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Benefit Assessment of Water Quality Improvements

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R&D Project Record P2/i583/7

FOREWORD

This Project Record provides additional supporting information to that found in the associated R&D Technical Report P39*. It details all work undertaken during the course of the project, which includes background information, description of water quality models, full details of the statistical analysis and property value estimation, detailed conclusions and also a series of appendices which contain the questionnaires used in the surveys, elements of the statistical analysis, and further details referred to within both this report and also R&D Technical Report P39.

* Wattage, P.M., Smith, A., Pitts, C., McDonald, A.T. and Kay, D. (1997) *'Benefit Assessment of Water Quality Improvements'*; Environment Agency R&D Technical Report P39. Environment Agency: Bristol.

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EXECUTIVE SUMMARY

Background

Water quality improvements in the Aire catchment have been identified as high priority and the regeneration of the Aire corridor is in progress with commercial, residential developments, tourism, recreation, amenity and conservation. The main objective of this project is to assess the benefits of water quality improvement within the corridor of the River Aire as it passes through the Leeds conurbation. This empirical study forms part of a broader initiative by the Environment Agency to develop techniques and approaches to the assessment of the societal benefits that are normally unquantified in environmental investment appraisals.

Empirical Studies Undertaken

Water quality models have been used to set consent limits which aim to ensure that water users are not affected adversely by polluting discharge. Predictive river water quality models were assessed in this study to define the feasible scenarios of water quality improvement, within the lower reaches of the river, resulting from investments in waste water treatment and integrated catchment control.

A contingent valuation survey was undertaken based on a defined corridor between Esholt and Knostrop to estimate the "willingness-to-pay" for water quality improvement. The survey acquired data on the socio-economic and demographic characteristics of the respondent population to enhance transferability of the information acquired. Interviewees were requested to classify present river water quality according to a six part (A to F) ladder which broadly paralleled current Environment Agency classification. The survey also revealed that the river was used by a number of those questioned for formal and informal recreation. A novel aspect of this survey was the development of a methodology which linked commercially available post code address files with a geographical information system to select the surveyed population. In addition to the survey, a supplementary study was conducted to assess the recreational and amenity values of the river in 10 selected locations. A parallel survey of property prices, rents and land values was conducted to determine changes in these characteristics that might be attributable to historical water quality improvements.

Results

The response rate of the sample survey was 87 percent - a total of 333 out of 384 questionnaires were accepted for the analysis. The current perception of respondents (80%) was that the River Aire water quality lay in class D (i.e. moderate pollution with poor fish stocks and reduced use potential) or lower. This indicates that the public perception of present water quality is pessimistic (i.e. it underestimates present water quality). The main recreational activities of those surveyed, under present water quality conditions, were walking, bird watching, nature appreciation and angling.

Respondents exhibited a mean "willingness-to-pay" of £3.91/month/household to effect a water quality improvement to facilitate direct contact recreational activities such as swimming with excellent fish stocks (i.e. from a mean perceived level of D to a new level of A). A

considerable proportion of respondents (48%) recorded a "willingness-to-pay" of zero. This may have been influenced by adverse publicity concerning the Regional Water Company during the survey period and the publics' perception that pollution remediation is outside their direct financial responsibility. Whilst the existence of 'zero value' responses are common in economic valuation of public goods, it does present certain statistical problems. This was particularly evident in the least squares regression analyses which exhibited generally low explanation. Partly to address these problems, further statistical tests were carried out. These tests revealed that independent variables are capable of predicting WTP values. Further analyses were conducted using logistic regression, logit and probit analyses to validate estimated WTP values.

Using a dichotomous choice procedure followed by integration of a logit bid curve resulted in a estimated "willingness-to-pay" of £8.68/month/household, higher than the open-ended questionnaire derived figure of £3.91/month/household. Other studies have also observed this generally higher "willingness-to-pay" estimates from dichotomous procedures. Assuming the true "willingness-to-pay" is bounded by these figures (i.e. £3.91-£8.68) and using the total household number in the surveyed corridor (i.e. 25,000) this would indicate a gross figure of £97,750- £224,500 per calendar month to effect water quality improvement. It should be noted that this does not include the broader catchment residents which might have an interest in water quality in the River Aire. If it were assumed, for example, that all City of Leeds residents were willing to pay the lower monthly contribution this would generate a revenue of approximately £800K per month. Some wider regional projections of "willingness-to-pay" monthly totals are presented in Table 5.1. However, an attempt to treat the mean values as a "price" for the good in question should be treated with caution.

Whilst property values in the City of Leeds doubled in the period 1985 to 1995, values in the surveyed corridor exhibited a 2.5 fold increase, principally due to residential development in the city centre. The displacement of industrial land uses with prestige residential and commercial activities suggests increasing importance of water quality to the property sector in the central zone of the city of Leeds. The range and intensity of recreational activities taking place by the river are greater on Sundays than during the mid-week at all sites. The most popular sites were those which possessed amenity facilities or were adjacent to residential areas. The most common activity taking place in the vicinity of the river is walking. Both surveys demonstrated that the river's main use is limited to non-contact water activities due to the poor water quality.

Conclusions

Linking of post code address information with geographical information systems offers an effective means of sample selection and survey design in contingent valuation analysis. This project has demonstrated the feasibility of initiating empirical investigations to define the "willingness-to-pay" of the population for environmental improvements through the application of widely accepted contingent valuation methods. Notwithstanding the proportion of zero value returns, the survey has demonstrated a significant financial commitment of the surveyed population to effect water quality improvements in this historically polluted urban watercourse. Building society, and other data sources, offer considerable potential for assessing the relative movement in property values adjacent to and distant from sites of environmental quality change although the present investigation was unable to isolate the contribution of water quality to this observed trend in the Leeds area.

KEYWORDS

Benefits of water quality improvement; River Aire; Water quality models; Contingent valuation; Willingness to pay; Property values.

1. BACKGROUND

1.1 Introduction

The report aims to quantify the benefits attributable to water quality improvement in the River Aire which would be apparent to residents of the immediate river corridor. A widely accepted method of benefit estimation in environmental goods, known as Contingent Valuation (CV), has been applied to acquire this information.

CV is a method of estimating the value of non-market goods such as clean air or water. It is assumed that there is a market for these public goods although the market is not well defined by usual economic means. A public good is a commodity or service that requires resources to produce, but once produced, additional people can consume the good without additional cost. The CV method describes the market for a good and then asks individuals what they would be willing to pay for that good. The monetary values estimated are those values that are contingent upon the existence of a market. To achieve an accurate measure of nonmarket benefits, the survey must simultaneously meet the methodological imperatives of survey research and the requirements of economic theory. The CV methodology satisfying these conditions has been used to generate WTP functions for a large and diverse set of consumer goods. An alternative method of examining environmental improvement is to measure the value attributed to other goods, for example land value, which occur as a result of the proposed improvement. Hedonic property models have been used to measure the implicit price that property owners pay for water quality as a portion of the overall prices of properties (Michael *et al.*, 1996). Such models assume that people might pay more, if all other characteristics are equal, for a property adjacent to a river with high water quality than they would for a property adjacent to a river with lower water quality. The share of the increased price of the property that is attributable to the change in water quality is identified through the price differentials between properties adjacent to the river with differing levels of water quality.

This study provides an empirical application of CV to the River Aire corridor in Leeds. It is then related to national efforts to develop benefits assessment as a planning tool by the Environment Agency.

1.2 Objectives of the Study.

The study objectives are:

1. to develop an empirical technique, based on underlying economic theory, to measure the welfare changes associated with an environmental improvement;

2. to translate theoretical concepts and definitions into operational techniques, providing guidance on how to apply these techniques to other urban areas;

3. to apply the techniques outlined in the Interim Manual of the Foundation for Water Research (FWR, 1994), to the River Aire watershed in Leeds, West Yorkshire and

4. to test different econometric and analytical techniques designed to measure the willingness to pay for improvement of water quality.

1.3 The River Aire and the City of Leeds : Overview

The River Aire rises near Malham in North Yorkshire and flows 148 km to its confluence with the River Ouse at Goole. The catchment area is 1100 km^2 with an estimated population of 1.1 million, the majority of whom live in the urban areas of Skipton, Keighley, Bingley, Bradford, Leeds and Castleford (Figure 1.1).

The focus of this study, the city of Leeds, is the major urban centre on the catchment. The city is committed to environmental improvement and is the largest metropolitan area in Britain to be designated an 'Environment City'. Leeds has a population of 700,000 people and provides employment for 300,000.

The River Aire is a focal point for development and regeneration in the city centre. This has formed part of the Leeds City Council Development Plan. Indeed, the corridor of the River Aire in the centre of Leeds has been given high development priority and holds the council designation of 'Riverside Quarter'. Recent riverside developments include the commercial offices of major companies such as ASDA and KPMG. Developments have also included tourist attractions (e.g. The Royal Armouries) and residential accommodation. Away from the city centre the river is important to the local community for its amenity value, examples of which are Armley Mills and Kirkstall Abbey.

1.3.1 Development activities

Economy

Economic development is a key element in the development plans of Leeds and Bradford Metropolitan District Councils. Both aim to provide the necessary infrastructure to strengthen the existing economic base and to maintain balanced, and diversified, development. The councils recognise that the economic structure is changing continually. It is envisaged that the decline in manufacturing industry will continue and, in response, both councils are encouraging economic activities in the retail, commerce, leisure and hospitality industries.

Residential

Both Leeds and Bradford local authorities have identified changes in the social life-style and demographic structure of the population. In consequence, each recognises the need to provide more single person accommodation. In addition, there are a considerable number of older houses in poor condition which are close to the end of their viable life and will therefore need to be replaced.

It is estimated that an additional 54,000 houses will be built on the River Aire catchment between 1991 and 2006. These will comprise 30,500 houses in Leeds, 23,000 in Bradford and almost 1000 in the Craven District.

1.3.2 Conservation and recreation

Environmental policies are prominent in the district and county development plans covering the Aire catchment. General policies in the Leeds development plan and in the Bradford development plan make firm commitments to environmental protection and improvement. More specific policies include those concerning wildlife protection, pollution to air and water, flooding and flood defence, protection of urban green space and the protection of urban green corridors.

The policy concerning the protection of green corridors is particularly important to this study because the River Aire through Leeds is designated as an urban green corridor. As such, the nature conservation and amenity aspects of the river are high on the agenda for development. Clearly, water quality within the river will be critical in the promotion of the River Aire as an urban green corridor.

Within the Leeds area, the River Aire plays a limited role in recreation, conservation and amenity. Nevertheless, the river is a key feature of the city and, since it is readily accessible to a large number of people, there is great potential to develop it as a focal point for amenity. This has been recognised by the 'Eye on the Aire' environmental group, who are concerned with the environmental maintenance of the river. They have highlighted a number of issues to be addressed to fulfill this potential (Eye on The Aire, 1992);

- Improve water quality;
- Improve amenity facilities;
- Improve river access;
- Reduce bankside litter;
- Preserve character and the urban greenspace it provides;
- Ensure development is balanced and controlled.

