated • The resulting curd is cut, fed into plastic block forms and the whey is drained off • The curd is milled and salt is added to both preserve and bring out the flavour of the cheese • The curd is then packed, pressed into moulds and left to mature • Whey, from the cheese making process, may be further processed to extract fat (whey cream) or dried to generate whey powder
Ice cream	• Powdered raw milk is taken to a weighing bowl by means of a screw conveyor • The ingredients (powdered milk, liquid milk, fats (butter), water) are mixed, homogenised and then pasteurised • The mix is ripened overnight • Flavours and colours are added • Mix is drawn from the ageing tanks or the flavouring tanks to ice cream freezers where it is partially frozen and mixed with air, before packaging.

Type of product	Processing steps
Yoghurt	• Skim-milk powder, water and sugar are blended into pasteurised skim-milk and stored in mixing tanks • Cream is added and agitated at high speed • The yoghurt milk is pasteurised and homogenised simultaneously • The product is inoculated and then packaged.
Butter	• Uses cream as a raw product • The cream is mixed with salt and churned • Butter is packaged • Butter milk is either powdered, packaged separately or treated as a waste

A14.3 Water Use Steps

- Cleaning-in-place;
- Wash water (floors etc);
- Steam heating;
- Cooling;
- Product (ice cream and some cheeses);
- Bottle and crate washing;
- Vehicle washing (inside of milk lorries);
- Utilities - boiler make up, cooling and refrigeration.

A14.4 Optimal Water Use

Type of product		Units	Water or steam	SWC (Specific Water Consumption) Average / Range	SWC (Specific Water Consumption) Best Practice
Milk	Milk Plant	m^3/t	Water	5.76[1,2,3]	
		m^3/t	Steam	0.192[1,2,3]	
	Pasteurised milk – bulk average	m^3/m^3	Water	1.6[4]	0.75[4]
	Pasteurised milk – bulk <1000 m^3/month	m^3/t	Water	3.2[4]	
	Pasteurised milk – bulk >1000 m^3/month	m^3/t	Water	1[4]	
	Pasteurised milk - sachets	m^3/m^3	Water	1.7[4]	1.1[4]
	Pasteurised milk - cartons	m^3/m^3	Water	2.2[4]	1.5[4]
	Pasteurised milk - bottles	m^3/m^3	Water	3[4]	2[4]
	Skimmed milk	m^3/t	Water	3.6[4]	2.1[4]
	Condensed milk	m^3/m^3	Water	4.4[4]	3.5[4]
	Sterilised/UHT products	m^3/m^3	Water	3.7*[4]	2*[4]
Powdered milk		m^3/t	Water	0.03[1,2,3] – 11.8[4]	8.7[4]
		m^3/t	Steam	0.091[1,2,3]	
Blue Cheese		m^3/t	Water	11.29[1,2,3]	
		m^3/t	Steam	0.353[1,2,3]	
Cheese		m^3/t	Water	8.5[1,2,3] - 23[4]	20[4]
				9.1[6]	
		m^3/t	Steam	0.25[1,2,3]	
Whey		m^3/t	Water	8.3[6]	
Ice cream		m^3/t	Water	0.88 - 2.5*[4]	1.9* [4]
Yoghurt		m^3/t	Water	4.24[1,2,3]	
		m^3/t	Steam	0.135[1,2,3]	
		m^3/m^3	Water	10.2* [4]	6.3* [4]
Butter		m^3/t	Water	1.5* [4] – 6.7[6]	1.3* [4]

* Water use from the intermediate product is used so an additional average SWC of 0.6 needs to be added for reception. The target for reception is set at 0.4[4].

A14.5 Variables Affecting Optimal Water Use

- Size of diaries – see table above;
- Type and range of product produced;
- Packaging of the product;
- Number of products being generated (more products generally means higher SWC);

- Composition of the milk used to produce cheese dictates the potential production ratio between cheese, whey and butter;

- Type of cheese produced – e.g. gouda requires brining and curing with a final product wash.

A14.6 Possible Optimisation Measures

- Optimisation of pasteurisation, separation and homogenisation stages [4];

- Use of indirect steam heating for pasteurisation (to allow for recycling) [4];

- Optimisation of cleaning-in-place (CIP) using measures such as pigging and automatic controls [4, 5,6];

- Optimisation of vehicle wash areas and equipment [4];

- Pressure and valve controls on water feed lines [4];

- Identification of reuse activities – for example using CIP final rinse water as a pre-rinse for CIP or for vehicles [5,6];

- Improved manual cleaning using dry cleaning prior to floor washing, trigger action hoses with compressed air and fitting screens to remove solids prior to discharge [5];

- Using condensate water as boiler make up and hot water supplement[6];

- Recycling used cooling water, followed by restricted (automatic) blowdown when total dissolved salts exceed 1800 mg/l[6].

A14.7 References

Dairy Design for practical reductions in energy and water operating costs. IChemE Symposium Series No. 84. D Harris. IChemE. 1984.

Liquid assets for your Dairy Plant. N. Carolina Cooperative Extension Service. http://www2.ncsu.edu/bae/programs/extension/publicat/wqwm/cd21.html.

Food Factories - Processes, Equipment, Costs. Alfred Bartholomai. VCH. Jan-88.

Steffen, Robertson and Kirsten Inc, Consulting Engineers, (1989), Water and Waste-Water Management in the Dairy Industry (Natsurv 4), prepared for the Water Research Commission, WRC Project No 145, TT38/89.

Environmental Technology Best Practice Programme, (1999), Reducing Waste for Profit in the Dairy Industry, Guide GG242.

Technical Report W6-056/TR1 – Appendix A4. Company F water survey report.

A15 FOOD PROCESSING - FLOUR AND CORN PRODUCTS (SIC codes: 204 AND 205)

A15.1 Type of Industry and Main Products

Wheat and corn grains are ground into flour or meal. These may be sold direct or used in the baking industry to produce a variety of baked goods.

A15.2 Processing Steps [1, 2]

Type	Processing steps
Bread	• Ingredients (yeast, salt and dough improvers) are premixed, with an average ingredient/water ratio of 1:4, using a high speed agitator • Flour is added to form a dough • A divider cuts the dough into chunks of pre-set volume and the dough pieces are then rounded • The pieces of dough are proofed or fermented • Moulding provides the finished texture and cell formation of the loaf • The loaves are deposited in baking pans, proofed and then baked • After baking, the bread is cooled, depanned, sliced and wrapped
Bakers Yeast	• A sugar-containing substrate such as molasses is pre-treated, inoculated with a small amount of yeast and aerated • The yeast cells reproduce, so generating large quantities of yeast that is then separated and packed
Corn Starch	• Corn steeping - to soften the corn ready for degermination • Degermination • Washing of husks and screening of starch milk • Purification of starch milk • Starch dewatering and drying • Dewatering and drying of germs • Evaporation of steep water • Concentration, dewatering and drying of gluten
Corn Snacks	• The corn meal is moisturised to prevent the product from burning and to aid expansion during extrusion • Heat and pressure convert the meal into a semi-liquid state before extruding it through the face plate • The extruded product is cut into the desired length by rotating knife, then it is coated and dried • Flavours are applied by spraying a metered amount of a slurry mixture onto the product
Pasta	• Flour is mixed with water and extruded through a die-head • Additives such as egg and spinach may be proportioned in to the extruder • Extruded product is dried and cut immediately for long-cut pasta or heated in a multi-stage unit before cutting for short-cut pasta

A15.3 Water Use Steps

- Ingredient feed;
- Mixing;
- Proofing;
- Cooling conveyor;
- Pre-treatment.

A15.4 Optimal Water Use

Type	Units	Water or steam	SWC (Specific Water Consumption) worst case**	SWC (Specific Water Consumption) Best Practice
Bread	m^3/t	Water	2 - 6*[1, 2]	-
	t/t	Steam	0.06[1, 2]	-
Bakers Yeast	m^3/t	Water	25.00[1, 2]	-
	t/t	Steam	0.40[1, 2]	-
Corn Starch	m^3/t	Water	6.28[1, 2]	-
Corn Snacks	m^3/t	Water	0.03[1, 2]	-
Pasta	m^3/t	Water	0.30[1, 2]	-

* Lower value based on audit of multi-product bakery in North Carolina [2]

** Water consumption data is based on actual requirement with no recycle. Treat as worst case values.

A15.5 Variables Affecting Optimal Water Use

- None currently identified.

A15.6 Possible Optimisation Measures

- None currently identified.

A15.7 References

1. Food Factories - Processes, Equipment, Costs. Alfred Bartholomai. VCH. Jan-88.

2. Liquid Assets for your Bakery. N. Carolina Cooperative Extension Service. 1996. http://www2.ncsu.edu/bae/programs/extension/publicat/wqwm/cd41.html.

A16 FOOD PROCESSING - FRUITS AND VEGETABLES (SIC code : 203)

A16.1 Type of Industry and Main Products

Fruit and vegetables may be preserved in a number of ways including: canning, drying, freezing and jams. They may also be converted into other food items such as soups, salads and sauces. Certain seeds are processed to produce edible oils.

A16.2 Processing Steps

Type	Processing steps
Frozen apple slices [3]	• Inspection/sorting: frozen apple slices are prepared from sound, fresh apples of proper maturity and ripeness • Apples are checked, washed, sliced • The slices are conveyed to tanks containing a solution, which retards enzymatic oxidation • The slices are then filled into a vacuum tank where they are brined and blanched
Fruit preserves and jams [3]	• Cold pack or canned fruit is mixed with water, sugar and pectin and heated to 60˚C • Water is evaporated at atmospheric pressure or under vacuum • After cooling is complete the finished product is deaerated and pasteurised, before further cooling and filling
Fruit puree [3]	• Fruit preparation - fruit washing, sorting and pulp extraction. The pulper converts the fruit into a puree and separates seeds and pits from the puree • Aseptic processing - puree is heated to the required sterilising temperature, held at this temperature for a prescribed length of time and then cooled to near ambient temperature • Filling operation - undertaken in an aseptic environment
Frozen vegetables [2]	• Harvest • Sort • Trim • Wash • Prepare (peel, cut, grate etc) • Rinse • Sanitise • Blanch • Cool • Freeze • Package
Tomato paste [3]	• Field tomatoes are washed, inspected to remove foreign materials and trimmed • The tomatoes are chopped, sterilised at 112°C • The pulp is cooled to 100°C and sent to a rough finisher-pulper for removal of the peel, sticks and pods • At the fine finisher, seeds and fibres are removed • The finished juice is evaporated in a double effect evaporator where it is concentrated from 5.5% to 32% solids • The paste is pasteurised, then cooled and packaged

Type	Processing steps
Mushroom farm [3]	• Compost is prepared from suitable material, wetted, filled into wooden frames and steamed to kill any bacteria • The compost is cooled to 35°C and then spawned • The bed is maintained at 35°C, without light and watering for five days in which time mushrooms appear • Light and ventilation are introduced • The mushrooms are harvested.
Refined vegetable oil [3, 4]	• Seed preparation with decortication, heating, presses and possibly solvent extraction. • Crude oil is mixed with caustic soda under controlled conditions to neutralise fatty acids that are then separated in a continuous centrifuge • Phosphoric acid can be used to remove any gums • The oil is washed to remove remaining soap, followed by vacuum drying • Lime or caustic soda is added to the oil under vacuum • The light-coloured oil is filtered and deodorised using live steam • Hydrogenation, if necessary • Packaging

A16.3 Water Use Steps

- Washing and rinsing of fruit and vegetables;
- Blanching;
- Heating and cooling;
- Raw material for product;
- Wash down (equipment, floor etc);
- Cleaning in place;
- Vehicle washing;
- Compost watering and steam (mushroom farm);
- Domestic.

A16.4 Optimal Water Use

Type		Units	Water or steam	SWC* (Specific Water Consumption)	SWC (Specific Water Consumption) Best Practice
Frozen apple slices		m^3/t	Water	2[3]	-
Fruit preserves and jams		m^3/t	Water and steam	8.03[3]	-
			Steam only	0.3[3]	-
Fruit puree		m^3/t	Water and steam	0.4[3]	-
			Steam only	0.18[3]	-
Frozen vegetables		m^3/t	Water	25[3]	-
Tomato paste		m^3/t	Water	0.33[3]	-
Mushroom farm	Total	m^3/t	Water and steam	25.00[3]	-
	Compost production only	m^3/t	Water and steam	2.1[3]	-
Vegetable oil		m^3/t	Water	1.67[3]	-
Edible oils	Milling	m^3/t	Water and steam	2.1 – 3.1[4]	-
	Refining	m^3/t	Water and steam	3.2 – 4.6[4]	-

* The number of industries used to derive these numbers is not known.

A16.5 Variables Affecting Optimal Water Use

- Packaging of final product (bulk, jars, cans etc);
- Seasons – this will affect productivity and number of staff;
- End product (extent of processing);
- Material being processed (certain fruits or vegetables require more water than others).

A16.6 Possible Optimisation Measures

- Recycle wash water [3];
- Air cooling [3];
- Steam recycle [3];
- Use of pigging to maximise on product recovery and cut down on waste water[1];
- Use dry floor clearing methods prior to wash down [2];
- Dry processing for example dry peeling [2].

A16.7 References

1. Environmental Technology Best Practice Programme, (2000), Pigging cuts Costs, Recovers Product and reduces Effluent, Final Results GC261.

2. Envirowise Practical Environmental Advice for Business, (2001), Reducing Water and Waste Costs in Fruit and Vegetable Processing, Good Practice Guide GG280.

3. Food Factories - Processes, Equipment, Costs. Alfred Bartholomai. VCH. Jan-88.

4. Steffen, Robertson & Kirsten Inc, Consulting Engineers, (1989), Water and Waste-Water Management in the Edible Oil Industry (Natsurv 6), prepared for the Water Research Commission, WRC Project No 145, TT 40/89.

A17 FOOD PROCESSING – SUGAR REFINING (SIC code : 206)

A17.1 Type of Industry and Main Products

Sugar can be refined from cane sugar or beet sugar. There are various product forms such as powdered sugar, brown sugar, caster sugar etc.

A17.2 Processing Steps

Type	Processing steps
Cane sugar refining	• Milling (if raw product is whole canes) and dissolving of sugar into solution to form a sugar (involves heating) • Sugar dissolution • Clarification – by either addition of lime and phosphoric acid or injecting with carbon dioxide • Filtration • Percolation to remove impurities or ion exchange to remove colour • Grading
Refined beet sugar	• Prewashing, weighing and slicing into strips • Sugar extraction counter current with warm water • Rough screening to remove foreign material • Precipitation of impurities • Bleaching • Concentrating • Decolourising, centrifuging, washing • Drying and granulating

A17.3 Water Use Steps

- Washing;
- Dissolution;
- Wash water;
- Backwashing of filters;
- Boiler feed;
- Cooling water;
- Domestic.

A17.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption) Average / Range	SWC (Specific Water Consumption) Best Practice
Refined cane sugar	m^3/t	41*[1,2,3]	-
Refined beet sugar	m^3/t	9*[1,2,3]	-
Sugar cane processing (milling and refining)	m^3/t	3.5 – 11.6** [4]	-

* It is not known how many industries were looked at to derive this figure – it is possible that the values are based on a single case.

** Based on average of 10 sugar processing plants.

A17.5 Variables Affecting Optimal Water Use

- Season;
- Cooling system employed.

A17.6 Possible Optimisation Measures

- Dry cleaning of floors prior to washing;
- Use of cleaning-in-place.

A17.7 References

1. Food Factories - Processes, Equipment, Costs. Alfred Bartholomai. VCH. Jan-88.
2. Water Survey 1974. Evans, J,S. BPBIF Bulletin. 1976.
3. IK Mathieson, JW Knox, EK Weatherhead, J. Morris, DO Jones, AJ Yates, N Williams. Optimum Use of Water for Industry and Agriculture. Phase II Technical Report W243.
4. Steffen, Robertson & Kirsten Inc, Consulting Engineers, (1990), Water and Waste-Water Management in the Sugar Industry (Natsurv 11), prepared for the Water Research Commission, WRC Project No 145, TT 47/90.

A18 FOOD PROCESSING - MULTI PRODUCT CONFECTIONERY PLANT (SIC code : 206)

A18.1 Type of Industry and Main Products

Sugar, cocoa and other ingredients are combined to produce chocolates, candy and other confectionery products.

A18.2 Processing Steps

Chocolate products [1]

The base chocolate is produced from milk, cocoa liquor, cocoa butter, sugar and emulsifiers. It is then further processed to make other products.

A18.3 Water Use Steps

Not specified

A18.4 Optimal Water Use

The only results found were based on a water audit of a Cadbury Schweppes plant in Australia producing chocolate confectionery products.

Type	Units	SWC	SWC Best Practice
Before Audit	m^3/t	6[1]	-
After Audit	m^3/t	-	1.5[1]

A18.5 Variables Affecting Optimal Water Use

- None currently identified.

A18.6 Possible Optimisation Measures

Main reasons for reduction in water consumption at the Cadbury Schweppes plant are[1]:

- specially designed wash bays;
- automatic hoses on nozzles;
- automatic taps and utensil washers.

A18.7 References

1. Cleaner Production Demonstration at Schweppes Cottee's. Environet Australia. http://www.environment.gov.au/portfolio/epg/environet/ncpd/auscase_studies/cs_schw2.htm.

A19 FOOD PROCESSING - MISCELLANEOUS (SIC code : 20)

A19.1 Type of Industry and Main Products

In this general section various food processing industries have been covered, where information was available. As additional information is acquired it may be necessary to subdivide this section.