1.4 River Aire Water Quality

According to the 1992 NWC classification, water quality in the river can be classed as follows (NRA, 1993);

Class 1	231.7 km
Class 2	68.7 km
Class 3	121.5 km
Class 4	14.4 km

Much of the poorer water quality occurs in the lower reaches of the catchment, particularly in the 45 km of main river downstream of Keighley.

The major threat to water quality is the effluent from the 40 sewage treatment works within the catchment which account for 65% of dry weather flow. Two thirds of the sewage effluents, by volume, are produced from the treatment works at Marley, Esholt and Knostrop.

Other sources of pollution include;

- sewage and silage liquor from agricultural activities;
- combined storm water overflows in Keighley, Bradford and Leeds;
- public / private surface water sewers;
- chlorides from minewater wastes and
- toxic pollutants from chemical and textile industries.

1.5 The Catchment Management Plan (CMP)

Water quality in the River Aire is managed through a process of catchment planning. Catchment planning gathered pace with the creation of the National Rivers Authority (NRA) (now Environment Agency) in 1989 culminating in the 'River Aire Catchment Management Plan' (NRA, 1993). The plan was developed through wide consultation with other organisations to create an integrated and balanced approach.

The Environment Agency is developing a number of policies aiming to improve further the water quality in the catchment. These include:

- improvements of effluent quality from Marley, Esholt, Smalewell and Knostrop STWs;
- regulation of combined storm water overflows from North Beck, Bradford Beck and Pudsey Beck;
- imposing strict consent limits on industrial discha
- the implementation of a rigorous sampling and monitoring program to identify transgressions of consents and licenses.

The influence of these water quality improvements on the quality of the broad riverine environment manifests itself through the protection, improvement and rehabilitation of existing, poor and degraded habitats through;

- the upgrading of moderate habitats and;
- the improvement of adjacent floodplain sites e.g. the Kirkstall Nature Reserve.

Improvements in conservation value will enhance water contact recreational activities such as canoeing and angling as well as more informal recreation such as nature and heritage appreciation.

Improvements in water quality will also contribute toward urban regeneration of the Riverside Quarter. More specifically, water quality may be an important factor in the attraction of non-manufacturing industry and residential developments to the area. Whilst in the past manufacturing industry may have had little concern for water quality, the leisure (Royal Armouries) and commercial (ASDA, KPMG and associated services) developments adjacent to the river may be more influenced by environmental quality. The development of high quality residential accommodation has taken place close to the river itself. In these areas, water quality may influence the quality of life and hence property values in the area.

2. RIVER WATER QUALITY

2.1 Introduction

Rivers and streams have been used by society throughout history for the transport of materials, removal of wastes, and supply of potable water. In many UK rivers, the polluting effects of sewage formed the focus of attention and drove early legislation. The origin of pollutants entering rivers includes those from point sources, such as effluents from sewage treatment plants, and non-point sources, such as agricultural run-off. Although, the quality of many UK rivers has improved over recent years, as a result of a change in industrial effluent and substantial investment in sewage treatment, water quality problems associated with old and overloaded sewage treatment works (STW's) are still widespread.

2.2 The Relevance of River Water Quality Models

River models have been used to predict the effect of discharges on downstream water quality. Such models can be used to set consent limits which aim to ensure that water users are not affected adversely by polluting discharge. This can be achieved by establishing the required Environmental Quality Objectives (EQO) or Environmental Quality Standards (EQS). EQOs are the result of setting objectives appropriate to the specific receiving water and then defining numerical standards to be complied with.

In this context, river water quality and sewage effluent quality are seen, not at ends in themselves but, as means of enabling rivers to be used for the purposes required of them. Hence, it will be possible to protect the aquatic environment to the degree that the public requires and also maintain the vital function of the river as a carrier for sewage and effluents.

2.3 Water Quality Impact Models

2.3.1 TOMCAT

TOMCAT (Temporal/Overall Method for CATchments) is a water quality model developed by Thames Water in 1982 to review collectively the quality requirements of all effluents discharging to a catchment. It is a relatively simple model which uses a mass balance approach to simulate movement of pollutants downstream. The model is relatively simple to use and requires only data collected from routine surveys.

The mass balance equation is used to calculate river quality downstream of a discharge using the mean and percentiles of river and discharge flow and quality data;

$$T = (FC + fc)/(F + f)$$

The concentration (T) in the river downstream of the discharge depends on:

- the upstream river pollution discharge concentration (C)
- the concentration in the discharge (c)
- river flow upstream of the discharge (F), and
- the flow of the discharge (f).

The mass balance approach involves modelling the mixing effect of the predicted wastewater discharge with an appropriate quantity of river water to give an estimate of the resulting downstream water quality. To simulate the mixing of sewage effluent within a stream, random values are drawn from the distributions of upstream flow and concentration. Similarly, random values are drawn from effluent flow and concentration. Using the random values, flow and concentration of the downstream water quality are estimated by iteration. The sets of downstream values are generated by defining distributions for each parameter. TOMCAT introduced several new concepts in river quality simulation of which the most far-reaching is temporal correlation (Brown, 1986). The concept considers any seasonal and diurnal effects that are present in water quality and flow data and then reproduces these effects in the simulated data.

The procedure is simple but the usefulness of the results are somewhat ambiguous. This kind of procedure is over-simplistic in practice and will produce incorrect results for almost any real river pollution problem (Warn and Brew, 1979). This is because the mass balance equation used does not accommodate in-channel processes and dispersion of pollutants.

2.3.2 CATNAP

CATNAP is a one dimensional segmented model for non-tidal rivers (McDonald *et al.*, 1994) The determinants included in the model are flow, biochemical oxygen demand (BOD), ammonical nitrogen, dissolved oxygen and temperature. To allow for the seasonally and randomly varying nature of these determinants, a Monte Carlo framework is used. This also allows assessment of compliance against a percentile target to be made, which is the method by which UK consents are assessed. The model contains processes of mass balance, reaeration, self purification and thermal exchange.

River network

The model allows a river network to be defined for a study area as a series of interlinked reaches, each with its own hydraulic and process characteristics. A reach is firstly defined in terms of its length and channel geometry. It can then be attached to other single reaches in the system. Alternatively, bifurcation can be defined. Flows are defined for both the head of the main river and any tributaries, and for lateral inflow to each reach. Process characteristics are then defined for each reach, covering self purification, reaeration and thermal exchange, along with defining the flow-travel time relationships, or via a relationship based on channel geometry. Finally, the quality of lateral inflow water for each reach can be assigned.

To simplify the task of providing a large quantity of catchment data, standard sub catchments can be defined for both quantity and quality. These can then be incorporated and proportioned for use where appropriate.

River processes

At each change in the system, flow and mass is conserved. This is carried out individually for each of the Monte Carlo simulations made. Plug flow and instantaneous mixing are assumed. To calculate the amount of self purification or reaeration, the travel time to the next feature is firstly calculated. First order expressions, incorporating temperature correction, are used to determine the amount of self purification which has occurred. The model utilises a form of the Streeter-Phelps equation to describe the oxygen balance which includes the equivalent oxygen demand of ammoniacal nitrogen. In addition to the above oxygen exchange processes, the model also incorporates the effects of reaeration over weirs. The air-water temperature exchange is modelled on a simple first order basis.

Representation of data

One of the powerful features of the model is that all flows and chemical determinants modelled can be represented in a number of ways. At its simplest, a constant input, or 'no effect' indicator can be used. However, data can also be represented as a probability distribution using normal, log-normal or specified percentiles. A further refinement is that these data can be represented as a single yearly distribution, as a distribution around individual monthly means or as individual monthly distributions. This feature allows a full representation of seasonality, and its implied correlation to other items of data, to be made.

A further feature in the representation of these data is that correlation between data sets can be incorporated by setting starting values for the Monte Carlo simulations. This ensures that correlated values for flows in different catchments are accounted for.

Abstraction and discharges

The model allows representation of abstractions and discharges to be made in a number of ways. For abstractions;

- the amount of water taken can be specifically defined.
- the ability to carry out abstractions subject to prescribed flow restrictions in the river.
- Abstracted water to the river can be returned at one or several locations, and
- allowances can be made for partial or total loss of abstracted water.

The quality of the returned water can be specified in a number of ways. It can be;

- reflected directly by the water taken out,
- subject to a change based on the abstracted water, or
- completely respecified.

Similarly, the system provides flexibility in investigating the impact of discharges. For the flow component of any discharge the minimum and maximum flows, based on the original distribution, can be specified. This allows for the easy representation of several effluent streams from a plant, which come into or out of operation at varying flows. To extend this further, flows and qualities from a discharge can be correlated. This allows;

- for several discharges from one plant to be sychronised.
- representation of processes which are related or inversely related to flow.
- representation of the future increase or decrease in magnitude of a discharge by the use of scale factors.

To permit discharge scenarios to be investigated, the system allows a discharge performance to be specified. This enables a quick examination of the impact of discharging at a particular consent. To allow a scenario to be examined in detail, a range of performance values can be specified, and results produced of each.

Calibration features

To calibrate the model, flow and quality data from monitoring stations can be used and compared with predictions using the Kolmogrov-Smirnov test. These tests, which can specify the determinants to be examined, are carried out across the whole of the probability distribution. Due account is taken of the number of data items representing the observed distribution. The model runs can be automatically refined to carry out either flow or quality calibrations only, or for both together.

2.3.3 MIKE 11

The Urban Pollution Management (UPM) Programme was initiated in 1985 to develop methodologies for the management of urban water quality under wet weather conditions The programme considers three major elements of urban wastewater disposal;

- the sewerage system,
- the sewage treatment works and
- the receiving water.

The improvement of water quality is dependent on capital works at various points in the disposal system. This investment can be made more efficient by employing tools which allow detailed investigation of each aspect of the urban wastewater disposal system. A group of mathematical models have been developed and used by the water industry in the UK, during last two decades for;

- simulating pollutant flows in sewerage systems (MOSQITO) (Shamash 1993),
- sewage treatment plants (STOAT) (Dudley and Dickson, 1992) and
- receiving waters (MIKE 11) (Danish Hydraulic Institute, 1992).

These models were originally designed to permit detailed studies of water quality and for the planning of sewer rehabilitation schemes. However, initial attempts have also been made to apply them in an integrated manner to pollution modelling within catchments. The models produced acceptable results. These complex dynamic models require more detailed input and a higher level of expertise than is needed to run TOMCAT.

MIKE 11 has three main modules which provide an aid to consent setting for intermittent discharge. The software is available in either MS-DOS or UNIX developed by the Danish Hydraulic Institute.

Hydrodynamic (HD) module

Channel hydraulics is the key to any river quality modelling and therefore the HD module is an essential element of MIKE 11. It is used to define and model the channel network.

structures, flows and levels. Data required to describe the flow in the channel are cross sections, roughness, river structures (e.g. weirs, bridges, etc.), tributaries, loops, and Q-h relationships[1]. The HD is an implicit finite difference model, which describe both sub and supercritical flows, as well as simulating backwater effects.

Advection-Dispersion (AD) module

The AD module allows for the study of pollutants (dissolved or suspended materials), which decay linearly by describing one dimension (1-D) longitudinal dispersion. This module uses input from the HD module, which includes discharge and water level, cross-sectional area and the hydraulic radius. The module is solved, similar to the method used for the HD module, using implicit finite difference equations. Time series boundary conditions used in the module are concentrated at headwaters and tributaries and/or lateral inflows. Erosion and deposition is also modelled as a source/sink within the AD structure. Both erosion and deposition depends upon the hydraulic conditions, while deposition is affected by the suspended sediment concentration.

Water Quality (WQ) module

The WQ module is linked with the AD module, and calculates the interaction and transformation of dissolved oxygen, temperature, ammonia, nitrate, BOD_d (biological oxygen demand from dissolved organic matter), BOD_s (from suspended organic matter), and BOD_b (sedimented/absorbed organic matter on bed). Thus, the WQ model uses six empirical equations to explain six different levels of model complexity by investigating varied water quality situations.

There are a number of constraints on the use of MIKE 11. They are basically the assumptions made on using the hydrodynamic model. Modelled catchments which have a combination of very steep slopes, low flows and major in-river structures are likely to be affected by the assumptions. In catchments where these assumptions do not hold true, problems may be encountered.

2.4 Water Quality Improvement Scenarios and CMPs

Proposals for improvement of water quality is one of the main aspects of CMP. This can be achieved by defining water quality improvement scenarios. EQO's are aimed at setting objectives appropriate to the specific receiving waters and defining numerical standards. TOMCAT, CATNAP or MIKE 11 predictions should ensure that consent levels for polluting discharges would maintain water quality at an acceptable level in receiving waters.
Model predictions have formed one element in water quality scenario assessment for the CMPs. Environment Agency staff have been consulted on the output from these exercises which were used in defining feasible improvement scenarios.

[1] The channel is represented by a series of alternating Q and h points at which discharge and water levels, respectively, are calculated. Q points are midway between the h points and also at structures, whilst h points are located at cross sections, or at equal intervals between them if the distance between the cross section is greater than dx-max, the maximum selected distance between two adjacent h points.

3. ESTIMATING THE BENEFITS OF WATER QUALITY IMPROVEMENT

3.1 Introduction

Welfare economics is concerned with the relationship between the well-being of people and how the productive resources available to society are used. One purpose of the economic system is to satisfy the needs and wants of people, given the distribution of property and other productive resources among the population. Mechanisms such as taxation and various transfer programs can be used effectively to redistribute wealth.

The Pareto Criterion[2] can be used to measure efficient resource allocation. This takes the utility function (peoples preference mapping for a good) as the measure of individual welfare. In simple terms, the resource allocation that provides a group of goods and services, which is preferred to a previous group because it provides a higher utility to individuals, is said to increase the individual's welfare. This basic concept of welfare change, as a result of an improvement of a good, can be used in developing a methodology for the measurement of benefits associated with water quality improvements.

3.2 Justifying Water Quality Improvement Scenarios

Water quality improvements in the River Aire catchment have been identified as a high priority as part of the regeneration of the Aire corridor in terms of commercial, residential developments, tourism (including national museums), recreation (including water based), amenity and conservation. Therefore, water quality improvement scenarios require justification in terms of benefits, priorities and appropriate standards.

The Environment Agency has developed Catchment Management Plans to drive the continuing improvement in the quality of rivers through the control of pollution. This approach ensures that the consequences of discharges are paid for by the dischargers and, as far as possible, facilitates the recovery of costs of water quality improvements from those who benefit. Catchment Management Plans also enable the optimum deployment of investment and resources to achieve efficient and effective operation. However, the non-market nature of water quality improvement hinders the use of traditional cost-benefits analysis to measure this efficiency.

Consider an example closer to the water environment. An investment in a sewage treatment plant would reduce pollution levels in a given river. In addition to the water quality, there are numerous other non-market values attached with the water quality in the river, which cannot be measured in monetary terms (pounds sterling). Therefore, these non-market goods are inappropriately valued at zero pounds. The estimation of welfare gains from such commodities is possible through non-market means such as surveys, questionnaires, bidding games, and voting procedures. Even if market-related measures of water quality benefits are available, estimations derived through non-market techniques are useful as a check on the consistency of the estimation procedures.

[2] Pareto criterion states that policy changes which make at least one person better off without making anyone worse off are Pareto-improving and should be undertaken.

Procedures for measuring benefits from non-market data involve revealing people's preferences for the provision of public goods. There are a few established approaches to the problem of preference evaluation. One commonly used method is to ask individuals to state their Willingness To Pay (WTP) for the environmental commodity (Mitchell and Carson 1989). The CV method is currently the best technique available to quantify non-market values in monetary terms.

Another commonly used non-market benefit evaluation procedure is known as the Travel Cost Method (TCM). The TCM uses travel costs as prices that reveal the demand curve for a particular recreation site. The idea behind the TCM is that people in population zones surrounding a recreation site will take trips to the site and that the rate of visitation will be a function of the travel costs to the site. The zones further away from the site are expected to have fewer visits, since the price of travel is higher. A statistical relationship is formed that expresses the number of trips per capita as a function of the travel cost to the site and some socioeconomic characteristics of each population zone. This relationship is the aggregate visit locus and provides one point on the demand curve for the site. By assuming that individuals would react to a site entrance fee in the same manner as they would react to an increase in travel costs, the demand curve for a specific recreation site can be developed. However, the TCM is not suitable for the valuation of water quality improvement in the River Aire largely because the river is currently used only for limited recreational activities due to the prevailing poor water quality.

The justification of water quality improvement scenarios is therefore dependent on the estimation of benefits of water quality by an accepted economic method such as CV.

3.3 Contingent Valuation Methodology (CVM)

3.3.1 Introduction

CV is a method of estimating the value of non-market goods such as clean air or water. The basic assumption is that although the markets for these goods are not well defined in usual economic terms they do exist. The CV method enables the market for such a good to be simulated and described and then asks individuals what they would be willing to pay for that good or what they would be willing to accept as compensation if this good were lost or unavailable. The monetary values estimated are those that are contingent upon the existence of a market. The ultimate aim of a CV study is to obtain an accurate estimate of the benefits of a change in the level of provision of a public good such as water quality.

These contingent markets are structured to confront respondents with a well-defined situation and to elicit a circumstantial choice contingent upon the occurrence of the posited situation. To achieve this structure and an accurate measure of non-market benefits, the survey must simultaneously meet the methodological imperatives of survey research and the requirements of economic theory. The basic welfare analysis is the underlying economic theory of the CVM. A CVM satisfying the basic welfare criterion can be used to generate Willingness To Pay (WTP) functions for large and diverse set of consumer goods.[3] This can provide an

[3] For an extended discussion of this issue, see Mitchell and Carson (1989).

estimate of the benefits, which may be used for many planning and policy activities dealing with environmental goods. CV is the only method which is capable of establishing general environmental values (FWR, 1994).

The notion of benefits from public goods is somewhat different from other types of benefits. Many people may consume a particular public good; however, one person's consumption does not preclude another person's consumption[4]. Furthermore, it is difficult to identify beneficiaries for environmental goods. **The total benefits from public goods are the sum of the benefits to all who consume the public goods.** However, the measurement of benefits associated with public goods seems somewhat difficult relative to the estimation of costs.

3.3.2 The theoretical framework underlying CVM

Modern welfare economics operationalises a variant of the Pareto Criterion by trying to find ways of placing a monetary value on the gains and losses of a provision of a public good. This is based on the two key assumptions. The most basic assumption is that the economic agent (consumer i), when confronted with a possible choice between two or more bundles, must have preference for one over another. The other assumption is that, through his/her actions and choices, the consumer attempts to maximize his/her overall level of satisfaction or utility. Both of these assumptions have implications for the CV methodology which is unique among benefit measurement techniques for its ability to obtain detailed distributional information. Additionally, CV is consistent with the consumer sovereignty assumption. According to the consumer sovereignty assumption, an agent's spending behaviour in a market is a sufficient signal of his preferences for various goods. The reason why he holds these preferences are of no economic importance.

The criterion used by welfare economics is to assess a given policy by judging whether a particular policy is effective for Pareto improving (improving one good without detriment to another). However, in practice, the compensation test of Pareto improvement is not in widespread use because compensation is rarely paid for losers. For such a criterion to be implemented, those who gain from a policy change need to compensate those who lose.

Some economists proposed a new welfare criterion known as Potential Pareto Improvement Criterion or the Potential Compensation Test (Hicks 1939; Kaldor 1939). This criterion has been controversial because, without the actual payment of compensation, it is possible to make a very small group of people much better off while making the vast majority worse off. Nevertheless, the potential compensation test is very popular and widely used among applied economists. CV methodology provides the information to evaluate benefits by a variety of criteria, including voting and the Potential Pareto Improvement Criterion. Application of the Potential Pareto Improvement Criterion requires the use of the Hicksian compensating version of consumer surplus.

The CV method provides the only way of directly measuring both WTP and Willingness To Accept (WTA). Depending on which Hicksian Consumer Surplus (HCS) measure a researcher wants to obtain, the elicitation question of the CV survey is phrased in terms of

[4] Note, however, that eventually the benefits derived from some public goods (say a view of some distant island) may be lost as higher numbers of 'consumers' spoil the effect of the 'solitary' view for other. Such public goods are said to be 'congestible'.

either WTP or WTA. For example, consider the utility function given in equation 3.1. Assume an individual who currently enjoys some specified level of a service, Q and a given Hicksian quantity of all other goods, collectively known as numeraire good, X. Their level of utility, U, is always dependent on the numeraire good (for convenience it is called income) and the quantity of the particular service Q where;

$$U = U(Q,X) \qquad 3.1$$

The situation can be explained clearly using Figure 3.1. The origin Q^0 indicates an individual's initial level of welfare. On the right side of the origin, towards Q^+, the level of the provision of Q to the individual increases while to the left of Q^0, it decreases. Movement up the vertical axis denotes that income decreases; while a movement down indicates an increase in income. The total value (TV) curve or Bradford Bid curve, is positively sloped, given that the service is a commodity and the individual is not satiated in the range under consideration. The horizontal axis of TV represents quantity in increasing amounts, and the vertical axis represents income in decreasing amounts. If it is possible to define the quantity of the service in undimensional, cardinal terms, the assumption of diminishing rates of commodity substitution is sufficient to ensure the curvature shown. Alternatively, if the quantity of the service is multidimensional, or if it cannot be defined accurately in cardinal terms, no *a priori* assumption can be made concerning the curvature of the TV curve (Bradford 1970). The empirical estimate of a TV curve provides the total value to an individual of an environmental good or service such as an increment or decrement. This can be estimated in a form entirely consistent with the Potential Pareto Improvement Criterion. To determine any proposed change in output, individual total values may be aggregated across the relevant population.

The TV curve is an indifference curve, passing through the individual's initial state, that is,

$$U(Q,X) = U(Q^-,X^+) = U(Q^+,X^-)\,2 \qquad 3.2$$

As noted in Figure 3.1 WTP is the total value to the individual of an increment from Q^0 to Q^+ and WTA is the total value to the individual of a decrement from Q^0 to Q^-. Thus, equation 3.2 becomes;

$$U(Q^0,X^0) = U(Q^-,X^0+WTA) = U(Q^+,X^0-WTP)\,3 \qquad 3.3$$

If quality improvement from Q^0 to Q^+ is a one-unit increment in Q, WTP is equal to the buyer's best offer for that increment. Similarly, with a unit of quality decrement from Q^0 to Q^- WTA is equal to the sellar's reservation price for that decrement. If an increment would cost more than an individual's WTP and a decrement would net the individual less than their WTA, they would probably refrain from any trade in Q and remain at his/her initial situation.