A19.2 Processing Steps

Type	Processing steps
Baby food [1,2,3]	**Preparation** • Soft fruit (e.g. berries) are pre-crushed, heated up to 100 - 110°C and deposited into the mixing vessel • Vegetables are sorted and then pre-crushed, heated, and transferred into the mixing vessel • Meat is cut, cooked, and pre-crushed **Mixing** • In the mixing vessel the final formula is thoroughly mixed • Seasonings are now added; for fruit and vegetable baby foods: sugar, corn syrup, starch powder, yeast extracts, vegetable protein, etc • For meat baby foods: salt, spices, milk protein, etc. **Finishing** • The finished formula is pumped into a colloid mill for grinding, emulsifying and homogenising • The product is de-aerated, which prevents any changes in flavour, aroma or colour due to oxidation • The product is heated and transferred into containers
Canned pet food [1,2,3]	No details for the production process at present.

A19.3 Water Use Steps

Type	Water use steps
Baby Food [1,2,3]	Product, washing, sterilising
Canned pet food [1,2,3]	Washing, cleaning, product

A19.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption) Average	SWC (Specific Water Consumption) Best Practice
Baby Food	m^3/t	0.2*[1,2,3]	-
Canned Pet food	m^3/t	2.75[1,2,3]	-

* This value appears too low to include water in product. Caution should be used when applying this value.

A19.5 Variables Affecting Optimal Water Use

- None currently identified.

A19.6 Possible Optimisation Measures

Suggestion [4]	Reason
Product Washing	• Wherever possible, counter current washing should be employed so that the cleanest water washes the nearly clean product and the reused water washes the dirty incoming product. This technique saves not only water, but also effluent volume. • Install automatic cut-off valves on water line if product flow-line is subject to stoppages.
Transporting product	• Particularly relevant to food industries. Recycling of water should be considered as should other modes of transport.
Clean-in-place (CIP)	• It is standard practice in automated CIP systems to reuse final rinse water as a pre-rinse. • In food factories the final rinse water should be of high microbiological standard with a free chlorine residual present.
Improved clean-up	• Trigger action hose guns in washdown • Dry clean-up techniques - brush clean • Industrial floor cleaners/ vacuum cleaners • Use of re-useable wastewater streams
Others	• Water monitoring and management system • Maximise condensate return to boiler house • Automatic taps

A19.7 References

1. Food Factories - Processes, Equipment, Costs. Alfred Bartholomai. VCH. Jan-88.

2. Water Survey 1974. Evans, J,S. BPBIF Bulletin. 1976.

3. IK Mathieson, JW Knox, EK Weatherhead, J. Morris, DO Jones, AJ Yates, N Williams. Optimum Use of Water for Industry and Agriculture. Phase II Technical Report W243.

4. John S Hills. Cutting Water and effluent Costs. 2nd Edition. IChemE 1995.

A20 FRESH RED MEAT PRODUCTION (SIC code : 201)

A20.1 Type of Industry and Main Products

The red meat industry involves the slaughter, processing and packaging of beef, sheep, goat and pork. To enable comparisons on water usage, animals may be sometimes considered as cattle units. A water use cattle unit equals 1 full sized cow, 2 calves, 6 sheep or goats and 2.5 pigs (the number of animals to a cattle unit will vary when looking at other factors such as tariffs, slaughtering etc).

A20.2 Processing Steps

- Lairage – holding areas with drinking water;
- Stunning – animal is killed (halaal and kosher animals are not stunned);
- Sticking – bleeding (blood is collected);
- Hoof and head removal – parts are usually transported or sold to a rendering plant;
- Hide removal – trimming will take place before being sent to tanneries (cattle) or fellmongeries (sheep);
- Dehairing – pigs only;
- Evisceration – internal organs are removed and inspected (parts will either go for rendering or go to offal handling);
- Offal handling – offal is thoroughly washed;
- Cold storage – to chill the meat;
- Cutting - carcasses are prepared into specific meat cuts, vacuum or gas film packaged, boxed then palletised;
- Further processing - pigmeat for curing is injected with curing solution and immersed in a brine tank, followed by curing;
- Dispatch.

A20.3 Water Use Steps

- Lairage washing;
- Cleaning of floors, walls and equipment;
- Sterilising of equipment e.g. knives;
- Sprays and rinses (carcasses and offal);

- Injection and curing;
- Scalding;
- Cooling;
- Vehicle washing;
- Personal hygiene (domestic).

A20.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption) Average / Range	SWC (Specific Water Consumption) Best Practice
Lamb only	m^3/t	2.2* [4]	1.6* [4]
Beef & lamb only	m^3/t	3.3* [4]	2.4* [4]
Beef only	m^3/t	5.8* [4]	4.3* [4]
Pig meat only	m^3/t	8.9* [4]	3.3* [4]
Large abattoirs (>100 cattle units per day)	m^3/cattle	0.7 – 2.9 [1]	1.1 [1]
Small abattoirs (<100 cattle units per day)	m^3/cattle	0.7 – 4.7 [1]	1.8 [1]
Cattle	l/animal	-	700 – 1000 [3]
Pigs	l/animal	-	160 – 230 [3]
Sheep	l/animal	-	100 - 150 [3]

Note: No significant differences in the specific water consumption due to production level [4].

A20.5 Variables Affecting Optimal Water Use

- Larger abattoirs can be more water efficient than smaller ones with lower production capacity;
- Shift duration and frequency.

A20.6 Possible Optimisation Measures

- Teat like drinking water dispensers rather than open troughs in the lairages [1];
- Dry-clean areas prior to washdown [1];
- Dry cleaning of animal products where possible [1, 3];
- Cold washing of blood soiled areas, prior to hot washing [1];
- Treatment of effluents to maximise water reuse [2, 3];
- Improved scheduling of operations to improve efficiency [3];
- Optimising delivery times [3];

- Directional spray nozzles for carcass washing [3];
- Maximise condensate return to boiler house [4];
- Trigger action hose guns in washdown combined with compressed air [4];
- Plastic cylindrical basins to minimise evaporative losses from sterilisers [4];
- Metering valves to reduce water wastage from steriliser basins [4];
- Cover water surface in scald tanks with plastic balls [4];
- Direct hot water spray scalding and carcass brushing to replace singeing plant [4].

A20.7 References

1. Steffen, Robertson & Kirsten Inc, Consulting Engineers, (1989), Water and Waste-Water Management in the Red Meat Industry (Natsurv 7), prepared for the Water Research Commission, WRC Project No 145, TT 41/89.

2. J A C Cowan, (1998), The Transfer of Waste-Water Management Technology to the Meat Processing Industry, Report to the Water Research Commission, WRC Report No 239/1/98.

3. Environmental Technology Best Practice Programme, (2000) Reducing Water and Effluent Costs in Red Meat Abattoirs, Guide GG234.

4. Energy Consumption Guide 32 - Red Meat Plants. Energy Efficiency Office, Best Practise Programme. ETSU. 1997.

A21 GOLF COURSES (SIC code : 799)

A21.1 Type of Industry and Main Products

Recreational activity.

A21.2 Processing Steps

- Maintenance of greens and tees;
- Maintenance of water features.

A21.3 Water Use Steps

- Irrigation of greens and tees;
- Domestic.

Types of irrigation systems in use are automatic systems with pop-ups, manual installations with sprinklers working from hose points and travelling sprinklers.

A21.4 Optimal Water Use

Consumption values are given but there is no information on the number of users so SWC cannot be determined

Source of water	Units	Water consumption
Public Water Supply only, direct or water into storage first	Ml/d	2.7 - 4.0
Direct only from abstraction or into storage first	Ml/d	2.9 - 5.4
All courses	Ml/d	3.2 - 6.4

The above data ranges cover UK 9 and 18 hole golf courses. The data is taken from a study carried out by the British Turf and Landscape Irrigation Association based on the responses from 89 golf course greenkeepers in southern and eastern England.

Three responses to the Phase 3 questionnaires (use varied between 7 and 57 megalitres per year) indicate that there is room for improved water management.

A21.5 Variables Affecting Optimal Water Use

- Location;
- Season;
- Area under irrigation;
- Number of water features;
- Water retention by underlying soils;

- Type of grass.

A21.6 Possible Optimisation Measures

- None currently identified.

A21.7 References

- Paul Herrington and Martina Hoschatt. Golf Course Water Use Study, British Turf and Landscape Irrigation Association (BTLIA), July 1993.

A22 HOSPITALS (SIC code : 806)

A22.1 Type of Industry and Main Products

Hospitals vary in size and type of patients being treated. Some will have full surgery components while others, such as psychiatric hospitals and clinics, may have no operating facilities.

A22.2 Processing Steps

Not applicable to hospitals.

A22.3 Water Use Steps

- Cleaning;
- Sanitary;
- Laundry;
- Food processing;
- Gardening;
- Domestic.

A22.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption)			
		Good	Average	Poor	Very poor
Acute hospitals with more than 100 beds	l/patient/d	<530[1,2]	531-[1,2]	711-1137[1,2]	>1138[1,2]
Long stay hospitals with more than 25,000 patient days per annum	l/patient/d	<330[1,2]	331-411[1,2]	412-689[1,2]	>690[1,2]
Long stay hospitals with less than 25,000 patient days per annum	l/patient/d	<217[1,2]	218-297[1,2]	298-379[1,2]	>380[1,2]

A22.5 Variables Affecting Optimal Water Use

- Size of hospital;
- Facilities offered at the hospital.

A22.6 Possible Optimisation Measures

- Installation of water efficient sanitary ware, e.g. low-flush water closets;
- Water-efficient laundry equipment;
- Automatic taps;
- Collection and use of rainwater;
- Grey water recycle;
- Educational initiatives.

A22.7 References

1. IK Mathieson, JW Knox, EK Weatherhead, J. Morris, DO Jones, AJ Yates, N Williams. Optimum Use of Water for Industry and Agriculture. Phase II Technical Report W243.

2. NHS Occasional Papers, Number 5. Untapped savings: Water Services in the NHS. Audit Commission. May 1993.

A23 LAUNDRY (SIC code : 721)

A23.1 Type of Industry and Main Products

Commercial laundries fall into two main categories: smaller laundries equipped with traditional washer extractors processing up to 50,000 pieces/week, and larger laundries equipped with a combination of tunnel washers and washer extractors processing up to 200,000 pieces/week.

A23.2 Processing Steps

- Dirt is removed from fabric by agitation in an alkaline, aqueous medium containing a detergent. The suspension formed is stabilised to prevent re-deposition of dirt on the cloth;

- Subsequent rinsing is to remove the stabilised suspension of dirt from contact with the article being washed;

- There can be up to four washes and rinses within the cycle.

A23.3 Water Use Steps

Percentage water use for each water use step [5].

Waster use step	Non recycle	Recycle
Washing	32%	9%
Rinsing	56%	73%
Steam generation	12%	18%

A23.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption) Average / Range	SWC (Specific Water Consumption) Best Practice
Hospital laundry (UK)	m^3/t	27[1,2,3,4]	21[1,2,3,4]
Hospital laundry (US)	m^3/t	38[1,2,3,4]	10[1,2,3,4]
Domestic washing machine	m^3/t	15 - 20[1,2,3,4]	15[1,2,3,4]
Laundries with recycle	l/kg	8 – 17[5] Weighted average = 9[5]	8[5]
Laundries without recycle	l/kg	23 – 58[5] Weighted average = 30[5]	30[5]
Phase 2 Laundry	l/kg kg steam/kg	13.42[6] (water consumption) 3.47 (steam consumption)	-

A23.5 Variables Affecting Optimal Water Use

- Presence of recycling in the process;

- Optimal use of detergent and water temperature.

A23.6 Possible Optimisation Measures

- Reuse of clean final rinse water through filtering and storage of effluent;
- Optimising boiler operations;
- Replacement of leaking valves;
- Collection and use of rainwater (rainwater harvesting).

A23.7 References

1. Washing Machine Energy Information Data. Creda.
2. Water and Heat Recovery in a Hospital Laundry. ETSU. Energy Efficiency Office, DOE. 1991.
3. Water and Chemical Conservation Through Installation of Ultra Tandem 65k/12 Tunnel Washer. Pacific NW Pollution Prevention Resource Centre. http://198.128.66.29/pprc/rpd/statefnd/nc_owr/waterand.html. 1996.
4. IK Mathieson, JW Knox, EK Weatherhead, J. Morris, DO Jones, AJ Yates, N Williams. Optimum Use of Water for Industry and Agriculture. Phase II Technical Report W243.
5. Steffen, Robertson & Kirsten Inc, Consulting Engineers, (1989), Water and Waste-Water Management in the Laundry Industry (Natsurv 8), prepared for the Water Research Commission, WRC Project No 145, TT 42/89.
6. Phase 2 – Company A audit report.

A24 LEAD ACID BATTERY PRODUCTION (SIC code : 362)

A24.1 Type of Industry and Main Products

Batteries are produced in a range of shapes and sizes to meet specified purposes.

A24.2 Processing Steps

The main raw materials are lead, lead oxides and sulphuric acid. The basic stages consist of casting the lead internal components, producing the lead oxides to fill the appropriate electrodes and assembly. Batteries may also be charged for industrial use e.g. for fork lift trucks. Automotive and standby batteries tend not to be charged hence the water cooling requirement is eliminated.

The quality of the water in contact with the battery internals is important to ensure an acceptable battery life.

A24.3 Water Use Steps

- Lead oxides slurry preparation;
- Cell filling;
- Plate washing;
- Cooling;
- Acid dilution.

A24.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption) Average / Range	SWC (Specific Water Consumption) Best Practice
Industrial	m^3/tonne lead processed	16 – 20[1,2]	15[1,2]
Automotive & standby	m^3/tonne lead processed	5 – 10[1,2]	5[1,2]

A24.5 Variables Affecting Optimal Water Use

- None currently identified.

A24.6 Possible Optimisation Measures

- Water monitoring and management systems [1, 2];
- Filter and reuse water from slurry preparation [1, 2];

- Reuse cooling water (charging operation) [1, 2];
- Reuse plate washing water [1, 2];
- Use of dry fume abatement systems [1, 2].

A24.7 References

1. Project Catalyst, Report to the DEMOS Project Event, June 1994 (Telephone ETBPP 0800 585794).
2. Private Communication with Chloride Motive Power Batteries.

A25 LEATHER TANNING (SIC code : 311)

A25.1 Type of Industry and Main Products

Hides are converted into leather. The end product may be an intermediary hide after the chromium tanning or it could be a finished hide.

A25.2 Processing Steps

- Curing to prevent organic degradation (uses salt or chemicals);
- Soaking to remove blood, manure and dirt;
- Unhairing
  - Lime sulphide paste is applied to flesh side of hides to loosen hair.
  - Mechanical de-wooling machine removes wool from hides.
  - De-wooled hides are dipped in a lime vat to remove epidermis and any remaining hair.
- Fleshing operation
  - Hides are pressed by a roller and shaved.
  - Rolling drum removes liming solution from hide.
  - Addition of salts, kerosene and degreasing agents to degrease hides.
  - pH adjustment with acid solution.
- Chromium tanning
  - Chromium sulphate solution stabilises the collagen in the hide.
  - Wet hides are aged for 24 hours on pallets.

After tanning and ageing, the hides are wrung and shaved. The hides are neutralised with sodium carbonate. After rinsing, the hides are re-tanned by adding tanning agents (vegetable or synthetic) and fat liquoring compounds that give the leather its feel and suppleness. The hides are then rinsed, air dried, trimmed, stretched, and pinned to a metal net for dying.

A25.3 Water Use Steps

- Soaking;
- Liming;

- Tanning;
- Washing;
- Domestic.

A25.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption) Range	SWC (Specific Water Consumption) Best Practice
Chrome tanning	m^3/t	40 – 67[1,2]	-
Vegetable tanning	m^3/t	16 - 27[1,2]	-
Tanneries with both tanning and re-tanning	m^3/hide	0.3 – 0.7[3]	-

A25.5 Variables Affecting Optimal Water Use

- Size of plant with larger sites usually being more water efficient.

A25.6 Possible Optimisation Measures

- Effluent recycle from secondary treatment to pre-tanning step [1, 2];
- Reuse effluent from liming wash [1, 2];
- Optimise boiler operations [3];
- Reuse of chrome and lime liquors [3, 4].

A25.7 References

1. Water Survey 1974. Evans, J,S. BPBIF Bulletin. 1976.
2. A Case Study from EP3: Pollution Prevention Assessment for a Large Manufacturing and Sheep Hide Tannery. United States Agency for International Development (USAID). US EPA. http://earth2.epa.gov/ep3/ep3-cs9.html.
3. Steffen, Robertson & Kirsten Inc, Consulting Engineers, (1989), Water and Waste-Water Management in the Tanning and Leather Finishing Industry (Natsurv 10), prepared for the Water Research Commission, WRC Project No 145, TT 44/90.
4. D Rawlings, M Hagger, D Hayes, G N Steenveld, (Leather Industries Research Institute and Binnie & Partners), (1987), A Guide to Waste-Water Management in the Tanning and Fellmongering Industries, prepared for the Water Research Commission, WRC Project No 41, TT 27/87.

A26 LEISURE PARKS (SIC code : 799)

A26.1 Type of Industry and Main Products

Leisure Parks is a broad term incorporating a number of facilities including theme parks, zoos, safari parks, holiday villages, etc, and all the associated infrastructure.

A26.2 Processing Steps

Not applicable in this case.

A26.3 Water Use Steps

- Maintenance of water features;
- Swimming pools and water rides;
- Aquaria maintenance;
- Domestic.

A26.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption) Typical*	SWC (Specific Water Consumption) Best Practice
Holiday village	l/visitor	240[1,2,3]	-
Theme park	l/visitor	69[1,2,3]	-
Maritime aquarium	l/visitor/month	13-182[4] (seasonal variation) 48[4] (average based on 3 years)	-
Museum (steam engine)	l/visitor	450[4]	
Museum and wildfowl park	l/visitor	240[4]	

* The information available is based on individual sites so an average cannot yet be determined.

A26.5 Variables Affecting Optimal Water Use

- Seasonal variations, such as visitor number;
- Type of facilities and attractions available.

A26.6 Possible Optimisation Measures

- Water – efficient ride design;
- Collection of spilled water;
- Installation of water efficient sanitary ware, e.g. low-flush water closets and percussion taps;
- Collection of roof water for irrigation purposes and support of freshwater water features;
- Grey water recycle;
- Educational initiatives;
- Minimise water used in swimming pools;
- Reuse of mainswater for washing wet suits;
- Location of an aquarium will dictate where the salt water is obtained from – either through direct abstraction and treatment or through production using mains water and chemicals. In the latter case, costs associated with water consumption are likely to be high and therefore reuse and recycle initiatives should be in place. In such circumstances, the aquarium may be a closed loop due to the cost of making the salt water.

A26.7 References

1. IK Mathieson, JW Knox, EK Weatherhead, J. Morris, DO Jones, AJ Yates, N Williams. Optimum Use of Water for Industry and Agriculture. Phase II Technical Report W243.
2. WS Atkins survey for a major UK Leisure Park, 1992.
3. Private Communication with Centre Parcs.
4. Technical Report W6-056/TR1– Appendix A4. Company A, G and H survey reports.

A27 LIGHT INDUSTRIAL ESTATE WATER CONSUMPTION (SIC code: VARIOUS)

A27.1 Type of Industry and Main Products

There are no specific products as these will be dependent on the individual companies present on the industrial estate.

A27.2 Processing Steps

Variable depending on company.

A27.3 Water Use Steps

This will vary depending on the operations taking place but is likely to be dominated by domestic requirements. Where relevant, water use has been specified in the optimal water use table.

A27.4 Optimal Water Use

Type of site and water usage	Units	SWC (Specific Water Consumption) Typical
Basic factory requirements for cleaning and sanitation	m^3/d per worker	0.05[1]
Average consumption in light industrial estates with no large water-consuming factories	m^3/d per worker	0.25 - 0.50[1]
Average consumption in light industrial estates that include a proportion of factories engaged in food-processing, ice-making and soft drinks manufacture	m^3/d per worker	0.9 - 1.1[1]
Typical factory consumption in SE England : • clothing and textiles • leather working (not tanning), fur, furniture, timber products, printing, metalworking and precision engineering. • plastics, rubber, chemical products, mechanical engineering and non-metallic products	m^3/d per factory	Clothing and textiles - 90% under 6[1] Leather etc. - 80% under 25[1] Plastics etc. - 85% under 125[1]

A27.5 Variables Affecting Optimal Water Use

- None currently identified.

A27.6 Possible Optimisation Measures

- None currently identified. However, wherever possible, the industry sector figure linked to production should be used.

A27.7 References

1. A. C. Twort, R. C. Hoather, F. M. Law. Water Supply. Edward Arnold (Publishers) Ltd.

A28 METAL FINISHING (SIC code : 347)

A28.1 Type of Industry and Main Products

Metal finishing involves preparation of machined metal products into finished goods by various surface preparation techniques including washing, polishing, acid/alkali cleaning, electroplating and galvanising.

A28.2 Processing Steps

Processes may be batch or continuous as outlined below. Continuous operations are most frequently used in finishing of metal wires in which the product is continuously drawn through the plating and cleaning baths.

Steps that may take place to finish metal products includes:

- pre-treatments with chemical or mechanical means;
- electroplating;
- post-treatment such as passivation;
- stripping using chemicals or electrolysis;
- anodising (protective oxide layer);
- protective coating.

A28.3 Water Use Steps

- Electroplating baths;
- Rinse baths.

Water consumption can be considerable in continuous operations due to drag-out of the bath liquors.

A28.4 Optimal Water Use

Water consumption is normalised against tonne of product or treated surface area depending on the form of product, e.g. plate material or door furniture.

Type	Units	SWC (Specific Water Consumption) Average / Range	SWC (Specific Water Consumption) Best Practice
Metal finishing	m^3/m^2	0.18 - 0.5 [1,5]	0.07 [1,5]
Metal finishing	m^3/t	2.5 - 11.7 [1,5]	0.5 [1,5]
US Electroplaters	m^3/m^2	0.04482 [2]	0.00077 [2]
Galvanisers	m^3/t	0.03 [1,2]	-
Electroplating (range for 22 sites)	m^3/m^2	0.03 – 1.3 [3] Weighted average = 0.13 [3]	-
Anodising (range for 13 sites)	m^3/m^2	0.03 – 0.96 [3] Weighted average = 0.1 [3]	-
Phosphating industry (range for 9 sites)	m^3/m^2	0.04 – 0.26 [3] Weighted average = 0.07 [3]	-
Operations treating < 10 000 m^2	m^3/m^2	-	0.2 [3]
Operations treating >10 000 m^2	m^3/m^2	-	0.1 [3]

A28.5 Variables Affecting Optimal Water Use

- Water use will be product, material and finish specific;
- Number of process stages;
- Size of the operation.

A28.6 Possible Optimisation Measures

- Reuse of rinse water (reduce water consumption by up to two thirds) [1, 2, 3];
- Use of static drag-outs to optimise subsequent rinses and provide make-up to solution tanks;
- Counter current rinsing (two counter-current tanks can reduce water use by up to 90-97%. The addition of a third tank will reduce water use by 95 to 99%) [1, 2, 5];
- Correct rinse tank design (ensure rinse water is completely mixed) [1, 2, 3];
- Zero discharge, complete recycle of water. Metals ions may be removed by membrane or ion-exchange techniques. Captured metal should be recovered otherwise waste must be landfilled [1, 2, 5];
- Vacuum devices to remove drag-out liquid [1, 2];
- Regulation of rinse flow [1, 3, 5];
- Filter press to dewater sludge [1];
- Fog rinsing instead of spray rinsing about the process bath [5].

A28.7 References

1. Water Use in the Metal Finishing Industry. EG45. Environmental Technology Best Practise Programme. ETBPP.

2. Low Cost Reduction in Water Consumption and Waste Production. USEPA. http://earth2.epa.gov/studies/cs470.html.

3. Binnie & Partners, Consulting Engineers, (1987), Water and Waste-Water Management in the Metal Finishing Industry, (Natsurv 2), prepared for the Water Research Commission, WRC Project No 145, TT 34/87.

4. Environmental Technology Best Practice Programme, (1999), Minimising Chemical and Water Waste in the Metal Finishing Industry, GG160.

5. Environmental Technology Best Practice Programme, (1996), Acid and Water Use in Galvanising, Guide EG46.

A29 METAL PROCESSING (SIC CODES : 331 - 339)

A29.1 Type of Industry and Main Products

Metal processing takes mined ore (mining not considered here) and processes the material to produce either the intermediate concentrate or the final metal product.

A29.2 Processing Steps

Metal processing may involve all or some of the following steps:

- Concentration
  - Milling;
  - Flotation to separate out metal rich material from tailings material.
- Smelting (pyro-metallurgical process)
  - Heating concentrate in a furnace;
  - Separation of slag (relatively inert waste material);
  - Moulding of impure metal into bars, anodes etc.
- Refining to reach correct level of purity
  - Leach processing (hydro-metallurgical process);
  - Electrowinning.

A29.3 Water Use Steps

- Milling;
- Reagent make up;
- Cooling;
- Wash down;
- Tailings disposal;
- Steam raising;
- Slag granulation;
- Acid dilution;
- Domestic.

A29.4 Optimal Water Use

Metal	Processing step	Units	SWC (Specific Water Consumption) Average / Range	SWC (Specific Water Consumption) Best Practice
Nickel	Smelting	m^3/t	0.6[1,2]	-
	Refining	m^3/t	5[1,2]	-
	Iron Castings	m^3/t	0.4[1,2]	-
Lead	Refining	m^3/t	0.4[1,2]	-
Chrome oxide	-	m^3/t	-	2[3]
Alumina	-	m^3/t	1 - 6[3]	-

A29.5 Variables Affecting Optimal Water Use

- Type of metal being processed and the number of processing steps;
- Use of pyro-metallurgical process or hydro-metallurgical process.

A29.6 Possible Optimisation Measures

- Efficient cleaning methods and coating make-up procedures;
- Recycling of cooling water;
- Efficient steam system, including condensate return and minimum leaks;
- Clean and dirty water separation.

A29.7 References

1. WMC, Environment Progress Report. WMC.

   http://www.wmc.com.au/environ/data1.html. 1995.

2. Private Communication with Britannia Refined Metals.
3. European Integrated Pollution Prevention and Control Bureau, (2000), Reference Document on Best Available Techniques for Non Ferrous Metals Production Process, pp 115-147, May 2000.

A30 PLASTICS MANUFACTURE (SIC code : 282)

A30.1 Type of Industry and Main Products

This industry produces plastics in a variety of different forms for a large and diverse market.

A30.2 Processing Steps

- Preparation of reactants[1,2]
  - purification of monomer feedstock and catalysts.
- Polymerisation[1,2]
  - addition polymerisation - monomer is polymerised using a catalyst to activate the monomer molecules and trigger polymerisation reactions.
  - polycondensation - two monomers are linked together in condensation reactions where water molecules are split off of the reacting monomers.
  - processes are either continuous, typically used for large-volume commodity polymerisations or batch/ semibatch for low volume, speciality polymerisations.
- Polymer recovery[1,2]
  - to recover the polymer, the reaction mixture goes through a series of three separation and purification steps.
  - unreacted monomer is separated from the polymer by volatilisation.
  - liquids and solids are separated.
  - polymer is dried to remove residual water or solvents.
- Polymer extrusion[1,2.]
  - molten polymer is extruded to form plastic pellets.
- Supporting operations[1,2]
  - equipment cleaning, reactant and product storage.

A30.3 Water Use Steps

- Polymer extruder quench water;
- Equipment cleaning;
- Cleaning of transport vehicles;

- Pollution control systems.

A30.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption) Range	SWC (Specific Water Consumption) Best Practice
Polyethylene	m^3/t	2.50 - 9.99[1,2]	-
Polypropylene	m^3/t	1.67 - 2.75[1,2]	-
Elastomer	m^3/t	9.16 - 37.47[1,2]	-
PVC	m^3/t	9.16[1,2]	-
Monomers	m^3/t	66.62[1,2]	-
Resin	m^3/t	5.83[1,2]	-

A30.5 Variables Affecting Optimal Water Use

- None currently identified.

A30.6 Possible Optimisation Measures

Water use reduction steps are similar to those outlined for speciality chemicals. Measures for water use reductions may be split into three distinct areas: good housekeeping, water management and reuse, recycle and redesign. The table lists those measures that have been successfully implemented for the speciality chemical sector and the corresponding reductions in water use.

Type of measure	Measures Introduced [1,2]	Reduction in water use (%)
Good housekeeping measures	Improved pipework to reduce leaks	10
	Good housekeeping, taps on hoses, etc	8
	Better housekeeping to avoid cleaning	3
	Storm water prevented from entering effluent system	7
	Leak detection and reduction	30
	Flow restrictors on vessel cooling lines	5
Water management techniques	Metering individual product areas and setting reduction targets	30
	A management system including production scheduling, improvements in plant wash-downs and use of trigger hoses	50
Reuse, recycle and redesign	Cooling water re-use	21
	Installation of cooling tower	50
	Improved cooling tower efficiency	50
	Re-use of wash water for batch dilution	25
	Installation of pressure washers for cleaning blending tanks	5
	Recirculation of water in liquid ring vacuum pumps	50
	Replacement of water seal vacuum pumps with dry versions	24
	Installation of air chillers	5
	Reduction in process water wastage	5
	Water minimisation project	20
	Modernisation of manufacturing facilities	38
	Improvements in process efficiency	5

A30.7 References

1. Texas Industrial Water Use Efficiency Study. Final Report Texas Water. Development Board. Pequod Associates, Inc. 1993.

2. IK Mathieson, JW Knox, EK Weatherhead, J. Morris, DO Jones, AJ Yates, N Williams. Optimum Use of Water for Industry and Agriculture. Phase II Technical Report W243.

A31 POULTRY PROCESSING (SIC code : 251)

A31.1 Type of Industry and Main Products

Poultry is delivered to site, slaughtered and processed.

A31.2 Processing Steps

- Reception area
  - Live birds are normally delivered to an abattoir in crates. The reception area is kept clean for hygienic reasons by frequent wash-down. Crate washing is also practised.
- Slaughter area
  - Birds are stunned by immersing their head and neck in an electrified water bath. Throats are slit.
- Scalding and defeathering
  - Birds are bled and then immersed in a scalding tank operating at 50-55°C in order to loosen the feathers. Following scalding, birds are defeathered. Feathers are collected in a flume and pumped over screens before further processing.
- Evisceration
  - Head and feet are removed and carcasses are sprayed with chlorinated water. Carcasses are cut open, viscera pulled out for inspection and then sorted into edible and inedible offal. Offal is transported in water flumes.
- Chilling
  - Birds are chilled to below 10°C using chilled water.
- General washing
  - Process areas are regularly cleaned as are vehicles
- By-product processing
  - Rendering of blood, feathers, inedible offal and condemned carcasses produces a saleable product. Water is used to wash rendering cookers. Water cooled condensers are used to condense malodorous vapours leaving the cookers.

A31.3 Water Use Steps

Breakdown of water use by different process at a turkey processor[4]

Water use step	Percentage water use
Floor washing/equipment cleaning	30%
Carcass chilling	27%
Evisceration	24%
Scald tank	9%
Crate and module washing	6%
Personal hygiene	2%
Feather fluming	1%
Vehicle washing	1%

A31.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption) Average / Range	SWC (Specific Water Consumption) Best Practice
Poultry >10 000 birds/day	l/bird	15 – 20[3] Weighted average = 17[3]	15[3]
Poultry < 10 000 birds/day	l/bird	15 – 30[3] Weighted average = 20[3]	20[3]
Chicken	l/bird	-	8-15[4]
Turkey	l/bird	-	40-60[4]

A31.5 Variables Affecting Optimal Water Use

- An abattoir operating at significantly below its design capacity will have its SWC pushed up by operations such as cleaning, which must be carried out to the same extent regardless of the number of birds being processed.

A31.6 Possible Optimisation Measures

- Dry clean-up - e.g. removing all dry waste from floor before cleaning with water;
- Water monitoring and management system;
- Maximise condensate return to boiler house;
- Trigger action hose guns in washdown;
- Metering valves to reduce water wastage from steriliser basins;
- Direct hot water spray scalding and carcass brushing to replace singeing plant;
- Vehicle washing and reuse of rinsate;
- Collection and use of rainwater (rainwater harvesting).

A31.7 References

1. Water and Wastewater Management in the Poultry Industry. WRC Project No. 145. Steffen, Robertson and Kirsten. Water Research Commission, Pretoria. 1989.

2. Reducing Water and Effluent Costs in Poultry Processing ETBBP (GG233).

3. Steffen, Robertson & Kirsten Inc, Consulting Engineers, (1989), Water and Waste-Water Management in the Poultry Industry (Natsurv 9), prepared for the Water Research Commission, WRC Project No 145, TT 43/89.

4. Environmental Technology Best Practice Programme, (2000) Reducing Water and Effluent Costs in Poultry Meat Processing, Guide GG233.

A32 POWER GENERATION (SIC code : 491)

A32.1 Type of Industry and Main Products

Steam driven turbines producing electricity by the burning of fossil fuels. Nuclear power has not been considered here.

A32.2 Processing Steps

- Burning of fossil fuels;
- Steam generation;
- Power generation;
- Cooling;
- Waste handling.

A32.3 Water Use Steps

The generation of electricity, through the combustion of fossil fuels, requires water for the following uses:

- Boiler feedwater;
- Auxiliary plant cooling;
- Control of flue gas concentrations;
- Ash handling;
- Sanitary, laboratory;
- Condenser cooling water system.

The major use of water in most thermal power stations is the cooling water system, which is used to condense the steam being exhausted from the low pressure end of the steam turbine. There are three main options commonly used for cooling power stations, as outlined below;

Cooling option	Description
Direct wet cooling	Water from the sea or river is passed once through the steam turbine condenser and is then returned directly to the source.
Indirect wet cooling	Cooling water is circulated many times around a separate closed loop cooling water circuit that incorporates cooling towers. A make-up flow is required to compensate for evaporative losses and the continuous purge flow that is required to prevent build-up of scaling deposits and loss of station efficiency. *Hybrid cooling* is also employed in which the water vapour plume from the plant is made less visible by introducing a flow of warm air.
Direct air cooling	Steam passes through finned tubes and is cooled by means of an induced air flow. This arrangement is often used in Combined Cycle Gas Turbines (CCGT).

A32.4 Optimal Water Use

Specific water consumption

Units are water consumed (i.e. lost to atmosphere) per Giga Watt generated per hour (m^3/GW/h)

Type	Units	SWC (Specific Water Consumption) Range	SWC (Specific Water Consumption) Best Practice
Coal			-
• Direct cooled	m^3/GWh	220 – 330[1,2]	-
• Indirect cooled	m^3/GWh	1280 - 2550[1,2]	-
Oil			
• Direct cooled	m^3/GWh	320 - 4600[1,2]	-
• Indirect cooled	m^3/GWh	-	-

Specific water abstraction

The figures for Specific Water Abstraction include water required for cooling, which is returned to the water source.