The appropriate measure to evaluate the benefits of water quality improvement in the River Aire watershed is the Consumer Surplus defined by the Hicksian measures. The project was not proposed primarily for the purpose of redistribution. Therefore, the Potential Pareto Improvement should be the proper criterion for water quality improvement using Hicksian compensating measures. Those compensating measures, by using the initial welfare level as the reference level, define the impact of changes as if the individual had a right to their initial level of welfare. Equivalent measure uses the subsequent welfare level as the reference level

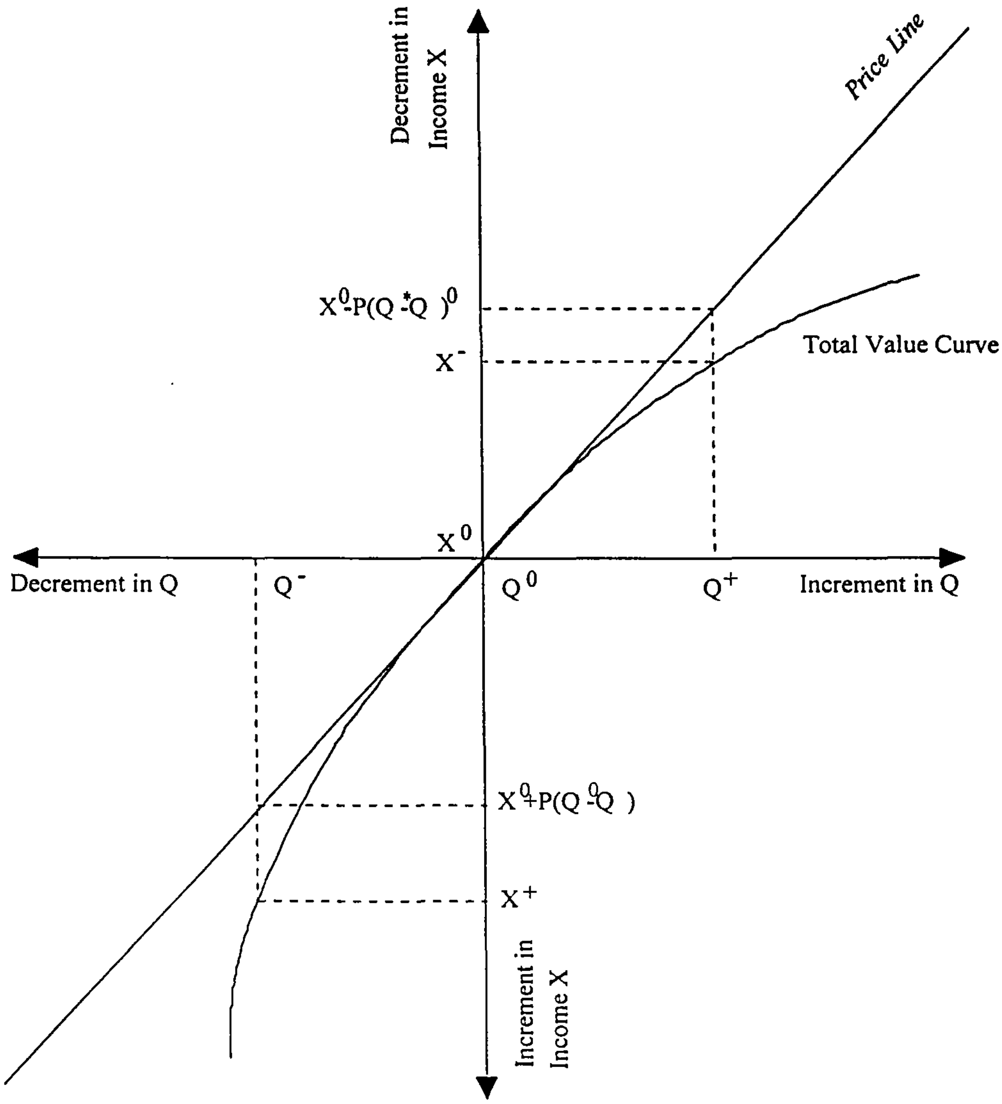

Figure 3.1. The total value curve for changes in Q (Adapted from Bradford, 1970)

and treats the individual as if they had only a right to their subsequent level of welfare. Hicksian compensating measures are consistent with the Potential Pareto Improvement Criterion, while equivalent measures are not.

During the last two decades considerable research effort in the economics of public goods, has been devoted to problems of estimating demand. A major part of this research effort has been devoted to finding a mechanism for direct questioning of consumers to reduce mis-representation of their preferences for public goods.

3.3.3 Variation in CVM elicitation designs

CV methodologies simulate a market for a non-market good. The process would estimate the respondent's consumer surplus for the environmental good, and the maximum amount the non-market good is worth to the respondent. The best way to do this would be to ask individuals their willingness to pay for the good and record the answer. This is called an open-ended CV format because the respondent is not given a price to accept or reject. Respondents often find it difficult to assign a value spontaneously without some form of assistance. As a result, many open-ended CV formats tend to produce an unacceptably large number of non responses or protest zero responses to the WTP questions (Desvousgas *et al.*, 1983). Asking respondents to give a monetary valuation in response to an open-ended question presents them with an extremely difficult task (Arrow *et al.*, 1993). CV proponents also recognise that presenting respondents with a set of money values from which they are to choose is likely to create anchoring and other biases. On the other hand, closed-ended CV surveys, known as referendum surveys, have recently become very popular as a technique for eliciting the value of water resources. The format of the closed-ended format is dichotomous-choice (DC) question, where the respondent is presented with a value and gives a yes or no answer as to whether or not they would pay this amount.

There are a few widely used elicitation techniques that attempt to overcome the weaknesses of general CV in both open-ended and closed-ended formats. Many CV researchers have accepted these techniques as capable of reducing non responses and making it easier for respondents to complete successfully the valuation process. The commonly used elicitation methods are;

- the bidding game;
- the payment card;
- the discrete choice (take it or leave it offer);
- the discrete choice with follow-up approaches and;
- the modified dichotomous approach

Each of these approaches are evaluated below.

Until recently, the most widely used CV method was the **bidding game** (Davis 1964). The process is identical to normal auctions and, therefore, is likely to be familiar to respondents. This is normally modelled on a real-life situation in which individuals are asked to state a price for the environmental non-market good. This bidding game format is best adapted to personal interview surveys, but it also may be used in telephone surveys. The use of this format in mail surveys, however, is very limited. The interviewer iteratively changes the stated amount of money to be paid or received until the highest amount the respondent is WTP, or the lowest amount the respondent is WTA, is precisely identified. Thus, the identified amount is an estimate of a point on the total value curve. According to Cummings *et al.*, (1986), the bidding process is likely to capture the highest price consumers are willing to pay and thereby measures the full consumer surplus. Also, as Hoehn and Randall (1983) stated, the process of iteration used in this CV bidding process will enable the respondent to consider more fully the value of the non-market good. Many researchers have demonstrated that starting-point bias occurs when the bidding game format is used (Cummings *et al.*, 1986; Boyle *et al.*, 1985).

The **payment card method** was first developed by Mitchell and Carson (1981 and 1984) as an alternative to the bidding game. This method maintains the properties of the direct question approach while increasing the response rate to WTP questions by providing respondents with a visual aid. This is a more sophisticated direct questioning technique, which specifies the increment or decrement in value for the non-market good to be provided in quantitative terms. Furthermore, this method provides substantial details about the institutional structure of the hypothetical market.

The question may be a open-ended or closed-ended format. The open-ended format provides an exact monetary amount for WTP by the respondent, which is a point on the TV curve. The closed-ended format provides a yes or no answer to a question specifying both the precise amount of a non-market good to be gained or lost and the precise amount of money to be paid or received. The payment card procedure avoids the need to provide a single starting point and offers the respondents more of a context for their bid than is provided by the direct question method. The adaptability of payment cards to mail surveys is very limited and the method seems to pose less of an anchoring problem than the bidding game or direct questioning. This method is potentially vulnerable to biases associated with the ranges used on the cards and the location of the bench mark (Mitchell and Carson 1989).

The third CV elicitation method is the **discrete choice** (also known as dichotomous choice, take-it-or-leave-it, referendum), which was developed by Bishop and Heberlein (1979). Only the closed-ended type of questions can be used in the dichotomous choice format. This approach uses a large number of predetermined prices chosen to bracket expected maximum WTP amounts of respondents. The most desirable form of CV elicitation is the use of a dichotomous question that asks respondents to vote for or against a particular level of taxation, as occurs with most real referenda (Arrow *et al.*, 1993). Because respondents find it very difficult to identify precisely their true point value of access to some environmental good, open-ended valuation questions can be unreliable or can discourage response. In contrast, most consumers are familiar with being confronted by a posted price for a good and the need to make a decision to purchase at that price. This is the strategy behind the discrete choice CV questions.

The advantage of the discrete choice method over other methods is that it simplifies the respondent's task in a fashion similar to the bidding game without having the iterative properties. The respondent, just like any other consumer, has only to make a judgment about a given price.

The main obstacle of this method, relative to other elicitation methods, is that many more observations are needed for the same level of statistical precision in sample WTP estimates because only a discrete indicator of maximum WTP is obtained instead of the actual maximum WTP amounts. Another problem is that analysis is dependent on some assumptions about how to parametrically specify either the valuation function or the indirect utility function to obtain the mean WTP. Bishop and Heberlein (1979) noted that a logistic or probit regression curve could be fitted to the percentages of respondent's willingness to pay each of the randomly assigned prices. Integrating the area below the logistic curve, would provide the equivalent measure to the mean WTP. It also is possible to obtain the mean WTP directly from the parameters of a probit equation.

The fourth widely used elicitation process is the **discrete choice with a follow-up approach.** Using this method Carson and Mitchell (1986) asked a question requiring a yes or no answer regarding the respondent willingness to pay a specified price. If the respondent says yes, another question is asked using a higher price randomly chosen from a pre-specified list. If the respondent says no, a lower price is used in the follow-up question. Although this procedure offers potential for considerable gains in efficiency, the inherent problems of discrete choice still remain. Further, the follow-up questions used in this method are similar to the iterative procedures of the bidding game. The main disadvantage is that this method is not suitable for mail surveys because of the follow-up approach.

An extension of this procedure, known as the **modified dichotomous choice** method, was used to measure the existence value of wildlife in USA by Stevens *et al.* (1991). In this approach, the respondent was confronted with the specified amount of money, he or she would contribute toward continued existence of the resource. The amount of money was randomly selected within fixed intervals over a range of $5 to $150. Also, all respondents were given an opportunity to bid an amount less or greater than the specified amount of money. Responses, therefore, could be viewed as originating from either an open-ended or a closed-ended dichotomous choice bidding format. Unlike the discrete choice follow-up approach, this method can be used in mail surveys.

3.3.4 Open-ended and close-ended formats

An open-ended and discrete choice with a follow-up method was used for the evaluation of benefits associated with the River Aire water resource protection. Among the alternative CV question formats, DC is emerging as the preferred method because it successfully elicits individual participation, and is free of starting-point bias.

Open-ended DC format used in the River Aire study

The open-ended format used in this study allowed the respondent to specify a monetary value for water quality improvement. Values provided by respondents were direct estimations of WTP and the points on TV curve. By asking the amounts respondents would pay, points on the individual's bid curve (Bradford 1970) or TV curve (Brookshire *et al.*, 1980) can be obtained. The dependent variable is the respondent's average WTP for water quality improvement in River Aire. The independent variables of the bid curve are specified as levels of gross income, age, present and expected level of water quality, education, family size, membership of an environmental organization and sex. The distance to River Aire from the land on which they live is also used as an independent variable. The open-ended CV model was specified as:

$$WTP = f(Q^n, X, E, F, A, S, D) 4 \qquad 3.4$$

where
Q = the level of provision of the service, Q^n is the present water quality,
X = gross income level
E = level of education
F = family size
A= Age of the respondent
S = gender (male/female)
D = distance to the River Aire
WTP = Hicksian equivalent measure of WTP.

The equation provides the relationship between the WTP value and each independent variable. Because there was no information *a priori* about the choice of a functional form, the bid curve can be estimated using ordinary least square (OLS) procedures. To find the inverse Hicksian Demand Curve (HDC), it is necessary to differentiate the bid curve. This demand curve is unique to the reference welfare level.

Closed-ended DC format used in the River Aire study

This procedure involves first establishing the attributes of the water resources and then asking the respondents about their WTP a single specific sum for keeping water resources clean. As previously outlined, the questioning strategy is attractive because it generates a scenario similar to day-to-day market transactions. A pre-tested hypothetical value can be tested to determine whether the respondents would agree to take it or leave it at that price. In this format the respondents were asked to give one of two responses, yes or no, to the following question:[5]

- *Assume that the **current water quality** level that you indicated in Q#7 is to be changed to the **best** level, that is to level "A." If you indicated that the current water quality is already "A" then assume that this level will be maintained indefinitely.*

- *Would you be **willing to pay** £10 each month over the coming year as more taxes for this level of change to be achieved and/or maintained?*

The relationship between independent variables and the WTP value can be observed using the sample survey responses to the above question. Independent variables, such as income, existing level of water quality, etc., are continuous.

The dependent variable is the WTP status, which is an attribute, a qualitative variable, or a discrete variable. For a single attribute, this dependent variable Y is a scalar, which can take

[5] See Appendix I, Survey Questionnaire.

only two values, and is defined as: $Y_i = 1$, if respondent says yes to the above question, or $Y_i = 0$, otherwise. The appropriate model to analyze this type of response data is a binary response model in which the dependent variable takes one of the two values (Seller *et al.*, 1985). The econometrics of the linear and non-linear CV models is given in Appendix III.

3.4. Estimating the Benefits of Water Quality Improvements

The objective of this study is to measure the benefits of protecting water resources from industrial river pollution using the framework of welfare economics. As discussed in section 3.3., there are strong theoretical grounds to use a survey based CV methodology for this purpose. The field survey was used to assess people's perception of water quality, possible uses of the river, respondents socio-economic background, and to obtain the individual's WTP measures for having clean water in the river.

3.4.1 Survey design and methods

In order to carry out the CV study, a sample survey was designed and applied to the River Aire catchment between Esholt and Knostrop sewage treatment plants in Leeds. There are major recreational areas in this corridor such as Kirkstall Abbey, parks, canoe sites and canal based recreation. There are also several areas suitable for wildlife and nature appreciation.

Sampling design & collection

The study focused on the River Aire as it runs through Leeds and the people it is likely to affect along this stretch. This is the section of poorest water quality with the most to gain from any improvements. Although those who are living relatively close to the river would be affected immediately by any improvements, the impact of total benefits may be more widespread over the catchment. However, given time and resource constraints, the study was limited to an area of 1km either side of the river in which the most significant impact of water quality improvement might be expected (Figure 3.2). This obviously places constraints on how the results are interpreted for the whole of Leeds but was necessary in practical terms.

In order to obtain a random sample of addresses within the specified river corridor the Post Office Address File (PAF) was obtained for those postcode districts lying within 1km of the river. These data consist of postcodes, grid-references for each postcode and the full address of every house within the postcode unit. An extract of this dataset is given in Table 3.1. Each entry has a grid-reference and represents one unit postcode for which there are typically 10 - 15 addresses. The file includes both residential and commercial properties which are coded R or C respectively. Those classed as residential were selected from the database.

Of the residential addresses, those falling within 1km of the river, were then re-selected using the MapInfo GIS's SQL functions. This dataset (around 2,500 records) now represents the base from which the random sample would be taken. A sample of 384 was calculated to be adequate to gain statistically meaningful results (see Appendix II).

Table 3.1 Sample PAF data (cut down from original).

POSTCODE	ROAD	LOCALITY	DISTRICT	ADDRESS1	ADDRESS2	X	Y
BD10 0AU	APPERLEY RD		BRADFORD		99 101 103 105 107 109 111 113 115 117	418400	437800
BD10 0AX	APPERLEY RD		BRADFORD	MILLHOLME FARM	125 127 129 131 133 135 137 139 141 143 145 147 149 151 153 155 157 159 161 163 165 167 169 171 173 175 177 179 181	418500	437800
BD10 0BA	BARRACLOUGH BUILDINGS		BRADFORD		1 3 5 7 9 11 13 4 6 8	419100	437300

Each entry in the selected dataset was given a unique number. A random number table containing 384 numbers in the range 1-2500 was generated and joined to the PAF dataset in MapInfo. The records from the PAF file whose unique numbers corresponded with the random number table were then selected resulting in the final random selection of 384 records, each with approximately 10 - 15 addresses, from which the survey would be carried out. These addresses are represented in Figure 3.3. For each record the fifth (or last if there was not 5 addresses) address in each record was selected from the final dataset for survey visits.

Questionnaire design

The questionnaire, presented in Appendix I, was designed to be easily understood and completed within 10-15 minutes.

There were six sections to the questionnaire. Each section began with a transition statement explaining why that section's questions were being asked.

- Section one of the questionnaire surveyed the location of the respondent, and their present use of the River Aire.
- Section two contained a series of questions that verified the water contact activities during 1995. For example, if the respondent or an immediate relative has used the river for any water related sports or other water contact activity, a set of questions were asked to assess diseases experienced and health impact.
- The respondents' attitude on potential sources of water pollution are revealed in section three.
- Section four included questions about surface water quality and WTP values. Water quality ladders have been used in the study to indicate current water quality and the expected water quality in terms of a scale from A to F. The F level indicates the worst possible water quality, which is very dirty and unfit for human, wildlife, livestock, and crops uses, whereas level A is the best possible water quality and is fit for swimming.

- Section five dealt with valuation of the property currently occupied by the respondent. The idea of investigating the land value was to monitor the changes of land value, if any, due to the deterioration or improvement in water quality.

- The final section pertained to respondents' socioeconomic and demographic attributes, which were recorded and used later as independent variables in the WTP function. The age, sex, education, income, family background, and membership of an environmental organization are among the characteristics that were included in this section.

A first draft of the questionnaire was sent out to the study group and colleagues for comment and discussion. It was further refined through discussions with Agency staff at project management meetings. The questionnaire was pre-tested with a target group and modified before the final draft stage. Field interviewers were trained and tested in the class room and in the field before the final survey.

Execution of the survey

The first communication with the respondents was a personalised letter indicating the objectives of the survey and the importance of their participation for the success of the study. Respondents were informed in advance that a representative from the Environment Centre, University of Leeds would visit them to complete a questionnaire. The letter identified the university departments involved, the funding institution, and the topics addressed, and explained how their name was selected, why their participation was important and their guaranteed anonymity. In addition to the questionnaire, a set of photos describing good and bad aspects of river water quality was used to provide interviewee with descriptive information on the river.

The main problem encountered during the survey involved the targeted respondents being unwilling or unavailable to respond to the questionnaire for a variety of reasons. The slow response rate experienced meant that the time allocated to complete the survey extended beyond the planned period. Several factors concerning the organisation of the survey helped achieve a high response rate. Future surveys should give attention to;

- targeting interviews to the most fruitful time of day
- selecting an accurate address data base, and
- the professional manner of the interviewers.

It was suspected that the area in which the interviewer was living would significantly influence the response rate. A useful exercise in this respect is to plot the sample addresses (see Figure 3.3) and compare this to the actual responses when received (see Figure 3.7).

Examination of these two maps, with regard to sample distribution and response rate, highlight further factors which should be taken into account in other studies of this type. Firstly, the random sample shows a good spatial distribution over the whole area. This should allow assessment of the response from several socio-economic groups. Secondly two major areas of non-response were recorded - the city centre and the more suburban / rural area of

Horsforth. We have identified two main reasons for this, namely the difficulty in locating residential housing in the city centre and the sparse population in the more rural area. It is also worth noting that there appeared to be no particular differences in the level of response between areas of differing socio-economic background.

The description of the sample addresses distribution in this manner is a useful exercise to be recommended in other studies. It allows spatial patterns to be described and non-response areas to be more closely targeted to help reduce bias.

3.4.2 Survey results

The final response rate to the survey was 87 percent - a total of 333 out of 384 questionnaires were accepted for analysis. A simple analysis of the sample could help to establish the representiveness of the population by the sample. The validity of results of the survey is contingent upon the sample respondents;

- age distribution
- educational background, and
- income levels.

In any society the economically active and responsive age group is generally assumed to be between 18 and 60. As depicted in Figure 3.4, the majority of the sample respondents belongs to this group. The distribution of education levels among the sample selected is shown in Figure 3.5. This is a typical education level distribution. The distribution of respondents income is also typical (Figure 3.6). A large proportion (20%) of the sample lies in the income group of less than £8000 per annum representing the unemployed, students and pensioners. Those with an income over £30,000 per annum are very rare in the sample. The results shown in these three figures suggest that the sample is a good reflection of the urban population living in this area.

Descriptive statistics

Statistical analyses were carried out using the SPSS 6.1 Windows version. The sample distribution of various activities was studied and respective sample percentages were calculated. Estimations of population parameters were not made using the sample distribution.

Therefore, the analysis presented here is based on the investigated sample not on the total population. The database used for the analysis was created in EXCEL. All relevant information, under each of the variables, was carefully examined to check for outliers. Minimum, maximum and mean values were calculated to provide an initial examination of the collected data.

In addition to SPSS and EXCEL analysis of data, sample addresses and WTP values were analysed for spatial patterns using MapInfo (see Figure 3.7), which suggested an even spread of WTP zero values, and no clear pattern of differences in willingness to pay for different areas. For a study covering a larger area, perhaps to the edge of the catchment boundary, we would expect this type of data display to uncover any relevant spatial patterns.