Type (Source)	Units	SWC (Specific Water Abstraction) Range	SWC (Specific Water Abstraction) Best Practice
Coal			
• Direct cooled (Sea)	m^3/GWh	12800 - 162000[1,2]	-
• Indirect cooled (River)	m^3/GWh	26000 - 3600000[1,2]	-
Oil			
• Direct cooled (Sea)	m^3/GWh	2500 - 6500[1,2]	-
• Indirect cooled	m^3/GWh	-	-

A32.5 Variables Affecting Optimal Water Use

- Gas powered stations use water for cooling. The figures quoted for oil burning may be used for a preliminary assessment

A32.6 Possible Optimisation Measures

- None currently identified.

A32.7 References

1. Private Communication with Alan Joslin. Generation Performance Engineer, National Power.

2. Towards a Waterless Power Station. PC Martin. PowerGen plc.

A33 PUBLIC SERVICES (SIC codes : 701, 806, 82)

A33.1 Type of Industry and Main Products

This covers a wide variety of services provided to the public e.g. schools, airports and hotels.

A33.2 Processing Steps

- Food preparation;
- Sanitary;
- Cleaning;
- Gardening.

A33.3 Water Use Steps

- Hotel
  - Food preparation;
  - Sanitary;
  - Cleaning;
  - Laundry;
  - Gardening.
- Airport
  - Food preparation;
  - Sanitary;
  - Wash-down / Cleaning of aircraft and other vehicles;
  - Landscaping;
  - Plane / vehicle washing.
- School
  - Food preparation;
  - Sanitary;
  - Cleaning;

- Laundry.

A33.4 Optimal Water Use

Type	Units	Performance	SWC (Specific Water Consumption) Range	SWC (Specific Water Consumption) Best Practice
Hotel	l/guest/d	Poor performance	500 - 600[1,2,3,4,5]	-
		Fair performance	440 - 500[1,2,3,4,5]	-
		Good performance	<440[1,2,3,4,5]	-
Airport	l/traveller/d	Poor performance	-	-
		Fair performance	40 – 160[1,2,3,4,5]	-
		Good performance	-	-
School	l/pupil/d	Poor performance	-	-
		Fair performance	58[1,2,3,4,5]	-
		Good performance	-	-

A33.5 Variables Affecting Optimal Water Use

- None currently identified.

A33.6 Possible Optimisation Measures

- Installation of water efficient sanitary ware, e.g. low-flush water closets;
- Automatic taps;
- Collection of rainwater;
- Grey water recycle;
- Educational initiatives.

A33.7 References

1. Ottawa International Airport, Environment Canada,

   http://www.ec.gc.ca/water/en/info/pubs/manual/cases/e_ottint.htm.1995.

2. Ottawa International Airport, Aviation Statistics, http://www.ottawa-airport.ca/c4-003.htm. 1995.

3. International Hotels Environment Initiative. http://www.hospitalitynet.nl/news/.

4. British Airways- Inside British Airways- Environment.

   http://www.british-airways.com/inside/comm/environ/docs/env4.shtml.

5. IK Mathieson, JW Knox, EK Weatherhead, J. Morris, DO Jones, AJ Yates, N Williams. Optimum Use of Water for Industry and Agriculture. Phase II Technical Report W243.

A34 PULP AND PAPERMAKING (SIC codes : 261, 262, 263)

A34.1 Type of Industry and Main Products

This is a wide and diverse industry supplying pulp to make a range of paper-based products.

A34.2 Processing Steps

- Pulping
  - Process is either achieved chemically (e.g. Kraft pulping) or mechanically. Choice of process is dependent on primary wood type. All processes have the same goal - to release the fibrous cellulose from its surrounding lignin. Fibres are bleached prior to papermaking.
- Papermaking
  - Beating - improves fibre qualities;
  - Pulp blending - to achieve desired properties;
  - Refining - addition of fillers, sizes and dyes;
  - Dewatering;
  - Drying;
  - Smoothing.

A34.3 Water Use Steps

- Pulping
  - Debarking
  - Mechanical pulping
  - Chemical pulping
  - Bleaching.
- Papermaking
  - De-inking (wastepaper only)
  - Steam raising
  - Cooling process.

A34.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption) Range	SWC (Specific Water Consumption) Best Practice
UK average (average over whole of industry)	m^3/t	35[1,2,3]	-
UK, well designed (production of paper from wastepaper)	m^3/t	3.72[1,2,3]	-
Netherlands average (Average of 18 mills)	m^3/t	8.5[1,2,3]	-
Fine Paper (Modern system with closed white-water system)	m^3/t	13.64[1,2,3]	-
Newsprint	m^3/t	2.27[1,2,3]	-
Packaging Board	m^3/t	1 - 50[4, 5] Mean = 14[4, 5]	-
Corrugated Case	m^3/t	2 – 46[4, 5] Mean = 23[4, 5]	-
Newsprint	m^3/t	Mean = 29[4, 5]	-
Printings/Writings	m^3/t	2 – 68[4, 5] Mean = 32[4, 5]	-
Tissue	m^3/t	44 – 75[4, 5] Mean = 60[4, 5] 8 - 50[7]	10 - 15[7]
Speciality	m^3/t	18 – 180[4, 5] Mean = 38[4, 5]	-
Pulp and paper mills	m^3/t	33 – 136[6]	-
Paper products factories	m^3/t	1 – 49[6]	-

A34.5 Variables Affecting Optimal Water Use

- Tree species;
- Pulp material;
- Efficiency of the mill in terms of process control and operation;
- Paper product produced;
- Degree of chemical recovery;
- Degree of waste-water treatment.

A34.6 Possible Optimisation Measures

- Closed circuit is feasible and has been demonstrated in Canada (dependant on paper quality);
- Mechanical seals rather than liquid seals on pumps;
- Close-up bleaching operation by use of chlorine-free bleach;

- Reduced water use can result in increased discharge levels and non-compliance with discharge standards;

- Improve white water systems

  - correct design and sizing;

  - separate white water systems for each paper machine;

  - storing pulp at a higher consistency;

  - effective maintenance and operation of fibre recovery systems.

- White water recycling

  - dilution of fibre raw materials;

  - dilution of fillers.

- Shower water systems

  - use of white water rather than fresh water. Not suitable for all locations.

A34.7 References

1. The Demand for Water by the Paper and Board Industry in England and Wales. Central Water Planning Unit, Reading. Technical Note 31. 1979.

2. Water Use and Reuse in Paper/Board making. Webb, L J. RSC Annual Congress, 'The Chemistry of Water Use and Reuse'. 1985.

3. IK Mathieson, JW Knox, EK Weatherhead, J. Morris, DO Jones, AJ Yates, N Williams. Optimum Use of Water for Industry and Agriculture. Phase II Technical Report W243.

4. Environmental Technology Best Practice Programme, (1998), Practical Water Management in Paper and Board Mills, Guide GG111.

5. Environmental Technology Best Practice Programme, (1997), Water Use in UK Paper and Board Manufacture, Guide EG69.

6. Steffen, Robertson & Kirsten Inc, Consulting Engineers, (1990), Water and Waste-Water Management in the Paper and Pulp Industry (Natsurv 12), prepared for the Water Research Commission, WRC Project No 145, TT 49/90.

7. Private Communication From Kimberly-Clark.

8. Dee Catchment Waste Minimisation Report, October 1997, The Environment Agency (Telephone 01248 670770).

A35 QUARRIES (SIC codes : 142, 144)

A35.1 Type of Industry and Main Products

This industry extracts and processes minerals for use in the construction industry. Quarries are classified as 'hard rock' (limestone, basalt, graphite) or 'sand and gravel'.

A35.2 Processing Steps

- Extraction;
- Washing;
- Drying (industrial silica sand);
- Classification.

A35.3 Water Use Steps

During processing in sand and gravel quarries, water is used for:

- washing out of clays and silts (fines);
- washing out of lignite;
- classification (separation) of the different sizes of sand particles;
- dust suppression;
- wheel washing of site vehicles;
- drying of sand.

During processing in hard rock quarries, water is used for:

- wheel washing;
- washing for ballast used in rail track bedding.

A35.4 Optimal Water Use

Type	Product	Units	SWC (Specific Water Consumption)
Sand and Gravel	Industrial Sand	m^3/t	0.61[4]
	Washed sand and gravel	m^3/t	0.02[4]

A35.5 Variables Affecting Optimal Water Use

- Collection efficiency;
- Treatment efficiency;
- Geographic location;
- Depth of quarry – some may require water abstraction to prevent flooding. Others may be a net 'producer' of water as the workings are below the local water table. If this discharge is back to the aquifer from which the water was originally abstracted then there is, in effect, no net usage of water by the quarry;
- Quality and type of deposits – fines content will affect water volume required for washing.

A35.6 Possible Optimisation Measures

- The main factors determining water usage are detailed above and are very specific to the particular type of quarry, its location and products;
- Process efficiency of the usage of water depends upon the efficiency of collection, treatment (usually settling in lagoons) and re-use of the water;
- Re-use of water used to wash sand and gravel;
- Re-use of water produced during drying process.

A35.7 References

1. Dee Catchment Waste Minimisation Report, October 1997, The Environment Agency (Telephone 01248 670770).
2. Private Communication From Tarmac Quarry Products.
3. IK Mathieson, JW Knox, EK Weatherhead, J. Morris, DO Jones, AJ Yates, N Williams. Optimum Use of Water for Industry and Agriculture. Phase II Technical Report W243.
4. Technical Report W6-056/TR1 -Appendix A4. Company D and E water survey reports.

A36 SEMICONDUCTOR WAFER FABRICATION (SIC code : 367)

A36.1 Type of Industry and Main Products

Semiconductors are generated for the computer and electronic industry.

A36.2 Processing Steps

The fabrication of integrated circuits for the semiconductor industry can take up to five weeks to complete in a complex and highly expensive operation involving up to one hundred stages.

A36.3 Water Use Steps

- Rinsing of wafers;
- Actual demand on municipal water supply is approximately 25% greater than the quantity of UPW (Ultra Pure Water), due to losses in the water purification step.

A36.4 Optimal Water Use

Ultra Pure Water (UPW) consumption,

Type	Units	SWC (Specific Water Consumption) Range	SWC (Specific Water Consumption) Best Practice
Semiconductor Wafer	m^3/m^2	56 – 345[1,2]	-

A36.5 Variables Affecting Optimal Water Use

- The amount of UPW used per wafer varies from site to site, from company to company, and with wafer size.

A36.6 Possible Optimisation Measures

- Rinse Water Reduction
  - Spray rinsing vs. overflow;
  - Rinse tank geometry improvements;
  - Hot UPW instead of cold UPW;
  - Megasonic rinsing;
  - Idle flow rate reduction.

- Water reclamation/reuse
  - Reuse of water in cooling towers and air scrubbers;
  - Recycle of spent rinse water back into UPW treatment system;
  - Analytical instrument discharge for various uses.
- Risks associated with water recycling
  - The introduction of impurity spikes into the system;
  - The build-up of recalcitrant compounds;
  - Inadequacy of present purification methods in removing process generated compounds;
  - Risk of new chemical interactions caused by recycle;
  - Contamination due to biofouling.

A36.7 References

1. Recovery, Reuse and Recycle of Water in Semiconductor Wafer Fabrication Facilities. John DeGenova. Environmental Progress (Vol 16, No.4,). 1997.
2. Printed Wiring Boards Cleaner Technologies Substitutes Assessment: Making Holes Conductive. US EPA. http://www.epa.gov/opptintr/dfe/pwb/ctsa/exsum/exsum.htm.

A37 STEEL MANUFACTURE (SIC code : 331)

A37.1 Type of Industry and Main Products

A wide and diverse industry providing a range of steel products for industry.

A37.2 Processing Steps

- Coke manufacturing
  - Prepared from high quality coal, heated for 18 hours.
- Ore preparation and sintering
  - Ore is passed beneath a sintering hood that produces an iron-rich material called sinter.
- De-sulphurisation
  - By injection of magnesium.
- Basic oxygen steel making
  - Oxygen is blown across the surface of the molten iron to oxidise unwanted elements, thus enabling them to be removed as gas or slag. Ferro-alloy additions are made as necessary to make the required steel composition.
- Slag removal
- Final specification
  - Molten steel is stirred with argon and trimmed as necessary for final specification. Vacuum degassing removes dissolved gases that are unwanted in the final steel product.
- Casting
  - Steel is cast into billets, blooms or slabs, or teemed into ingots.
- Milling
  - Steel billets are sold direct to customers. Slabs, blooms and ingots are rolled into finished products

A37.3 Water Use Steps

- Coke ovens;
- Sinter and ore preparation;

- Blast furnaces;
- Basic oxygen steel making;
- Continuous casting;
- Milling;
- Steam generation;
- Domestic.

A37.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption) Range	SWC (Specific Water Consumption) Best Practice
Steel making	m^3/t	2.8[1] – 100[2]	-

A37.5 Variables Affecting Optimal Water Use

- None currently identified.

A37.6 Possible Optimisation Measures

- Cooling water recycling;
- Cascade use of water;
- System / leakage monitoring – particularly at large and complicated sites.

A37.7 References

1. Water Minimisation in Steel Manufacturing. Alva Argaez, A. Umist MSc Thesis.
2. European Integrated Pollution Prevention and Control Bureau, (2000), Reference Document on Best Available Techniques for Steel Making Industry, pp 23, October 2000.

A38 TEXTILE MANUFACTURE (SIC codes : 221 - 229)

A38.1 Type of Industry and Main Products

In its broadest sense, the textile industry includes the production of yarn, fabric and finished goods.

A38.2 Processing Steps [1, 2, 3]

Natural fibres

- Yarn formation - textile fibres are converted into yarn by grouping and twisting operations used to bind them together. Natural fibres are processed as follows:
    - opening/blending - bales of fibres are separated;
    - carding - fibres are mechanically aligned into parallel sheets;
    - combing - similar operation to carding;
    - drawing - fibres are combined and stretched into a rope-like strand. Blending of fibres may occur;
    - drafting - yarn is stretched further on a frame;
    - spinning - fibres are spun together into yarn.
- Fabric formation - the major methods of fabric formation are weaving and knitting. Yarn is normally coated with a size solution before processing to prevent snagging and abrasion.
- Wet processing - woven and knit fabrics cannot be processed into apparel and other finished goods until the fabrics have passed through several water intensive wet processing stages. Wet processing involves the following stages:
    - singeing - protruding fibres are burnt to give the fabric a smooth finish;
    - desizing - size solution is removed by enzymatic action;
    - scouring - fabric is cleaned using alkali solution;
    - bleaching - decolourises fabric prior to printing;
    - mercerising - improves dyeability of cotton goods;
    - dyeing - addition of colour to the textile. Many different methods are available;
    - printing - variety of techniques including rotary screen, direct, discharge, resist, ink-jet and heat transfer;

- finishing - chemical and mechanical treatments performed on the yarn or fabric to improve appearance, texture or performance.

Man-made fibres

- Viscose fibres - regenerated cellulose fibres derived from wood pulp. Typical processing is as follows:

  - pulping of wood;
  - purification of pulp - bleaching and pressing operations;
  - alkalisation - loosen cellulose fibres by immersion in alkali;
  - shredding.
  - ageing/preripening;
  - xanthanation - formation of cellulose xanthanate by reaction with carbon disulphide that is then dissolved in a weak solution of caustic soda;
  - spinning - viscose solution is extruded into an acid bath;
  - after treatment - filaments are stretched, washed, twisted and wound on to bobbins.

- Acrylic - acrylic or polyacrylic is a fibre produced from acrylonitrile by forcing the acrylonitrile to undergo a polymerisation reaction with various combinations of styrene, vinyl acetate, vinyl bromide, and vinyl chloride in the presence of an activator, and a catalyst. The resulting polymer is shaped into fibre by dry or wet spinning. After treatments include washing, drawing, finishing and crimping.

A38.3 Water Use Steps

- Fabric or yarn pre-cleaning and rinsing prior to dyeing;
- Dyeing or printing operation, soaping and after-treatment;
- Rinsing;
- Wash water;
- Domestic.

A38.4 Optimal Water Use

SWC values are given in m^3/tonne unless otherwise stated.

Type	Process	Units	SWC (Specific Water Consumption) Average / Range	SWC (Specific Water Consumption) Best Practice
Cotton	De-sizing	m^3/t	3 - 9[1,2,3]	-
	Scouring or kiering	m^3/t	26 - 43[1,2,3]	-
	Bleaching	m^3/t	3 - 124[1,2,3]	-
	Mercerising	m^3/t	232 - 308[1,2,3]	-
	Dyeing	m^3/t	8 - 300[1,2,3]	-
Wool	Scouring	m^3/t	46 - 100[1,2,3]	-
	Dyeing	m^3/t	16 - 22[1,2,3]	-
	Washing	m^3/t	334 - 835[1,2,3]	-
	Neutralisation	m^3/t	104 - 131[1,2,3]	-
	Bleaching	m^3/t	3 - 22[1,2,3]	-
Nylon	Scouring	m^3/t	50 - 67[1,2,3]	-
	Dyeing	m^3/t	17 - 33[1,2,3]	-
Acrylic	Scouring	m^3/t	50 - 67[1,2,3]	-
	Dyeing	m^3/t	17 - 33[1,2,3]	-
	Final scour	m^3/t	67 - 83[1,2,3]	-
Polyester	Scouring	m^3/t	25 - 42[1,2,3]	-
	Dyeing	m^3/t	17 - 33[1,2,3]	-
	Final scour	m^3/t	17 - 33[1,2,3]	-
Viscose	Scouring and dyeing	m^3/t	17 - 33[1,2,3]	-
	Salt bath	m^3/t	4 - 13[1,2,3]	-
Acetate	Scouring and dyeing	m^3/t	33 - 50[1,2,3]	-
Woven cloth	Preparation	m^3/km	9[4]	2[4]
	Batch dyeing	m^3/km	17[4]	2[4]
	Continuous	m^3/km	31[4]	7[4]
	Printing	m^3/km	40[4]	2[4]
	Printing with wash off	m^3/km	11[4]	10[4]
	Finishing	m^3/km	4[4]	1[4]
	Overall process	m^3/km	37[4]	1[4]
Fibre and yarn	Batch dyeing	m^3/t	63[4]	-
	Finishing	m^3/t	-	4[4]
	Overall process	m^3/t	65[4]	4[4]
Knitted cloth	Preparation	m^3/t	45[4]	27[4]
	Batch dyeing	m^3/t	98[4]	52[4]
	Finishing	m^3/t	4.5[4]	0.8[4]
	Overall process	m^3/t	142[4]	70[4]
Garments	Overall process	m^3/t	161[4]	66[4]
Fine wool *	Overall process	m^3/t	2 – 10[7]	-
Coarse wool *	Overall process	m^3/t	1 - 13[7]	-
Wool scouring*	Overall process	m^3/t	20 – 30[7]	-
Loose fibre dye houses	Overall process	m^3/t	28 – 54[7]	-
Yarn dye houses	Overall process	m^3/t	17 – 22[7]	-

* The water consumption has been compared to raw product rather than final product.

A38.5 Variables Affecting Optimal Water Use

- Types of process and fabrics;
- Production processes either dry (garment manufacture) or wet (dyeing);
- Type of dye stuff used;
- Season and market demand;
- Number of employees.

A38.6 Possible Optimisation Measures

- Reduce the number of process steps [5];
- Optimise and reuse rinse water [5, 6];
- Move from batch to continuous processing;
- Improved understanding of water use at each stage of the process [6.]

A38.7 References

1. Environmental Project No. 369 - Environmental Assessment of Textiles, 1997. Danish EPA

2. Water Conservation for Textile Mills. DEHNR. http://www.owr.ehnr.state.nc.us/ref/00026.htm

3. Cleaner Production in Wool Scouring. Environet Australia. http://www.environment.gov.au/portfolio/epg/environet/ncpd/auscas_studies/conagra.htm. 1992

4. Case Study CS533. Nordic Project on Water Used Reduction in Textile Industries. Envirosense. http://es.epa.gov/studies/cs533.html

5. Profile of the Textile Industry - Sector Notebook Project. EPA Office of Compliance. EPA/310-R-97-009. 1997

6. Water not Wasted. L.G.Almeida and M.T.Amorim, Centre de Technologia Textil, Portugal. Textile Asia. Jan-88

7. Textile Research Conference, The Use of Water by the Textile Industry. Scottish College of Textiles. Wira, Leeds. 1973

8. The Textile Industry and the Environment. UNEP. United Nations Publication. 1994

9. Water and Wastewater Management in the Textile Industry. Environmental Technology Vol 15, p917 - 929

10. Washing Machine Energy Information Data. Creda.

11. IK Mathieson, JW Knox, EK Weatherhead, J. Morris, DO Jones, AJ Yates, N Williams. Optimum Use of Water for Industry and Agriculture. Phase II Technical Report W243..

12. Water Use in Textile Dyeing and Finishing ETBBP (EG98)

13. Environmental Technology Best Practice Programme, (1997) Water Use in Textile Dyeing and Finishing, Guide EG98.

14. Environmental Technology Best Practice Programme, (1997), Water and Chemical use in the Textile Dyeing and Finishing Industry, Guide GG62.

15. Steffen, Robertson & Kirsten Inc, Consulting Engineers, (1993), Water and Waste-Water Management in the Textile Industry (Natsurv 13), prepared for the Water Research Commission, WRC Project No 145, TT 50/90.

16. European Integrated Pollution Prevention and Control Bureau, (2001), Reference Document on Best Available Techniques for the Textile Industry, pp 115-147, February 2001.

A39 VEHICLE MANUFACTURE (SIC code : 371)

A39.1 Type of Industry and Main Products

Motor vehicle manufacture will range from engines and passenger cars, through to large coaches or trucks.

A39.2 Processing Steps

- Not currently identified.

A39.3 Water Use Steps

- Engine test bed cooling;
- Production;
- Domestic.

A39.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption) Average / Range	SWC (Specific Water Consumption) Best Practice
Passenger vehicle (car)	m^3/vehicle	2.6 - 8.0[1,2,3,4]	-
Commercial vehicle	m^3/vehicle	12 - 16.0[1,2,3,4]	-
Engine manufacture	m^3/vehicle	0.04[1,2,3,4]	-

A39.5 Variables Affecting Optimal Water Use

- None currently identified.

A39.6 Possible Optimisation Measures

- Cooling water recycle;
- Cascade rinsing in metal finishing operations.

A39.7 References

1. Cleaner Production demonstration at Holden's Engine Company, Port Melbourne, Victoria. Environet Australia. 1995. http://www.environment.gov.au/portfolio/epg/environet/ncpd/.

2. Daimler-Benz, Environmental Report 1997.

3. A. C. Twort, R. C. Hoather, F. M. Law. Water Supply. Edward Arnold(Publishers) Ltd.

4. Fax from Corporate Communications, Volvo Car Corporation.

A40 WALLCOVERINGS (SIC code : 267)

A40.1 Type of Industry and Main Products

The basic process consists of coating and printing paper to produce the product which is then cut and assembled as a roll.

A40.2 Processing Steps

The exact nature of the coating and printing depends upon the specification of the product designs that are constantly changing to meet the fashion demands of the market.

A40.3 Water Use Steps

- Preparation of coating agents;
- Wash down;
- Cooling;
- Steam heating;
- Domestic.

A40.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption) Range	SWC (Specific Water Consumption) Best Practice
Typical	l/roll	1 – 5[1]	-

A40.5 Variables Affecting Optimal Water Use

- None currently identified.

A40.6 Possible Optimisation Measures

- Efficient cleaning methods and coating make-up procedures;
- Recycling of cooling water;
- Efficient steam system, including condensate return and minimum leaks.

A40.7 References

1. Fax from Peter Gleaves, Borden Decorative Products Ltd.

A41 WASTE INCINERATION (SIC code : 496)

A41.1 Type of Industry and Main Products

Waste incineration is a method of disposing of waste. It does not have a specific product but will have a number of waste products, such as ash.

A41.2 Processing Steps

- The waste is received and a sample is taken to assess the suitability of the waste to be incinerated and the likely gases to be evolved;
- It may then be necessary to mix several different wastes to form a liquor suitable for feed to the incinerator;
- Sometimes the feed to the incinerator is supplemented with a fuel to aid ignition.

A41.3 Water Use Steps

- Boiler makeup;
- Cleaning;
- Domestic.

A41.4 Optimal Water Use

Type	Units	SWC (Specific Water Consumption) Typical	SWC (Specific Water Consumption) Best Practice
Typical	m^3/t	0.32[1]	-

A41.5 Variables Affecting Optimal Water Use

- None currently identified.

A41.6 Possible Optimisation Measures

- Efficient steam system, including condensate return and minimum leaks.

A41.7 References

1. IK Mathieson, JW Knox, EK Weatherhead, J. Morris, DO Jones, AJ Yates, N Williams. Optimum Use of Water for Industry and Agriculture. Phase II Technical Report W243.

APPENDIX A: Conversion Table

Conversion Table

LENGTH		
1 centimetre (cm)	= 10 mm	= 0.3937 in
1 metre (m)	= 100 cm	= 1.0936 yd
1 kilometre (km)	= 1000 m	= 0.6214 mile
1 inch (in)		= 2.54 cm
1 yard (yd)	= 36 in	= 0.9144 m
1 mile	= 1760 yd	= 1.6093 km
AREA		
1 sq cm (cm^2)	= 100 mm^2	= 0.1550 in^2
1 sq metre (m^2)	= 10 000 cm^2	= 1.1960 yd^2
1 sq km (km^2)	= 100 ha	= 0.3861 $mile^2$
1 sq in (in^2)		= 6.4516 cm^2
1 sq yard (yd^2)	= 9ft^2	= 0.8361 m^2
1 sq mile ($mile^2$)	= 640 acres	= 2.59 km^2
VOLUME		
1 cu cm (cm^3)		= 0.0610 in^3
1 cu metre (m^3)	= 1000 dm^3	= 1.3080 yd^3
1 cu metre	= 1000 litres	
1mm ha	=10m^3 (1mm of irrigation over 1 hectare)	
1 litre (l)	= 1 dm^3	= 0.2200 gal
1 hectolitre (hl)	= 100 l	= 21.997 gal
1 cu inch (in^3)		= 16.387 cm^3
1 cu yard (yd^3)	= 27ft^3	= 0.7646 m^3
1 pint (pt)	= 20 fl oz	= 0.5683 l
1 gallon (gal)	= 8 pt	= 4.546 l
WEIGHT		
1 gram (g)	= 1000 mg	= 0.0353 oz
1 kilogram (kg)	= 1000 g	= 2.2046 lb
1 tonne (t)	= 1000 kg	= 0.9842 ton
1 m^3 of water	= 1 tonne	
1 ounce (oz)	= 437.5 grains	= 28.35 g
1 pound (lb)	= 16 oz	= 0.4536 kg
1 ton	= 20 cwt	= 1.016 t

PART B: AGRICULTURAL COMPONENT

B1 IRRIGATION OF OUTDOOR CROPS

B1.1 Revised Irrigation "Look Up" Tables: Agronomic Optima

The Phase II methodology introduced a series of "look up" tables that summarised the optimum irrigation needs for different crop/soil/agroclimates. These data were based on an irrigation scheduling water balance model that took into account local soil type, crop type, standard recommended irrigation plans (for that crop on that soil) and local climate.

A detailed explanation of the methodology is given in the Phase II Technical Report.

In this study, those optimum irrigation needs have been redefined as "agronomic optima". Agronomic optima are independent of irrigation costs and benefits which are unique to a particular farm, and are a useful first stage in the overall methodology. They are also more likely to remain constant over time than economic needs or farmers' actual applications.

The 22 modelled crop types and the three different soil types, representing soils of low, medium and high available water capacities (AWC) are presented in Table 2 and Table 3, respectively.

The revised irrigation "look up" tables summarising the agronomic optima for the "design dry" year, by crop category against agroclimatic zone for each soil type, are shown in Table 4.

The definition for "design dry" year is unchanged, namely:

- the "design dry" year irrigation needs are defined as the 80% non-exceedance level, i.e. meeting the irrigation need for 80 years in 100.

The 7 agroclimatic zones remain identical to those presented in the Phase II study, defined in terms of potential soil moisture deficit (Table 5). The zones have been mapped for each Environment Agency Region. Sample maps, reduced to A4 size, are shown in Figure 1 to 8 for each Environment Agency Region.

A1 size laminated agroclimatic zone maps were produced for each Environment Agency Region in Phase II, for wall mounting. The maps were also provided on CD.

A worked example on how to use the look up tables is provided in Section B1.5.

.

Table 2 Crop categories and crop types modelled

Crop category	Crop type	Latin name
Potatoes	Maincrop potatoes	*Solanum tuberosum*
	Early potatoes	*Solanum tuberosum*
Sugar beet	Sugar beet	*Beta vulgaris*
Vegetables*	Calabrese (green sprouting broccoli)	*Brassica oleracea italica*
	Brussels sprouts	*Brassica oleracea gemmifera*
	Cabbage	*Brassica oleracea capitata*
	Carrots	*Daucus carota*
	Cauliflower	*Brassica oleracea botrytis*
	Onions (autumn)	*Allium cepa*
	Parsnips	*Pastinaca sativa*
	Peas (vining)	*Pisum sativum*
	Runner beans	*Phaseolus coccineeus*
Salad crops *	Lettuce (summer)	*Lactuca sativa*
	Salad onions	*Allium cepa*
Orchard fruit	Apples (mature)	*Malus spp*.
	Pears	*Pyrus communis*
	Plums	*Prunus spp.*
Small fruit	Strawberries	*Fragaria spp*.
	Raspberries	*Rubus idaeus*
	Blackcurrants	*Ribes nigrum*
Grassland	Permanent grazed	*Lolium mulitflorum*
Cereals	Spring cereals	*Hordeum spp*.

* grown in the open

Table 3 Soil moisture properties of typical soils (adapted from MAFF, 1984)

Soil AWC	Definition	Typical soils
Low AWC	AWC <12.5% by volume (not more than 125mm per 1m depth)	Coarse sand Loamy coarse sand Coarse sandy loam
Medium AWC	AWC >12.5% by volume but < 20% by volume (more than 125 mm but less than 200mm per 1m depth)	Sand Loamy sand Fine sand Loamy fine sand Clay Sandy clay Silty clay Clay loam Sandy loam Sandy clay loam Silty clay loam Fine sandy loam Loam
High AWC soil	AWC > 20% by volume (greater than 200 mm per 1m soil depth)	Very fine sand Loamy very fine sand Very fine sandy loam Silt loam Silty loam Peaty soils

Note:

Available water is less with increased stones, higher bulk densities (increased compaction) and reduced organic matter. Thus topsoils tend to have higher AWC's than subsoils of similar texture.

Table 4 'Look up' table summarising the agronomic optimum irrigation needs (mm) in a design dry year, by crop category, by soil AWC type, for each agroclimatic zone

Low AWC soil – design dry year

Crop category	Crop type	Agroclimatic zone						
		1	2	3	4	5	6	7
Potatoes	Maincrop	170	185	200	215	225	240	255
	Early	90	95	100	105	110	115	120
Sugar beet	Sugar beet	115	130	140	155	170	180	195
Vegetables*	Broccoli	75	85	90	100	105	110	120
	Brussels sprouts	80	85	90	95	105	110	115
	Cabbage	165	175	190	200	210	220	235
	Carrots	140	155	170	180	195	210	220
	Cauliflower	175	185	195	210	220	235	245
	Onions	125	135	145	150	160	170	180
	Parsnips	145	155	170	180	195	210	220
	Peas (vining)	65	70	75	80	85	90	95
	Runner beans	160	175	185	200	210	225	235
Salad crops*	Lettuce	160	170	175	185	195	205	215
	Salad onions	110	120	130	140	150	155	165
Orchard fruit	Apples (mature)	100	115	125	135	145	160	170
	Pears/plums	***	***	***	***	***	***	***
Small fruit	Strawberries	225	225	235	240	240	245	250
	Raspberries	150	160	170	180	190	205	215
	Blackcurrants	150	160	170	180	195	205	215
Grassland	Grazed grass	175	190	205	220	235	255	270
Cereals	Spring cereals	100	110	125	135	145	155	165

Notes:

* grown in the open

** assumes double cropping i.e. two crops grown in a single season

*** as for apples

Table 4 (continued) **'Look up' table summarising the agronomic optimum irrigation needs (mm) in a design dry year, by crop category, by soil AWC type, for each agroclimatic zone**

Medium AWC soil – design dry year

Crop category	Crop type	Agroclimatic zone						
		1	2	3	4	5	6	7
Potatoes	Maincrop	150	165	175	190	205	220	235
	Early	90	95	100	105	110	115	120
Sugar beet	Sugar beet	100	110	120	135	145	155	170
Vegetables*	Broccoli	65	70	80	85	90	100	105
	Brussels sprouts	75	80	90	95	100	110	115
	Cabbage	150	165	175	185	195	210	220
	Carrots	140	155	170	180	195	205	220
	Cauliflower	160	175	185	195	210	220	230
	Onions	95	105	110	120	125	135	140
	Parsnips	115	125	140	150	165	175	190
	Peas (vining)	65	70	75	80	80	85	90
	Runner beans	165	175	190	200	215	225	235
Salad crops*	Lettuce	150	160	170	180	190	200	210
	Salad onions	110	115	125	135	145	150	160
Orchard fruit	Apples (mature)	75	85	95	105	115	130	140
	Pears/plums	***	***	***	***	***	***	***
Small fruit	Strawberries	220	225	225	235	240	245	250
	Raspberries	145	160	170	180	190	200	215
	Blackcurrants	145	155	170	180	190	200	215
Grassland	Grazed grass	170	185	200	215	230	245	260
Cereals	Spring cereals	65	75	80	90	100	110	120

Notes:

* grown in the open

** assumes double cropping i.e. two crops grown in a single season

*** as for apples

Table 4 (continued) **'Look up' table summarising the agronomic optimum irrigation needs (mm) in a design dry year, by crop category, by soil AWC type, for each agroclimatic zone**