Recreational activities

The survey revealed that the river was used by a number of those questioned for formal and informal recreation. The main recreational activities of those surveyed, under present water quality conditions, were walking, bird watching, nature appreciation and angling (Table 3.2). In addition to the survey, a supplementary study was conducted to assess the nature and the intensity of public use of the river for recreational activities (Appendix VII). It was also apparent that improvements in water quality would increase recreational activities and therefore enhance the amenity value of the river. Indeed, the increase in contact activities is most notable, for example canoeing increases by more than 8-fold. This may be attributed to the perceived decrease in health risks associated with improvements in water quality.

Table 3.2 Percentage of people questioned using the River Aire for recreational activities

Activity	Those who use now (%)	Would if WQ improved (%)
Angling	6.3	15.6
Canoeing	1.2	9.9
Sailing	0.9	4.5
Walking	46.3	65.8
Nature appreciation	8.1	14.7
Bird watching	9.0	14.7

Pollution perception

The public perception survey showed that all categories of pollution sources listed were thought to have some impact on the water quality of the River Aire (Table 3.3). The main

Table 3.3 Opinions of people questioned on the significance of pollution sources in the River Aire (percentage)(Ranking 1 = low; 5 = high)

Source of pollution	Rank 1 (%)	Rank 2 (%)	Rank 3 (%)	Rank 4 (%)	Rank 5 (%)	Average score
Sewage treatment works	3	5	14	23	52	4.07
Water treatment works	8	14	24	23	21	3.03
Industrial effluents	3	3	13	24	54	4.16
Run-off from roads etc.	17	28	26	14	9	2.51
Landfill waste leachates	13	19	25	21	14	2.80
Agriculture (manure, pesticides)	8	11	21	27	26	3.33
Building & developments	18	27	25	14	8	2.43
Illegal waste dumping	3	8	14	25	45	3.87
Leaks from underground stores	16	17	12	17	23	2.68
Household wastes	8	17	26	23	20	3.09
Mine drainage	21	20	19	14	14	2.42

sources of pollution perceived to be in the river were effluents from industry (ranking 4.16) and sewage treatment works (ranking 4.07). Those perceived to be of least significance were run-off from roads (ranking 2.51), building developments (ranking 2.43) and mine drainage (ranking 2.42). Over 80% of those surveyed thought that current water quality in the River Aire through Leeds was level D or lower (Table 3.4). However, it was the opinion of almost 90% of those surveyed that levels of acceptable water quality should be at level B or better.

Table 3.4 Opinion of those questioned on the water quality in the River Aire (%)

Water quality level	Present water quality (%)	Acceptable water quality (%)
A	0.6	52.3
B	1.5	36.6
C	15.6	9.6
D	27.6	0.0
E	29.1	0.3
F	23.7	0.0

Willingness to pay

Almost half of those surveyed (48%) were not willing to make any form of financial contribution toward water quality improvements in the River Aire (Table 3.5). The mean willingness to pay was £3.91, with 95% confidence intervals of £0.77, and the maximum willingness to pay was £75.00. Spatial distribution of WTP is shown in Figure 3.7.

Table 3.5 Number of people surveyed and their willingness to pay

Amount willing to pay (£)	Number of people surveyed
0.00 (zero)	160
0.01 - 1.99	29
2.00 - 4.99	37
5.00 - 9.99	38
10.00 - 19.99	55
20.00 - 39.99	10
40.00 or more	4

A wide range of reasons were given by the 160 people surveyed who were unwilling to contribute financially towards the improvement of water quality of the River Aire (Table 3.6). The reason most frequently given was that the water utility company (Yorkshire Water plc) should pay for the necessary improvements.

3.4.3 Analysis and discussion

Analyses of the WTP responses and related statistics were carried out using different econometrics techniques. The object of this approach was not only to obtain WTP values but to compare and analyse various estimation techniques and their suitability under different situations. The two main estimation methods are linear regression and maximum likelihood analysis. Either is suitable for this type of analysis (FWR, 1994).

Table 3.6 Reasons for zero willingness to pay of the 160 surveyed (%)

Reason for zero willingness to pay	Willing to pay zero (%)
Can not afford to and / or unwilling to pay more	13.1
Water utility companies should pay for improvements	19.4
Industrial polluters should pay for improvements	8.1
It is the responsibility of national and / local government	6.3
Those who do not use the river	13.1
Inappropriate to place monetary value on the river	6.9
No response	12.5

First, the mean bid values of WTP were estimated for River Aire water quality improvements. The same analysis was extended to obtain the influence of other independent variables to the WTP values using the OLS procedures. As explained earlier, a WTP function can be estimated using limited dependent variables. The dichotomous choice dependent variable (yes = accept WTP value stated) takes only two values, either 0 or 1. The analysis of such variables can be performed using the Maximum Likelihood Estimation (MLE).

The second analysis involves estimating a Logistic Regression Model, Logit, and Probit using MLE procedures. The third approach is quite different from the first two. The numerical integration of the area under the cumulative density function is used to estimate the WTP values for DC dependent variable.

Bid values - OLS procedures

Data were further interrogated to produce a number of models from which the economic benefit of the water quality improvement can be derived. The value of benefits (WTP) from the improvement of water quality in the River Aire depends on a number of factors that affect the decision on how much a respondent would be willing to pay. These can be expressed in a multiple-regression equation.

Multiple regression analysis (MRA)

An iterative process of repeated multiple regression analysis identified that the most important variables for predicting the maximum willingness to pay were gross annual income, acceptable water quality and the perceived distance to the river from their household. Additional variables, for example age, contributed little to the model and did not have the appropriate significance values. Multiple regression models inclusive of all independent variables are given in Appendix IV. The selected model can be written as:

$$WTP = -3.81 + 0.99 (Q^a) + 0.81 (X) - 0.68 (D) \qquad 3.5$$

where

Q =	the level of provision of the service, Q^n is the present water quality, Q^a is the acceptable water quality
X =	gross income level
E =	level of education
H =	household size
A=	Age of the respondent
S =	gender (male/female)
D =	distance to the River Aire
WTP =	Hicksian equivalent measure of WTP.

Most of the other predictor variables such as the present water quality, level of education, household size and gender were not significant and were excluded from the model. Selected model variables are significant and the signs of the estimated parameters follow standard economic theory.

Table 3.7 Analysis of variance for multiple regression equation

Variance due to	DF	Sum of Squares	Mean Square	F-ratio	P value
Regression	3	1190.57662	396.85887	8.23206	0.0000
Residual	329	15860.74875	48.20896		

Multiple R	0.26424
R Square	0.06982
Adjusted R Square	0.06134
Standard Error	6.94327

Table 3.8 Coefficients, standard error and significance values for variables in the multiple regression equation

Variable	Coefficient	Standard error	Significance
Constant	-3.81	3.14	0.226
Acceptable water quality	1.00	0.56	0.073
Gross income	0.81	0.44	0.000
Distance to river	-0.68	0.18	0.123

The coefficient of determination, R^2 represents the proportion of the variation in the dependent variable "explained" by the independent variables. This R^2 value for the model is low, indicating that most of the variation in WTP was not explained by the predictor variables.

There are two reasons for the poor relationship between the variables. The major reason was the very large number of zero value returns attributed to the dependent variable. This indicates an unwillingness to pay anything for water quality improvement by a large proportion of respondents. The other reason is the estimation error. The existence of the disturbance term, coupled with the fact that its magnitude is unknown, makes calculation of these parameters impossible. For cross-sectional data, typical R^2s are not generally high. The global 'F Statistic' is the test of overall significance of the regression. This tests the hypothesis that all the coefficients are zero. The constrained regression in this case would have only an intercept component. The F test is a formal test of $R^2 = 0$ and tests the explaining power of the model. High values of the F statistic leads us to reject the null hypothesis that the constraints are true.

Using the critical values of the F distribution table for the 0.05 level, with degrees of freedom 3 and 329 then the critical value is 2.60. The computed F value is 8.2 (Table 3.7) which is in the rejection region. The null hypothesis that all the regression coefficients are zero is therefore rejected. The alternative hypothesis is accepted indicating that not all the regression coefficients are zero. From the practical standpoint this means that the independent variables do have the ability to explain the variation in the dependent variable (WTP). This is to be expected. Logically the acceptable level of water quality, gross income and distance to the river have a significant impact on WTP for water quality. The global test of whether the multiple regression model is valid assures us that they do.

Estimation of logistic regression model

The linear specification of the model is quite restrictive and has the unattractive property that marginal WTP is constant. It is quite likely that a more flexible form is preferable (FWR, 1994). In logistic regression, the parameters of the model are estimated using maximum-likelihood, in which the coefficients that make the observed results most likely are selected. The non-linear logistic regression model uses an iterative algorithm for parameter estimation. An iterative process of repeated logistic regression used willingness to pay five pounds (WTP5) as the dependent variable. The reason for selecting the five pound level as the dependent variable was that is the closest choice value to the average WTP of £3.91.

Logistic regression model based on the willingness to pay £5 value (WTP5);

$$WTP5 = 1.21 - 0.95\,(Q^a) - 0.18\,(D) + 0.08\,(X) - 0.13(H) \qquad 3.6$$

An iterative process of repeated logistic regression analysis identified that the most important variables for predicting the willingness to pay £5 were current water quality, perceived distance from the river, gross annual income and household size. Additional variables contributed little to the model. The low chi-square value of the model indicates that the model is a good fit. Model variables are significant and the signs of the estimated parameters follow standard economic theory.

-2 Log Likelihood 286.61167

Estimation terminated at iteration number 3 because Log Likelihood decreased by less than .01 percent.

-2 Log Likelihood	282.854
Goodness of Fit	228.453

	Chi-Square	df	Significance
Model Chi-Square	3.757	4	.4399
Improvement	3.757	4	.4399

Table 3.9 Coefficients, standard errors and significance values for variables in the logistic regression model

Variable	Coefficient	Standard error	Significance
Constant	1.2133	0.5233	0.0204
Current water quality	-0.0953	0.1306	0.4654
Distance from river	-0.1792	0.1509	0.2349
Gross income	0.0752	0.0659	0.2541
Household size	-0.1253	0.1124	0.2650

Estimation of Probit and Logit model

This section outlines the estimation of parameters for the Probit and Logit models and the problems associated with the estimation procedures. The dependent random variable Y in this model is assumed to be binary, taking two values, say 0 and 1. The outcomes on the dependent variable are assumed to be mutually exclusive and exhaustive. Y generally, is dependent upon K exogenous variables, which account for the variation of P. Thus, the relationship can be expressed as :

$P=P(Y=X_1,...,X_k)$,

where
X denotes the set of K independent variables.

This assumption is similar to the assumption of the standard regression model. In OLS regression, Y and X are linearly related, but in Probit and Logit cases the relationship between Y and X are quite different. As in OLS regression, the data are generated from a random sample of size N with a sample point denoted by i=1,...,N. Thus, the observations on Y are statistically independent of each other ruling out serial correlation. As for the linearity assumption in OLS, this method assumes that there is no exact linear dependence among the X_{ik}s. Furthermore, it implies that N>K and that each X_k must have some variation across observations. Thus, there are no two or more X_ks, which are perfectly correlated. However, as with OLS, Probit and Logit suffer the problem of multi-collinearity if near, though not exact, linear dependencies exists.

Logit analysis on untransformed data

Probability models are, as a rule, estimated from survey data, which provide large samples of independent observations with a wide range of variation of the regressor variable. One of the preferred methods of estimation is Logit. This permits the estimation of the parameters of almost any analytical specification of the probability function; in addition, it yields estimates that are consistent and asymptotically efficient with ready estimates of their asymptotic covariance matrix.

Logit uses an iterative scheme, which is supplemented by starting values for the parameter vector and by a convergence criterion to stop the process. As for the convergence criterion, the iterative process stops when successive parameter values are nearly equal or when the score vector comes quite close to zero. This should be achieved in five or, at the most, ten iterations. However, using SPSS 6.1 for windows convergence of the Logit in this study was reached after 13 iterations.

This was due to the nature of the raw data which may be ill-conditioned with an almost singular regressor matrix, with regressors of widely different order of magnitude, or with the sample frequency of the attribute under consideration very close to 0 or 1. However, in some cases of Probit and Logit the number of iterations was below 10. The Logit equations for River Aire water parameter estimation are given below.

Optimal solution found parameter estimates converged after 13 iterations. Parameter estimates:

(LOGIT model: (LOG(p/(1-p))) = Intercept + BX).

	Coefficient	Standard Error	Coeff./S.E.
Regression	0.18469	0.01491	12.39078
Intercept	-1.55382	0.14745	-10.53804

Pearson Goodness-of-Fit Chi Square = 31.092; DF = 3 & P = 0.000

Table 3.10 Logit analysis of untransformed response data

WTP	Total subjects	Observed responses	Expected responses	Residual	Probability
2.00	173.0	29.0	40.526	-11.526	0.23426
5.00	173.0	66.0	60.105	5.895	0.34743
10.00	173.0	104.0	99.086	4.914	0.57275
20.00	173.0	159.0	154.788	4.212	0.89473
40.00	173.0	169.0	172.495	-3.495	0.99708

There is no universally accepted goodness-of-fit measure for probit or logit estimation (Kennedy, 1994). The most common is the likelihood ratio index, which was not produced by the software used in this analysis. An alternative way of reporting goodness of fit, is a table giving the number of y=1 values correctly and incorrectly predicted, and the number of y=0 values correctly and incorrectly predicted, where an observation is predicted as y=1 if the estimated prob(y=1) exceeds one-half. Although, it is tempting to use the percentage of correct predictions as a measure of goodness of fit, the table was not produced by the SPSS computer package. Many computer packages, for example SAS and LIMDEP produce the likelihood ratio and the table. The purpose of the chi-square goodness-of-fit test is to determine how well an observed set of data fits an expected set. If there is an unusually small expected frequency in the data set, chi-square might produce an erroneous conclusions.

Logit analysis ($\log_{10}$ transformed data)

Optimal solution found parameter estimates converged after 15 iterations. Parameter estimates:

(LOGIT model: (LOG(p/(1-p))) = Intercept + BX).

	Coefficient	Standard Error	Coeff./S.E.
Regression	3.90916	0.25702	15.20977
Intercept	-3.12953	0.24140	-12.96409

Pearson Goodness-of-Fit Chi Square = 13.457 DF = 3 P = .004

Table 3.11 Logit analysis of $\log_{10}$ transformed response data

WTP	Total subjects	Observed responses	Expected responses	Residual	Probability
0.30	173.0	29.0	21.496	7.504	0.12425
0.70	173.0	66.0	69.546	-3.546	0.40200
1.00	173.0	104.0	118.609	-14.609	0.68560
1.30	173.0	159.0	151.573	7.427	0.87614
1.60	173.0	169.0	165.776	3.224	0.95824

Chi-square values of the two logit models are 31.09 and 13.46. This measures the accuracy of the model in terms of the fit between the calibrated probability and the observed response frequencies. A high chi-square value and low probability value indicate that the fit of data is not very satisfactory.

Estimation of Probit Model

Probit model parameter estimation is another step in estimating the nonlinear probability model. The same data as used in the logit model above were examined. Tables 3.12 contain the results from the Probit model. In both Logit and Probit cases, the parameter estimation are not much different illustrating the Behaviour of the variables.

Optimal solution found parameter estimates converged after 13 iterations.

Parameter estimates: (PROBIT model: (PROBIT (P) = Intercept + BX).

	Coefficient	Standard Error	Coeff./S.E.
Regression	0.09599	0.00708	13.56312
Intercept	-0.83734	0.08148	-10.27695

Pearson Goodness-of-Fit Chi Square = 76.148; DF = 3 & P = 0.000

Table 3.12 Probit analysis of untransformed response data

WTP	Total subjects	Observed responses	Expected responses	Residual	Probability
2.00	173.0	29.0	44.868	-15.868	0.25935
5.00	173.0	66.0	62.351	3.649	0.36041
10.00	173.0	104.0	94.941	9.059	0.54879
20.00	173.0	159.0	148.866	10.134	0.86050
40.00	173.0	169.0	172.768	-3.768	0.99866

When the dependent variable is qualitative, the accuracy of the model can be judged either in terms of the fit between the calculated probabilities and observed response frequencies or in terms of the model forecast to observed responses. In the case of a binary dependent variable such as WTP, the direct chi-square (χ^2) measure can be used for this purpose. However, the estimated chi-square indicate that the model observed responses and expected responses are different. Moreover, the estimated P-value is equal to zero. This indicates that the fitted model for that data may not be significant. Note that the predicted value of WTP is a probability, whereas the actual value is either 0 or 1. The correlation between the WTP binary dependent variable and a probabilistic predictor are measured by the R^2 values are not that meaningful.

Numerical integration procedure

Based on the responses to each WTP value, five bid amounts were chosen for the dichotomous Choice (DC) analysis. In a deliberate attempt to avoid the fat tail problem in the Logit curve, we set the highest bid amount equal to £40.00 per month. The highest reported WPT value in the open-ended survey was £75.00 per month. Table 3.13 shows the sample sizes and proportion of "no" responses for each of the bid values used in the analysis. A logit CDF was estimated from this data set, using only an intercept and bid value as explanatory variables.

$$LOG\left[\frac{P}{1-P}\right] = \alpha + \beta X_i \qquad 3.7$$

Table 3.13 Sample sizes and proportion of "No" responses

Bid Amount	Sample Size	No.of Responses	% "No" responses
2.00	173	29	0.168
5.00	173	66	0.382
10.00	173	104	0.601
20.00	173	159	0.919
40.00	173	169	0.978

Values for parameters α and β are -1.55 and 0.18 respectively. Now we have,

$$LOG\left[\frac{P}{1-P}\right] = -1.55 + 0.18X_i \quad 3.8$$

The estimate of slope parameter β is positive and is smaller than 1, implying that E(WTP) is finite. This indicates less of a "fat tail" problem; the integral of the CDF in this case is bounded.

The estimated CDF is shown graphically in Figure 3.8 along with the actual proportions of "no" responses observed for each of the five bid levels. An analytical solution to this equation has been obtained using the MAPLE V, release 3, mathematics software. The solution to the "a" value is as follows:

$$a = \frac{10^{(-1.55+0.18X)}}{10^{(-1.55+0.18X)}+1} \quad 3.9$$

The value for integration of the function between the bid amounts 0 and 40 was obtained using the same software. The estimated area under the curve is:

> int (a, x=0..40); 31.3218

This will give us the E(WTP) value,

E(WTP) = 40.00 - 31.32 = 08.68.

Using the integration procedure, we have the E(WTP) value of £8.68, which is somewhat larger than the WTP value obtained from the open-ended questions. Several authors have found that respondents to DC valuation questions will give answers that imply WTP values

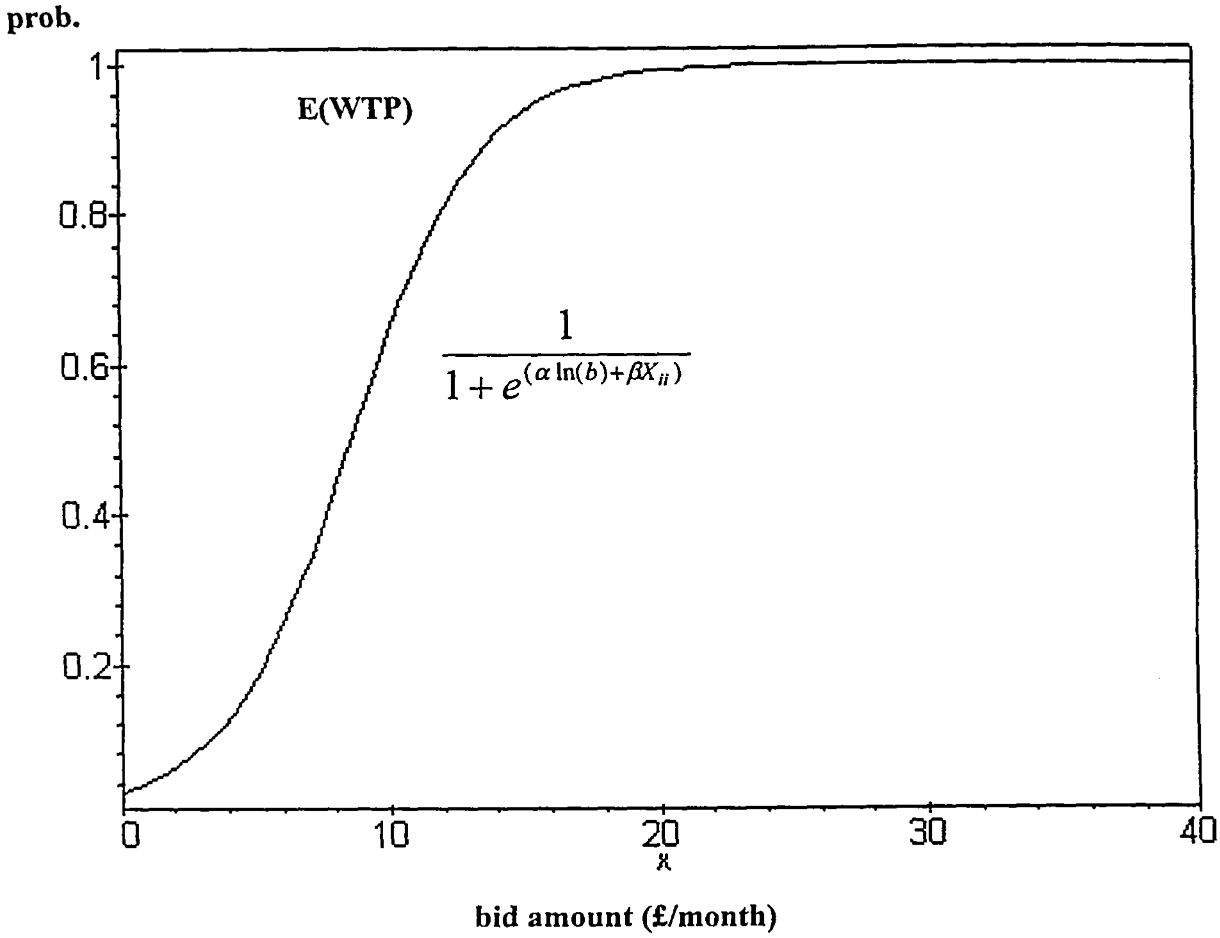

Figure 3.8. Integration of the Logit Curve

that are higher than those stated by respondents to open-ended questions (Kristom 1993, Kealy & Turner 1993).