High AWC soil – design dry year

Crop category	Crop type	Agroclimatic zone						
		1	2	3	4	5	6	7
Potatoes	Maincrop	115	130	145	160	175	190	200
	Early	85	90	95	100	105	110	115
Sugar beet	Sugar beet	45	55	65	75	85	95	105
Vegetables*	Broccoli	35	40	45	50	55	60	65
	Brussels sprouts	70	75	85	90	95	105	110
	Cabbage	125	135	150	160	170	180	190
	Carrots	125	140	155	165	180	195	210
	Cauliflower	135	145	160	170	185	195	205
	Onions	65	70	80	85	90	100	105
	Parsnips	95	105	115	130	140	155	165
	Peas (vining)	55	65	70	75	80	85	90
	Runner beans	155	170	180	195	205	220	230
Salad crops*	Lettuce	150	155	165	175	180	190	200
	Salad onions	105	115	125	135	140	150	160
Orchard fruit	Apples (mature)	60	70	80	90	100	115	125
	Pears/plums	***	***	***	***	***	***	***
Small fruit	Strawberries	215	225	225	235	240	245	250
	Raspberries	140	150	160	170	185	195	205
	Blackcurrants	140	150	165	175	185	200	210
Grassland	Grazed grass	155	170	185	200	220	235	250
Cereals	Spring cereals	15	20	30	35	40	45	50

Notes:

* grown in the open

** assumes double cropping i.e. two crops grown in a single season

*** as for apples

Table 5 Classification of agroclimatic zones

Agroclimatic zone	PSMDg (mm)*
1	0 – 75
2	76 – 100
3	101 – 125
4	126 – 150
5	151 – 175
6	176 – 200
7	> 200

Note:
* PSMDg, potential soil moisture deficit for grass

Figure 1 Sample map (reduced scale) showing the agroclimatic zones for EA Wales

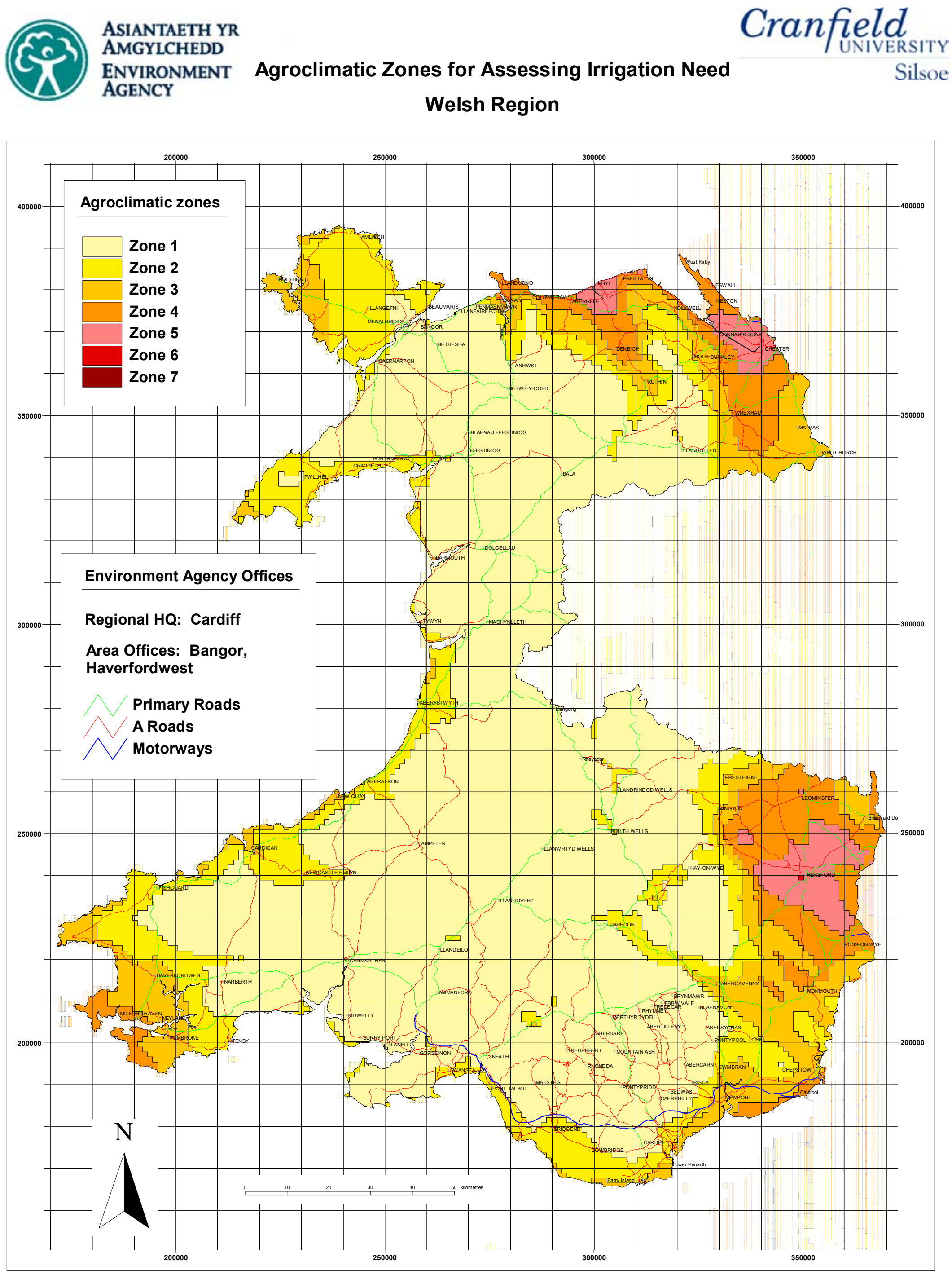


Figure 2 Sample map (reduced scale) showing the agroclimatic zones for Anglian Region

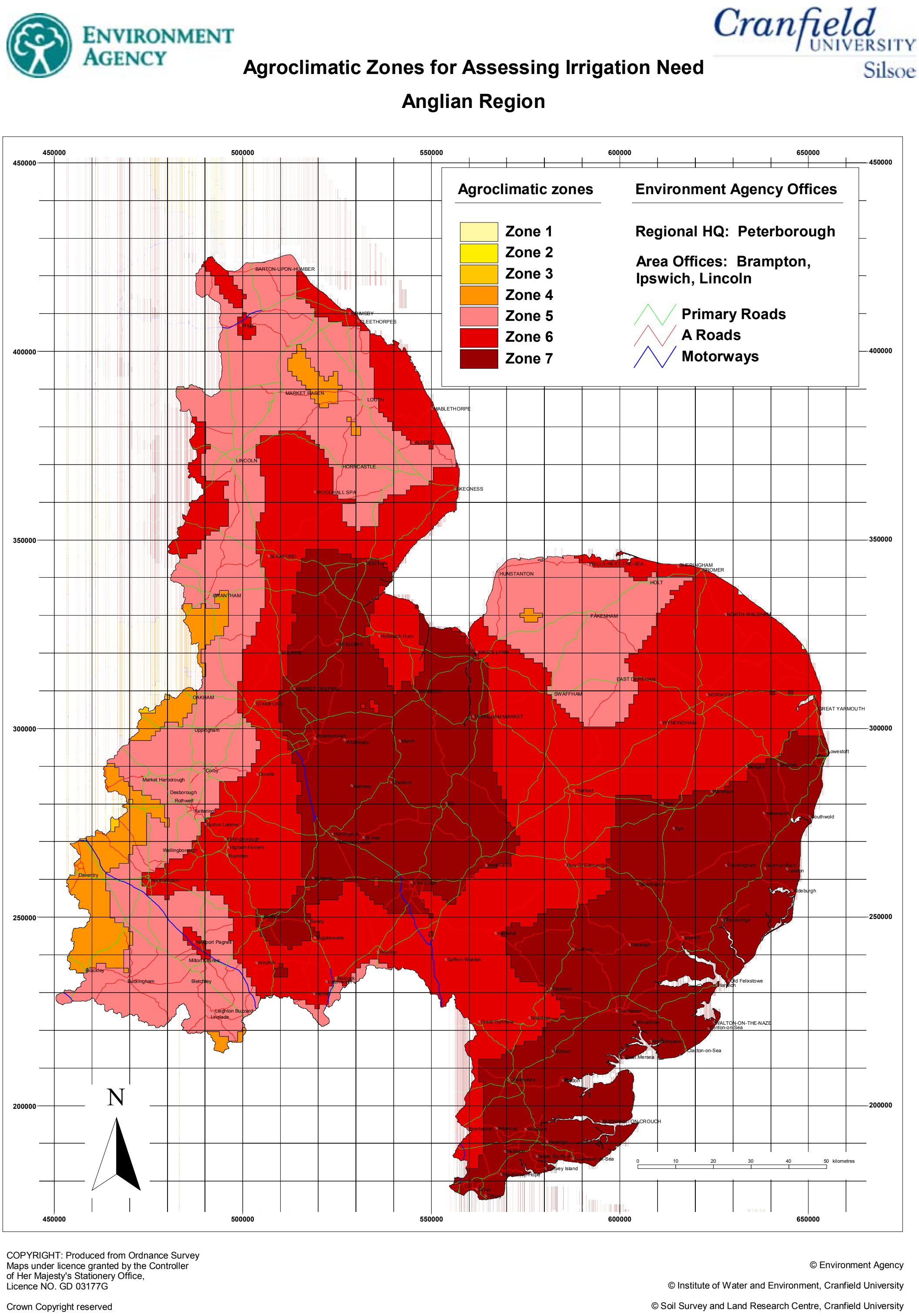


Figure 3 Sample map (reduced scale) showing the agroclimatic zones for Midlands Region

Agroclimatic Zones for Assessing Irrigation Need

Midlands Region

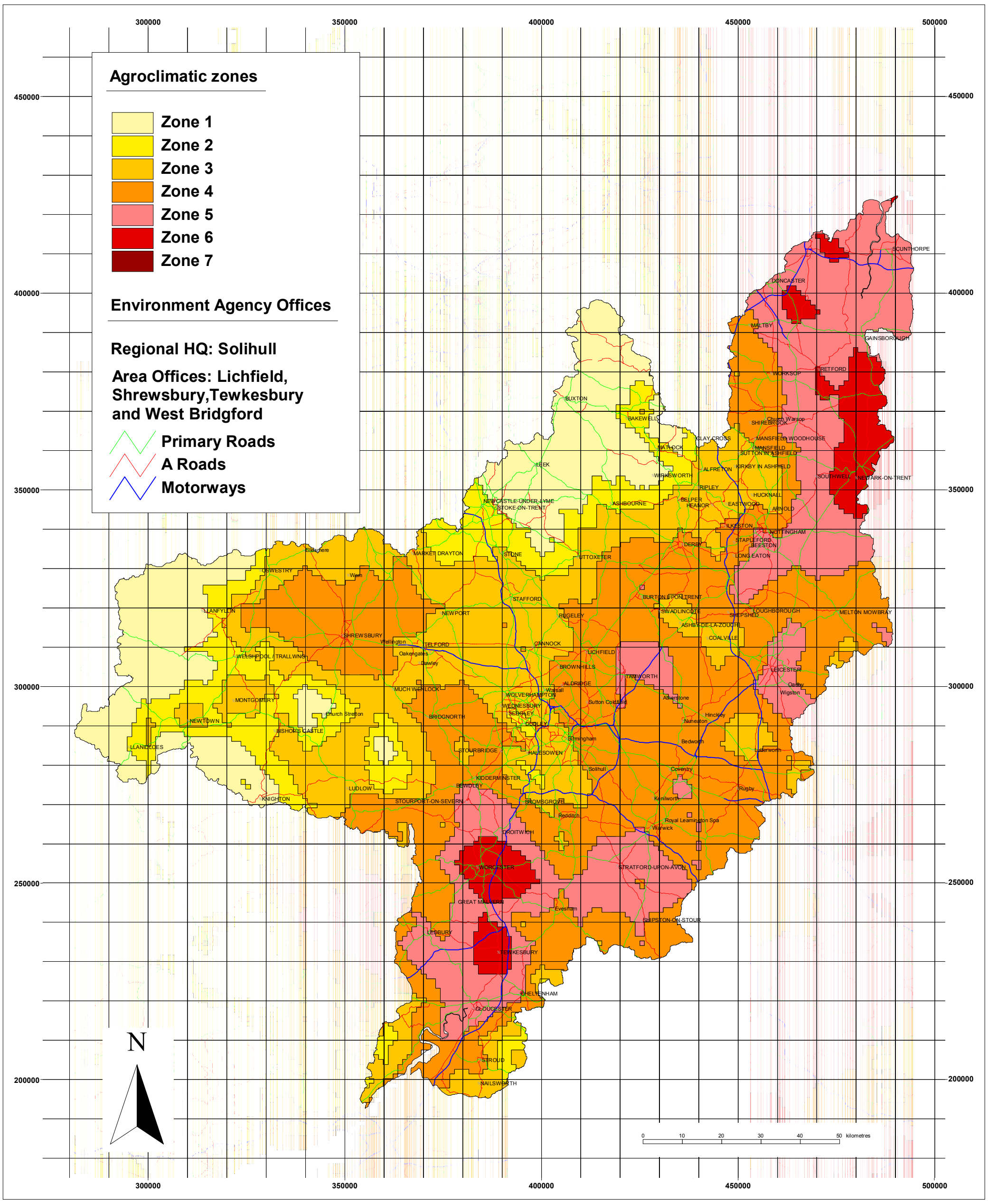


Figure 4 Sample map (reduced scale) showing the agroclimatic zones for North East Region

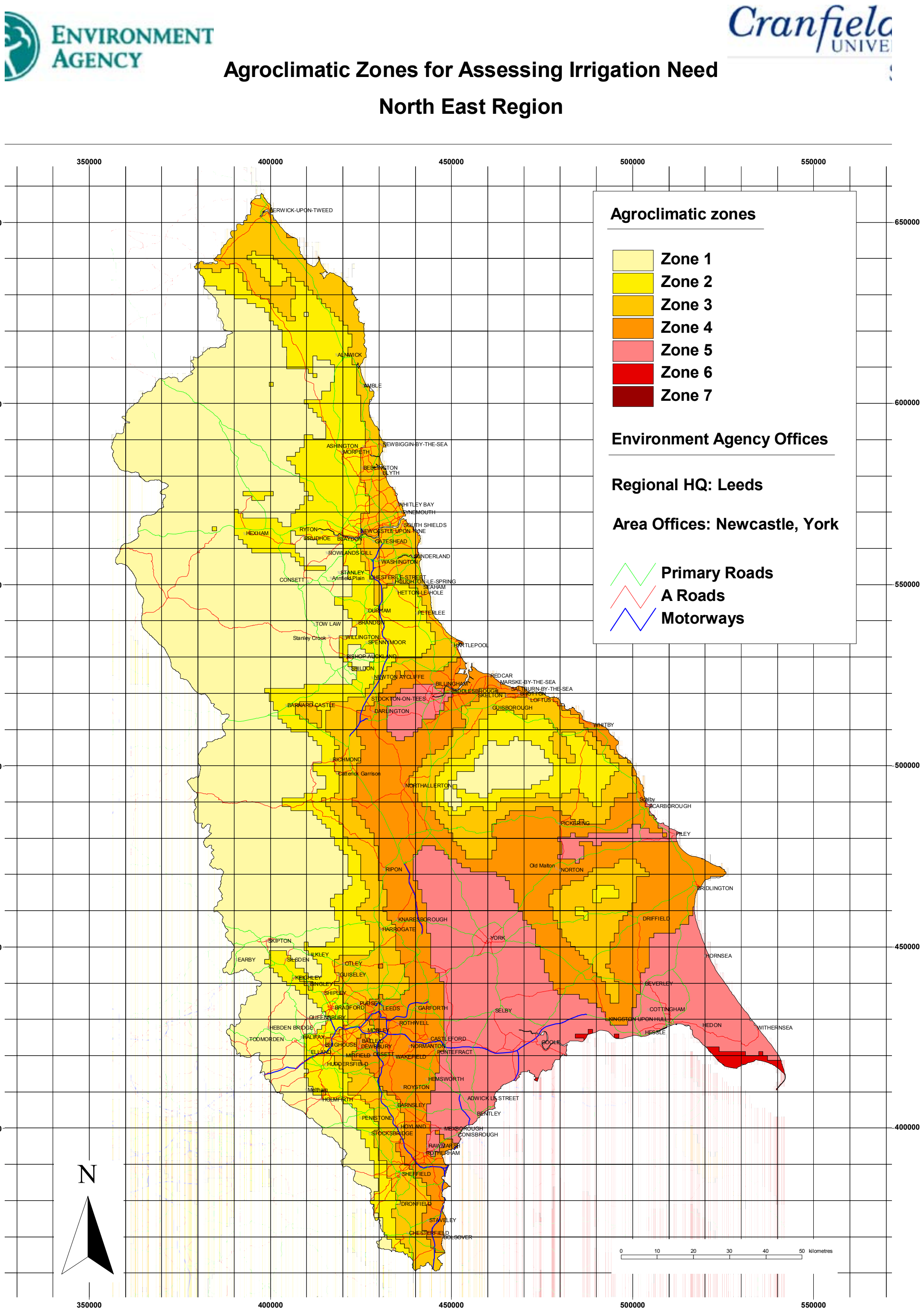


Figure 5 Sample map (reduced scale) showing the agroclimatic zones for North West Region

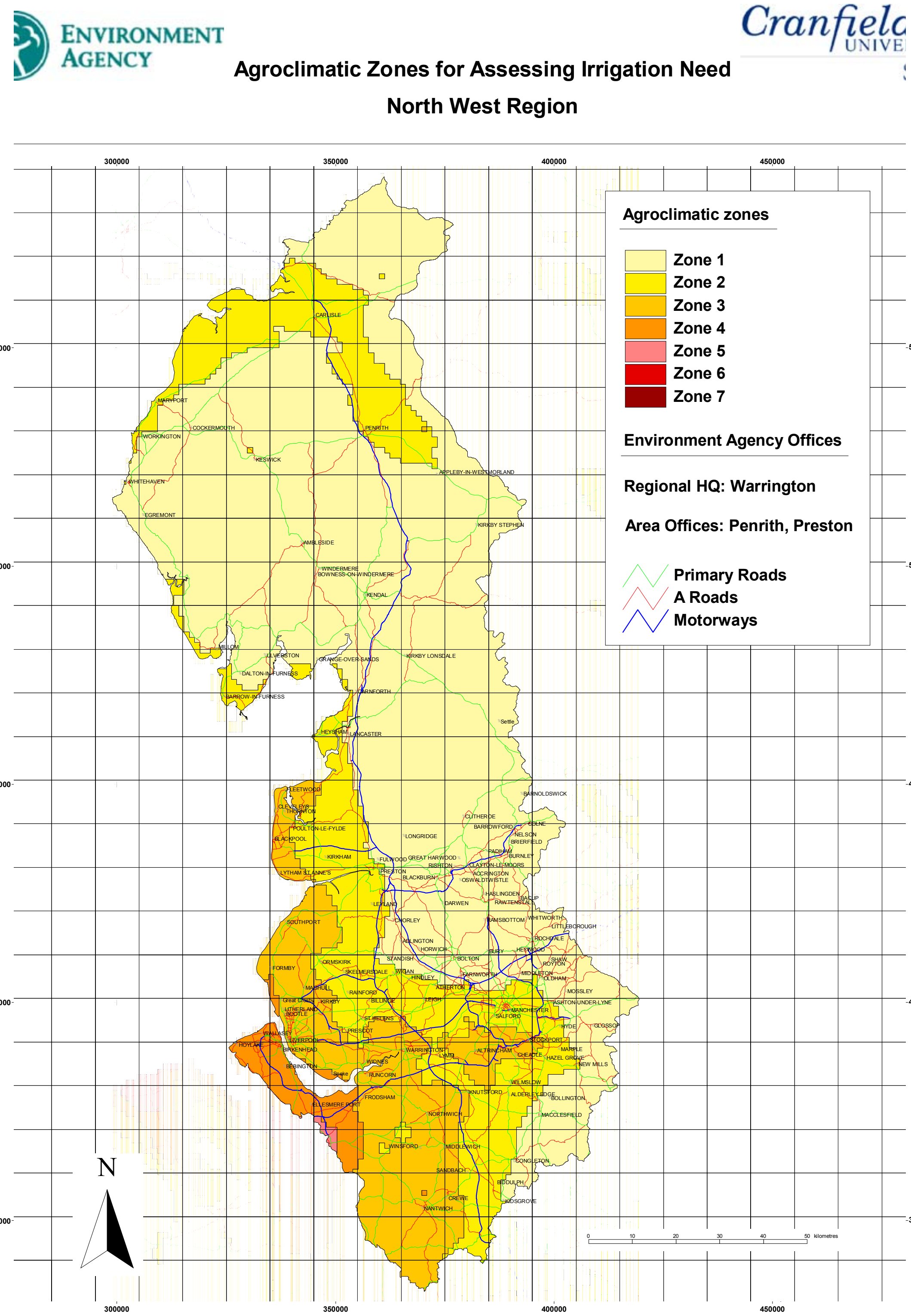


Figure 6 Sample map (reduced scale) showing the agroclimatic zones for Thames Region

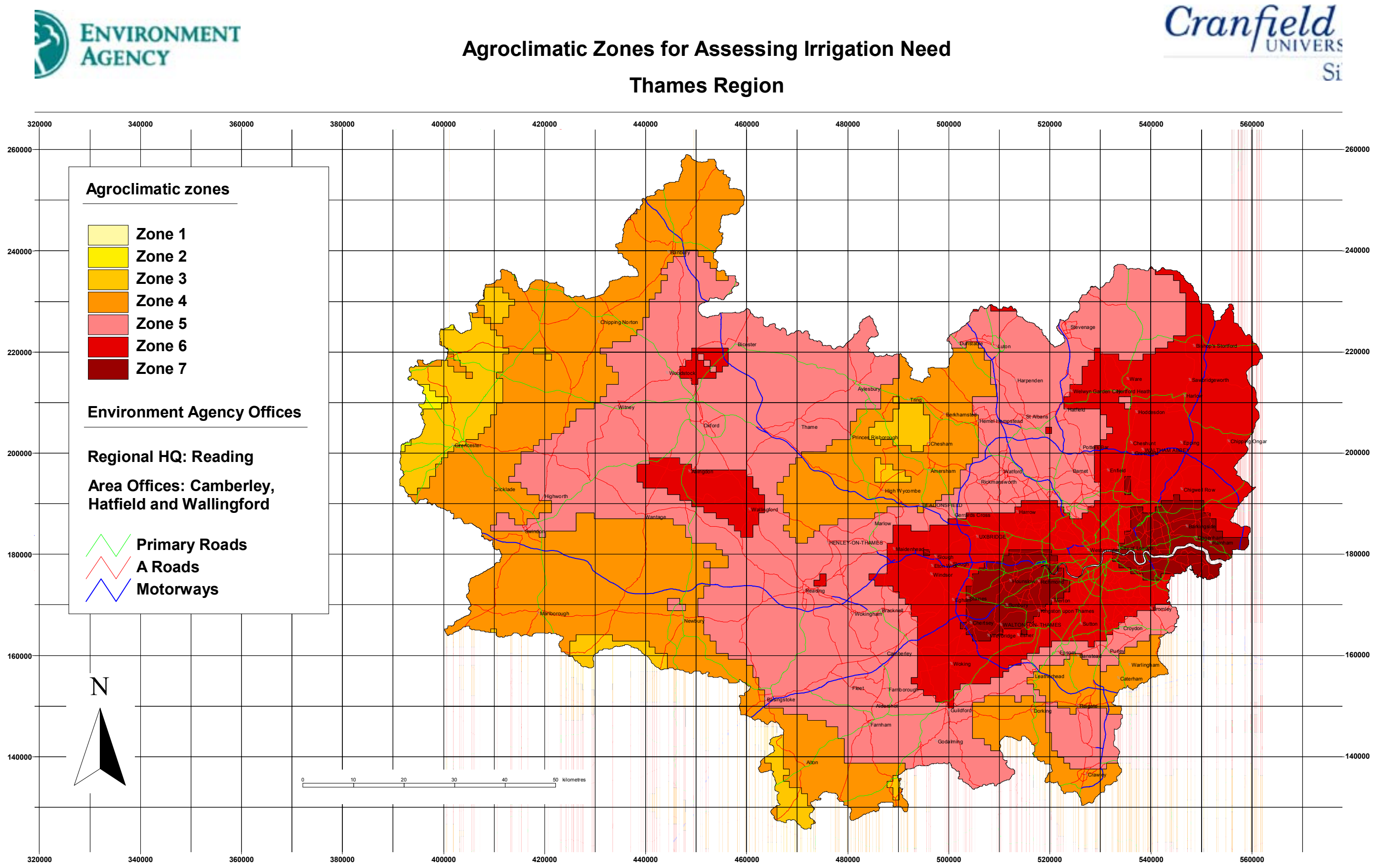


Figure 7 Sample map (reduced scale) showing the agroclimatic zones for Southern Region

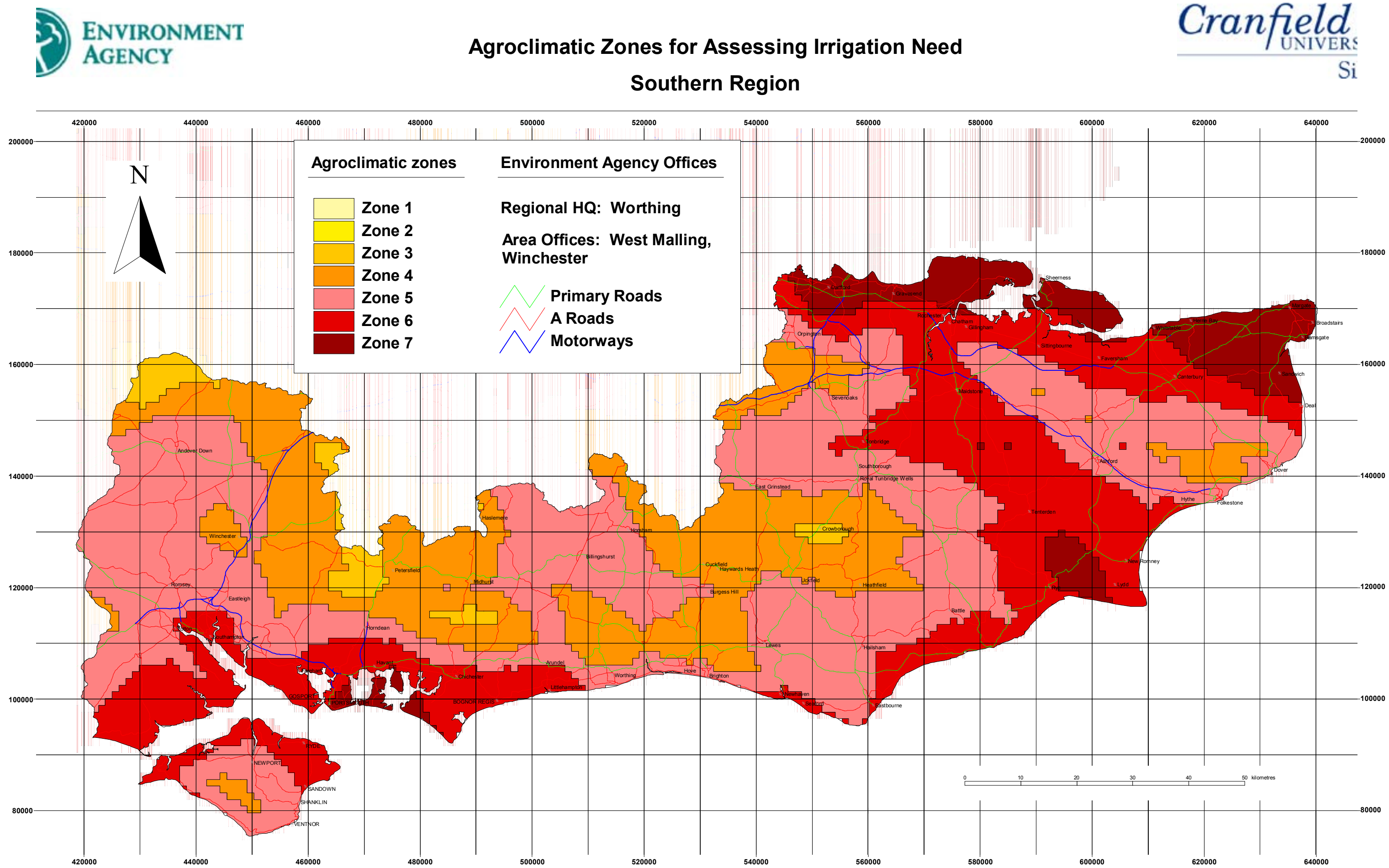
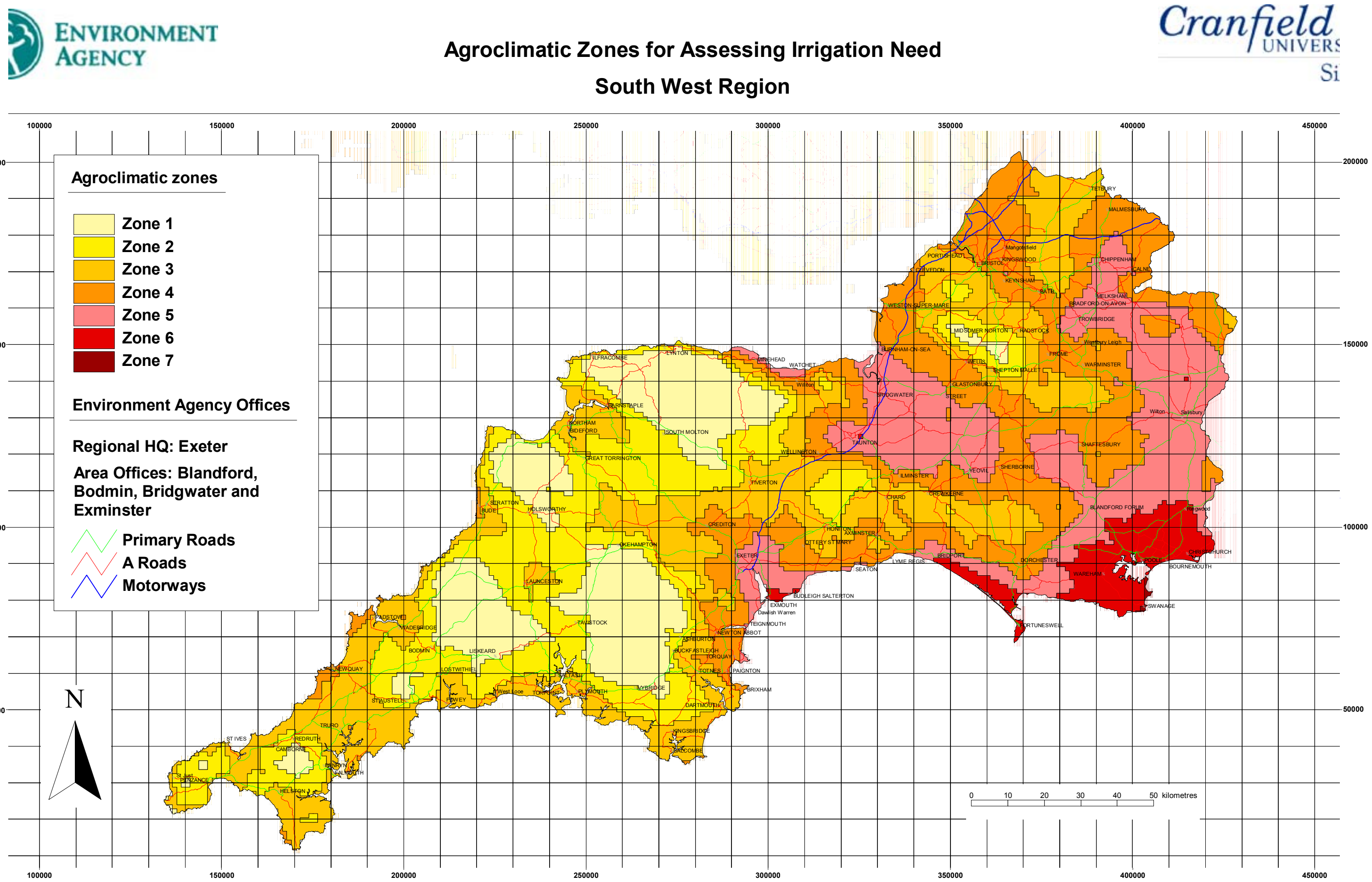


Figure 8 Sample map (reduced scale) showing the agroclimatic zones for South West Region



B1.2 Economic Irrigation Needs

The agronomic optima do not take into account the costs and benefits of irrigating, other than where implicit in the recommended schedules. In many situations, decreasing returns to irrigation may only justify investment in a lower level of irrigation application and/or irrigation capacity, resulting in less water use. Conversely, for high value crops, particularly where crop quality is a major objective, a higher reliability than 80% may be justifiable.

Table 6 presents typical ratios between the agronomic and economic optima, by crop type. The data assumes direct abstraction from surface waters to hosereel irrigators, but very similar results are obtained for groundwater abstraction. Systems with winter storage reservoirs and/or trickle irrigation have significantly different cost structures and may need to be considered separately.

The maximum ratio has been set at 100%. However, it is recognised that some individual applicants, particularly those irrigating high value crops and using solid set systems such as trickle, or with additional market demands in dry years (e.g. fresh strawberries, salads), may be able to make a valid case to Environment Agency licensing officers for a higher reliability.

The analysis suggests that irrigation of sugar beet and grass is typically only justifiable when practised in rotation with a more responsive crop that covers the fixed costs, or where the capital costs have already been incurred. Under these circumstances, applying the agronomic optimum may then be financially viable for the farmer. The licence allocation should therefore depend on the areas of other crops and the rotation planned, and needs to be justified by the applicant.

Table 6 Typical ratios (%) between economic & agronomic optima by crop category

Crop category	Crop type	Ratio of economic to agronomic optima (%)	
		Alone	In rotation with other crops bearing fixed costs
Potatoes	Maincrop	100	100
	Early	100	100
Sugar beet	Sugar beet	0	100*
Vegetables*	Broccoli	100	100
	Brussels sprouts	100	100
	Cabbage	100	100
	Carrots	100	100
	Cauliflowers	100	100
	Onions (autumn)	100	100
	Parsnips	100	100
	Peas (vining)	65	100*
	Runner beans	100	100
Salad crops	Lettuce	100	100
	Salad onions	100	100
Orchard fruit	Apples (mature)	100	100
	Pears	100	100
	Plums	100	100
Small fruit	Strawberries	100	100
	Raspberries	100	100
	Blackberries	100	100
	Blackcurrants	100	100
Grassland	Grass (grazed)	0	100
Cereals	Spring cereals	0	100

Notes:

Based on typical long-term costs for hosereel systems using direct abstraction without storage, and yield and quality benefits previously estimated for the South Level Fens (from Morris *et al*., 1997).

Values greater than 100% reduced to 100%

- but limited to area justified by other crops.

B1.3 Crop Rotation and Land Suitability

In assessing an application for an abstraction licence for irrigation, the Environment Agency must also assess whether the proposed areas to be irrigated are indeed reasonable/feasible. The suitability of local soil types and the impacts of crop rotations on irrigation demand needs to be considered.

B1.3.1 Land suitability

The concept of land suitability for a particular crop or cropping system is complex. Inevitably, some land is well suited to many crops, and other land has low suitability to all crops. The criteria of unsuitability vary with individual crops but are chiefly related to soil type, climate, gradient and, for root crops, stoniness. Particularly relevant for heavy soils are trafficability and workability for planting and harvest; both are dependent on soil moisture regime which is controlled by soil characteristics and weather.

Irrigation can make land suitable that would otherwise be too drought-prone.

A good indication that land is suitable is if nearby farmers on similar soils are already growing similar crops.

Land suitability guidelines for specific crops are discussed in more detail in the Phase III Technical Report.

B1.3.2 Crop rotations

The rotation of crops around different fields is usually essential for disease control and maintaining fertility. This can significantly reduce the total water demand for a given farm area.

Typical crop rotation guidelines for specific crops are given in Table 7, and discussed in more detail in the Technical Report.

If the proposed rotation is around areas under different licences, it may be necessary to base each licence on the worst case for each site. However, consideration should be given to linking the licences together under a combined total abstraction.

Table 7 Typical crop rotations, by crop category

Crop category	Specific crops	Typical rotation interval (years)	Possible rotation range (years)
Potatoes	Early	Continuous	Continuous
	Maincrop	1:5	1:4 to 1:8
Sugar beet		1:4	1:3 to 1:6
Vegetables (field scale)			
Umbelliferae family	Carrots Parsnips	1:5 1:5	1:5 to 1:8
Brassicaceae family	Cabbage Brussels sprouts Cauliflower Broccoli Calabrese Turnips/swede	1:5 1:3 1:5 1:5 1:5 1:5	 1:3 to 1:5 1:5 1:5 to 1:6
Alliaceae family	Onions Leeks	1:5 1:5	1:3 to 1:9 1:5 to 1:6
Pulse crops	Peas (vining) Field beans Runner beans	1:5 1:5 1:5	1:2 to 1:6 1:2 to 1:5 1:2 to 1:5
Salad crop	Lettuce/endive Celery	Continuous 1:5	1:4 (then sterilisation) 1:4 to 1:5
Herbs	Various	Continuous	5-10 years
Cereals		1:2	1:2 to 1:4
Grassland		Continuous	Continuous
Soft fruit	Strawberries Raspberries Blackcurrants	1:3 Continuous Continuous	1:2 to 1:7 10-15 years 25 years
Orchard fruit	Apples Pears/plums	Continuous Continuous	

(See Phase III Technical Report for references)

B1.4 Peak "Daily" and "Hourly" Abstraction Rate Assessment

The methodology so far has considered <u>seasonal</u> water use. Environment Agency licensing officers also need to consider peak <u>rates</u> of water use, particularly for abstractions from rivers and streams, and set sensible limits in the licence conditions such as peak monthly, peak daily, peak hourly and/or peak absolute rate of abstraction.

Setting *too high* a peak rate could risk excessive peak abstraction, particularly at times of low flow, and hence limit the Environment Agency's ability to protect the environment and/or licence water to other users.

Setting too low a peak rate would unnecessarily restrict the abstractors, and hence not make best use of the available water resources. It would restrict the irrigators' ability to conserve water, reduce energy costs and utilise staff effectively.

B1.4.1 Environmental sensitivity

The number of different rates stipulated in a licence should be kept to the minimum. For each licence application, it is recommended that the most sensitive rates be identified and set first. The sensitivity depends on the water source:

- minor streams and rivers whose flow is small compared to the abstractions are particularly sensitive to peak absolute rate and peak hourly rates;

- large surface water bodies, whose water level is hardly affected by short-term pumping, are more sensitive to daily, monthly or even total seasonal abstraction;

- groundwater in unconfined aquifers is typically most sensitive to monthly or total seasonal abstraction; in confined aquifers shorter duration rates may be more important.

Sensitivity must be judged in the context of the other licence conditions, such as minimum flows or levels. The situation becomes more complex when one source is feeding into another, for example aquifers feeding spring lines and streams.

Rates should not be set where they are unnecessary, or covered by other restrictions (For example, a peak hourly rate limit may implicitly set an acceptable peak daily rate).

B1.4.2 Peak monthly and peak daily requirements

The peak monthly and peak daily irrigation requirements are determined by the peak crop water use in the middle of hot dry summers. There is some buffering over periods ranging from a few days to several weeks depending on the amount of water storage in the soil moisture reservoir, determined by soil type and rooting depth. The factors involved are thus very similar to those involved in determining annual requirements, i.e. crop, agro-climate and soil type. Crops with high monthly and daily peaks tend to be those with high annual irrigation needs. The peak rates are therefore set as proportions of the "design dry year" or optimum need.

B1.4.3 Peak hourly and peak absolute rates

The peak hourly rate needed is largely determined by the hours available to complete the irrigation and the flow requirements of the irrigation equipment.

Licensing staff can provide flexibility by setting higher hourly/annual ratios; otherwise abstractors may need to invest in tanks or reservoirs.

Hours available

Most large-scale arable irrigators with hose-reel irrigators would typically plan to complete their irrigation in about 16 hours. This still allows some flexibility for unavoidable down-time, equipment maintenance and movement between fields, and reduces the need for night-time equipment moves.

Special circumstances can reduce the irrigation hours available, for example:

- non-standard field sizes;
- insufficient staff and/or automation to spread irrigation out;
- lower evaporation, less wind and off-peak electricity tariffs make it more efficient to irrigate only at night (an Environment Agency recommendation);
- golf courses can need to irrigate in as few as 8 hours overnight, starting after the last players leave at dusk and finishing in time for water to infiltrate before the early morning golfers arrive;
- noise issues (diesel pumps, impact sprinklers) restricting night-time irrigation;
- Health and Safety considerations advising against moving portable equipment in the dark.

In such cases, irrigators have to invest in additional irrigation equipment and apply the water in fewer hours.

Equipment flow requirements

The flow requirement of an irrigation system is set by its design. Most irrigation equipment has a wide range of flow rates available, but can only be used over a narrow range once purchased. Minimum flow rates, e.g. to give adequate throw, may require higher flows than typical working hours would suggest. Centre pivots and linear move systems often have a required flow rate set by the standard sprinkler packages available. Trickle systems on row crops will typically apply the daily requirements in only one or two hours; however the irrigation can be cycled around sectors to minimise peak flows and pump size. Field size and shape may dictate sector size.

B1.4.4 Setting peak rates

1. Determine the minimum flow/water level conditions to which the licence will be subject.
2. Assess whether the source is sensitive to any of monthly, daily, hourly and/or absolute peak flow rates under those conditions.
3. For the <u>most</u> sensitive duration, determine whether the suggested peak rate (Table 8) provides adequate protection. Select a suitable rate to protect the source.
4. For other durations, where necessary, aim to set less onerous (higher) rates. Do <u>not</u> set rates where they are unnecessary, or covered by other restrictions.

Table 8 Suggested peak requirements as a fraction of licensed annual abstraction (m^3)

a) Summer abstraction direct to irrigation

Period	Units	Fraction of licensed annual abstraction (m^3)
Monthly	m^3/month	1/2
Daily	m^3/day	1/40
Hourly	m^3/hr	1/600
Absolute	m^3/hr	As hourly

*b) Winter abstraction from surface water to reservoir storage**

Period	Units	Fraction of licensed annual abstraction (m^3)
Monthly	m^3/month	1 to 1/3 (depending on source reliability)
Daily	m^3/day	1/30 to 1/90 (depending on source reliability)
Hourly	m^3/hr	1/720
Absolute	m^3/hr	As hourly

c) Winter abstraction from groundwater to reservoir storage

Period	Units	Fraction of licensed annual abstraction (m^3)
Monthly	m^3/month	1/3
Daily	m^3/day	1/90
Hourly	m^3/hr	1/2160
Absolute	m^3/hr	As hourly

* These values should not be used where high hands-off flows have been set and the abstractor has agreed to take water at high flows or flood conditions only.

Note that the ratios only set limits on how <u>fast</u> the water can be abstracted. Slower abstraction and longer working hours are not precluded.

The suggested figures for abstraction direct to irrigation allow for 20 days (e.g. 4 weeks at 5 days/week) irrigation with an average 15 hour day during the peak month, using up half the annual water requirement. Alternatively, they would allow irrigation for 10 hrs/night every night during the peak month, using up half the annual water requirement, or 8 hrs/night every night during the peak month using 40% of the annual water requirement.

Some exceptions may need to be considered individually, for example:

- Irrigators with limited soil water storage, e.g. with shallow rooting crops and/or light soils and/or trickle irrigation, may need a higher daily/annual ratio;

- Specialised growers may have a shorter season, and would then need higher monthly/annual and daily/annual ratios;

- Small-scale irrigators may not be able to spread irrigation over as many hours per day as large growers, nor irrigate 6 days a week, and require higher hourly/annual and daily/annual ratios.

The suggested figures for winter abstraction from surface water to reservoir storage allow for 720 hours of pumping. Utilising off-peak electricity, this could be 120 days at 6 hrs/day or 90 days at 8 hrs/day. However, if the source is at all unreliable, the option of pumping continuously for 30 days should be retained if possible.

The suggested figures for winter abstraction from groundwater to reservoir storage allow for 90 days of continuous pumping.

B1.4.5 Tanks and balancing reservoirs

The use of a tank or balancing reservoir allows an abstractor to smooth out peaks in irrigation need, and allows significantly lower peak ratios. Relatively small tanks can spread hourly peaks over a day's abstraction; many days storage would be needed to spread daily peaks; a half season's reservoir storage may be needed to spread monthly peaks. The use of storage should be discussed with the applicant where problems with short-term peaks may make issuing of a licence problematical. Where the applicant also has a winter abstraction licence, the winter storage reservoir may usefully provide a balancing function for the summer abstraction by pumping via the reservoir. However, the additional capital cost and energy use through double pumping should be taken into account.

B1.5 Worked Example

Step 1 Establish soil and AWC class

Identify the soil type using local knowledge or refer to the National Soils Map.

Refer to **Table 3** to determine AWC class, and/or standard texts (e.g. Soils and Their Use in Eastern England, Hodge *et al*., 1984).

> *In this example, the soils map shows the area to be Worlington Association. Reference to Hodge et al (1984) shows this Association to be mainly sands and loamy sands and hence low AWC. There may be patches of medium AWC land but the farmer has indicated he only wishes to irrigate cereals on his lightest land.*

Step 2 Confirm crop areas are reasonable

Check whether the proposed crops and rotations are typical of local practice. Refer to the Technical Report for more guidance, if necessary.

> *This farmer's neighbour is already growing these crops. The farm area allows a 1 in 5 year rotation, which is not unreasonable.*

Step 3 Establish agroclimatic zone

Refer to the relevant map (Figure 1 to Figure 8), your laminated agroclimatic zone wall map or the CD (provided in Phase II).

This farm lies in agroclimatic zone 6 but close to the boundary with zone 7 (Because the site lies close to the boundary with agroclimatic zone 7, agronomic needs for zone 7 might also be calculated and an average taken).

Step 4 Establish agronomic optimum water needs

Find the agronomic optimum water needs from Table 4.

The dry year agronomic demands for these crops in agroclimatic zone 6 for a low AWC soil are 240mm, 170mm and 155mm, respectively.

Step 5 Establish economic to optimum needs ratios

Find the economic to optimum needs ratios from Table 6.

The ratios for these are 100%, 100% and 0%, respectively. The applicant may be required to show that the irrigation of the cereals is economic on this farm; but it is noted that the full area is included in the potato rotation.*

Step 6 Calculate irrigation water requirements.

Crop	Agronomic need	Economic to agronomic ratio	Irrigated area	Crop water requirement	
	mm	%	ha	ha.mm	m^3
Maincrop potatoes	240	100	40	9,600	96,000
Onions	170	100	40	6,800	68,000
Cereals	155	0*	100	0*	0*
Total			**180**	**16,400**	**164,000**

* but 100% may be justifiable on area where capital costs already incurred or covered by other crops.

Step 7 Set peak abstraction rates

Determine the minimum flow/water level conditions to which the licence will be subject, and assess whether the source is sensitive to any of monthly, daily, hourly and/or absolute peak flow rates under those conditions (Liase with water resource and environmental staff in the Agency).

This application is from groundwater; the aquifer is agreed to be environmentally sensitive to monthly and daily abstraction.

For the most sensitive duration, determine whether the suggested peak rates (Table 8) provides adequate protection. Select a suitable rate to protect the source. For other durations, where necessary, aim to set less onerous (higher) rates. Do not set rates where they are unnecessary, or covered by other restrictions.

From Table 8a, for summer abstraction direct to irrigation, the monthly limit is set at ½, and the daily limit at 1/40, of the seasonal limit. An hourly rate is either not set, or set at a rate allowing flexibility, e.g. well above 1/600.

Step 8 Compare irrigation volume requested by applicant with estimated volume calculated using optimum water use methodology

The Environment Agency licensing officer should now be in a position to discuss with the applicant the Environment Agency's estimated irrigation demand, based on the information supplied by the applicant. Any significant differences between the volume requested and calculated using the above methodology can now considered and addressed.

B2 GLASSHOUSE PRODUCTION

Note: This section remains unchanged from Phase II.

B2.1 Crop Location

The 1997 MAFF Survey of Glasshouse Crops shows the total glasshouse area in England and Wales to be 2172 ha, compared to 2157 ha for the 1997 MAFF Agricultural and Horticultural Cropping Census.

For this analysis, the 1997 MAFF Survey of Glasshouse Crops area data has been used and data from the 1997 Agricultural and Horticultural Cropping Census adjusted accordingly.

Table 9 Main protected crops (MAFF, 1998)

Region	Area (ha)	Percent of total area
1. SE excluding East Sussex	442	20.4
2. East Anglia including Herts and Beds	407	18.7
3. Lincs and South Yorks	330	15.2
4. Lancs and Cheshire	221	10.2
5. Hereford and Worcs	104	4.8
Total	**1504**	**69.3**
Overall Total	**2172**	**100.0**

B2.2 Water Use

B2.2.1 Growing systems

Three main types of growing system are used in the production of glasshouse crops.

Direct soil cultivation

This is the most common means of glasshouse production in which the crop is irrigated as if it were a field crop. Usually the glasshouse is under-drained. Sufficient irrigation is then applied to ensure that a continuous downward movement of salts through the system is maintained.

Rockwool

This is an artificial growing medium made from a mixture of basalt and limestone. It is available in the form of slabs designed to hold about 60 percent water and 40 percent air. It is widely used by tomato, pepper and cucumber growers. Due to risks of salt build-up, irrigation is normally set at 10-15 percent above crop demand to permit flushing of salts.

Nutrient film technique (NFT)

This is a hydroponic system. Roots are bathed in a circulating solution of nutrients and supported by wires as necessary. The only water used is that required for transpiration. The system requires high levels of management. It is mainly used on tomatoes, peppers and some lettuce crops.

A summary of the systems used and their typical levels of water usage, by crop category, is given in Table 10.

Table 10 Estimated levels of water consumption, by crop category, and system

Crop	System	Design water use (m^3/ha/year)	Unit of production	Water use per unit of production
Tomatoes Cucumbers	Rockwool	15,000	Tonnes	20-30 m^3/t
Tomatoes	NFT	9,500	Tonnes	12-20 m^3/t
Lettuce	NFT	9,500	Head	4-5 l/head
Lettuce	Soil based	6,000	Head	4.5-5.5 l/head
Nursery stock	Soil based	10-20,000	n/a	n/a

B2.2.2 Water re-use/reduction issues

- High levels of water use efficiency are usually achieved, with crop transpiration typically accounting for 75-95 percent of total water use.
- Drainage water, used to flush salts through rockwool systems, is re-used on more modern installations.
- NFT systems are more efficient in terms of water use but require very high levels of management to avoid the increased levels of disease risk associated with this form of production.
- Water costs, even when from mains, form a small part of total production costs, and are not high on the management list of priorities.
- Concerns regarding root disease discourage the collection and re-use of roof water run-off.
- Roof water re-use schemes are operating successfully on glasshouses, and growers need to be made more aware of the potential benefits of roof water collection.
- In lowland areas, a roof water run-off collection system for rockwool tomatoes with water storage of 50 m^3/ha of glass would meet about 30 percent of demand and utilise about 70 percent of roof water run-off.

B3 STOCK WATER REQUIREMENTS

Note: This section remains unchanged from Phase II.

Although spray irrigation is a major water use in agriculture, stock water use can create significant local demands. Stock water requirements can vary with type of livestock and the methods by which they are managed on a day to day basis.

Table 11 shows average water use for the main livestock groups. Figures on water use for slaughter houses and food production are provided in the industrial section (Part A) of the report.

Table 11 Typical stock water requirements

Animal	System	Litres/day/animal
Dairy cows	Cleaning non-power hose	14-22
	Cleaning power hose	27-45
	Drinking [1]	45-70
Calves	Drinking	15-25
Beef cows	Drinking	25-45
Pigs [2]	Cleaning after each batch (10 pigs/pen)	16-24
	Lactating sows	15-30
	Pregnant sows and boars	9-14
	Weaners	5
Sheep	Drinking	2.5-5
	Dipping (per dip)	2.5
Poultry	Layers /100 birds	20-30
	Fattening/100 birds	13
Turkeys	Fattening/100 birds	55-75

[1] Higher values for lowland production in Southern England.

[2] For outdoor pigs the maximum litres/day/animal should be increased by 50% to allow for wastage and wallows.

B4 FURTHER INFORMATION

For further information, refer to the R&D Technical Reports W243 and W6-056/TR1 (Phases II and III) which contain details of the research informing this manual, together with additional data and references.