3.4.4 Validity, reliability and the biases of the methodology

The use of the CV approach to value public goods has grown dramatically in the last 25 years, with more sophisticated survey designs being the major improvement. The issue of random behaviour and the approaches to establishing the validity and reliability have been emphasized in CV methodologies. Random behaviour is the antithesis of validity and reliability. The validity is dependent on the difference between that which one wished to measure and that which one actually measured. The reliability is the error term of the estimated equation. If the estimated value of the error term is a non-random variable, then a bias is likely to be present.

One exercise in validity testing is to examine whether the measures produced by the estimated model relate to other measures as predicted by theory. We have seen in the multiple regression model equation, that the CV measure conforms to theoretical expectations (theoretical validity) and also the CV measure is correctly correlated with other measures of the water quality (convergent validity). A further variant of this approach is to examine the explanatory power of bid functions (Bateman and Turner, 1993). However, the large number of zero WTP values and the high variance associated with CV, have resulted in a low R^2 *value* of 0.07. Mitchell and Carson (1989) suggest an R^2 value of 0.15 as minimum. However, psychologists point out that the very nature of social survey techniques make R^2 statistics of limited use (Bateman and Turner, 1993).

According to standard economic assumptions, the strategic behaviour in CV will be a function of the respondents' perceived payment obligation and the respondents' expectations about provision of a public good. Because of strategic behaviour, respondents tend to give a WTP amount that differs from their true WTP amounts in an attempt to influence the provision of the public goods. Samuelson (1954), in his original article on the provision of public goods, maintained that individuals could not be expected to reveal their true WTP for strategic reasons. There are some tests available to overcome strategic behaviour. We noticed in the field survey that CV estimates are unlikely to be over estimates, although money (i.e. WTP amounts) does not actually change hands at the time of the survey. A simple strategy we practiced in the survey was to use both open-ended and closed-ended questions. Although the good is desired, we have not experienced many unusually large WTP amounts. We also note that if the payment is thought to be probable there is a tendency to give a zero WTP value. We experienced a large number of zero responses, which might be expected under the circumstances in which the survey was carried out, i.e, public discontent with the water company after adverse media attention. Mitchell and Carson (1989) pointed out that the percent of respondents giving very large monetary amounts is very small, while the percent of respondents giving a zero WTP amounts is fairly large.

The CV approach suffers from a variety of theoretical and practical difficulties. There are several potential sources of bias given the nature of the CV technique and the survey instrument. Among the more important biases are hypothetical, strategic, starting point, information, sample-related, and the vehicle biases (Edwards and Anderson 1987). The iterative bidding game technique, used in the closed-ended format of the present survey, generally suffers from starting-point bias. An iterative bidding procedure begins with some arbitrary initial value. If the respondent agrees to that value, the bid value is increased until a negative response is reached. If the initial value is a negative one, the bid value is revised downward until reaching an acceptable response. The final bid value is equivalent to the Hicksian compensating or equivalent surplus. In general, starting-point bias occurs because the value selected to initiate the bidding game has an appreciable impact on observed final bids. This impact could take place in two ways. First, if the starting point is far away from the true value, the procedure terminates before the true bid is reached. The average true WTP value reported in the sample is £3.91, which is not far away from the starting point. The starting value also conveys information to the respondent about expected or reasonable bids and, thereby, influences the final bid outcome. The information transfer effect is related directly to the initial or starting bid amount. Although, the respondent may anchor to an initial point in a bidding experiment, we have noticed that only very few accepted the initial bid amount of £10.

When respondents are asked how much in increased taxes they would be willing to pay versus how much they would pay via other methods, the response may be significantly different.

This difference in WTP, dependent on the method of payment, is known as vehicle bias. Generally, the vehicles used in CV are utility bills, entrance fees, taxes, user fees, and higher prices. At times, respondents do not understand the scenario in the way intended by researchers because of the gap between plausibility and understandability. Therefore, the payment vehicle is either misperceived or is itself valued in a way unintended by the researchers. We realised in the survey that an increase in taxation would be the best payment vehicle in this study given the present water crisis.

Respondents also may change their values depending on the amount of information they are given about the environmental commodity or situation. For example, if information on present tax expenditures is given, the respondent may provide a different value than they would were they not informed about the tax expenditure. This phenomenon is termed information bias. An information overload effect can occur whereby respondents ignore important information and focus on and possibly misinterpret unimportant information. The definition of the population, decisions about the sampling frame, and attempts to obtain valid WTP responses and non-responses are some of the decisions to be made. Although the theoretical and practical problems associated with sampling errors should not be taken lightly, non-response is probably a much greater source of bias in survey research (Cochran 1983). Whether or not sampling errors exist, systematic differences between respondents and non-respondents will usually invalidate inferences based solely on data from respondents. This could be evaluated by sub-sampling at least 10 percent of the non-respondents when testing for sampling bias. Although, we have not investigated a sub-sample, it would be a good area to explore in a future study.

Sample selection bias concerns differences in Behavioural parameters that weight the determinants of Behaviour. This occurs when the probability of obtaining a valid WTP response among sample elements is related to the respondent's value for the good. Field interviews are generally free of sample selection bias because there is less potential for non-respondents to be consciously self-selected. Edwards and Anderson (1987) demonstrated various sources that could influence the sample selection bias and two parametric procedures that test for their occurrence. However, we do not see the relevance of conducting such tests in this study. They also provide an illustration of the magnitude of non-response bias in estimates of aggregate benefits. Mitchell and Carson (1989) demonstrated various sources of bias and their magnitude along with methodological problems and possible treatments.

At the design stage of the survey questionnaire, we made an attempt to reduce bias problems to an acceptable level. Questionnaire was modified significantly, following the pilot survey and individual comments.

3.4.5 Total economic value

The total value comprises direct use values and passive use values. Direct use can be most easily defined as requiring the agent to experience physically the commodity in some fashion. For example, the use of the river for swimming is a direct use. Passive use value is synonymous with the non-use value which a multiattribute environmental asset. Passive use values are more problematic to estimate. These values are not associated with actual use or even an option to use. Instead, such values are taken to be entities that reflect people's preferences. Total economic value is then made up of actual use values, option values (future personal recreation) and existence values (preserving biodiversity). However, in a CV study of water quality improvement, the component of total benefits (use and non-use) cannot simply be aggregated. There are often trade-offs between different types of use values and between direct and indirect use values. Similarly, partitioning of use and non-use values may be problematic. Aggregation of use and non-use values has to be used with great care and with a full awareness of its limitation. This is one of the future research areas required within CV. However, this study was not designed to explore this specialist subject.

3.5 The Total Benefits of Water Quality Improvement

The survey methods used in this study have facilitated an estimate of the benefits of water quality improvement in the River Aire. We have estimated two different WTP values using two different types of valuation question to assess individual preferences of water quality. The difference in mean WTP values for the open-ended and closed-ended formats may be due to the nature of the question. Respondents often find it difficult to pick a value out of the air, as it was, without some form of assistance in the open-ended format. As a consequence, it tends to produce an unacceptably large number of nonresponses or protest zero responses to the WTP questions (Desvousges *et al.,* 1983). The estimation procedure used in the analysis for the open-ended format is quite different to the procedure that is adopted in the closed-ended format. The selection of the right functional form, and the selection of the method that is suitable for the data is a significant factor in getting an acceptable WTP measurement.

The estimated average value of the individual WTP for water quality improvement under the open-ended format is £3.91 per month per household. Using the integration of the Logit bid function, we have expected WTP value of £8.68, which is somewhat larger than the WTP value obtained from the open-ended format. In comparing the mean WTP values from open-ended and closed-ended questioning, it appears that the respondents were thinking in the same monetary region to assign a value for improved water quality. The high level of estimated mean values obtained in the closed-ended format, may reflect considerable concern felt by the respondents or the greater probability of respondents agreeing to higher values than they would willingly state themselves.

Policy makers investing in water quality improvements can take these values into consideration in their decision making process. Assuming the true "willingness-to-pay" is bounded by these figures (i.e. £3.91-£8.68) and using the total household number in the surveyed corridor (i.e. 25,000) this would indicate a gross figure of £97,750- £224,500 per calendar month to effect water quality improvement as defined above. It should be noted that this does not include the broader catchment residents which might have an interest in water quality in the River Aire. If it were assumed, for example, that all City of Leeds residents were willing to pay the lower monthly contribution this would generate a revenue of approximately £800K per month. Some wider regional projections of "willingness-to-pay" monthly totals are presented in Table 5.1.

CV can provide information on some of the environmental and social benefits of water quality improvement. The benefit information provided here can be compared with actual expenditure to facilitate analysis of cost and benefits using the discounting approach. However, this step was not part of the present study.

4. PROPERTY VALUE ESTIMATION

4.1 Introduction

Economic theories suggest that land / property values may be influenced by environmental quality. Furthermore, economic assessments of such a phenomenon may be measured because environmental quality varies in space and time. Hence, it is possible to formulate relationships between differences in water quality and spatial and / or temporal variations in property values.

4.2 Factors Affecting Property in Leeds

Leeds is a large regional urban centre accommodating a population of 700,000 people and providing employment for 300,000. The city also houses the regional administration offices of major companies as well as many cultural and media facilities. Consequently, in comparison to other urban areas in the region, property values in Leeds are higher than average. However, as observed throughout the country in recent years, property values in Leeds are also subject to fluctuations which result from changes occurring in the national economy.

Property development in Leeds is controlled by the planning department of Leeds City Council and promoted through the Leeds City Development Corporation. There is a commitment of these two agencies to develop and regenerate the riverside in the city centre.

The water quality of the River Aire will only impinge on the value of properties in close proximity to the river. Hence, the focus of the investigations were directed to property within a 200 meter corridor of the river.

This narrow corridor area of the River Aire in Leeds encompasses a variety of property types;

- Residential (inner city) — e.g. Armley & Bramley
- Residential (suburban) — e.g. Horsforth
- Industrial — e.g. Armley & Holbeck
- Commercial — e.g. City centre
- Retail / leisure — e.g. City centre

The categories of property which would most probably benefit from water quality improvements are residential, commercial and retail / leisure. The benefits gained by industrial property is considered to be limited because of the adverse impacts which industrial sites have on general environmental quality.

4.3 Aims of the Water Quality and Property Values Investigations

In this study an investigation into the effect of water quality on property values adjacent to the River Aire was carried out. Particular attention was paid to the time period between 1985 and 1995. Two approaches were taken to elucidate the relationships between water quality and property values;

- A survey of estate agents and property surveyors and
- Interrogation of the Housing Database of the Halifax Building Society.

4.3.1 Estate agent survey

A number of the main estate agents and property surveyors were selected from the Leeds edition of the Yellow Pages (Appendix V). They were asked to complete a copy of a questionnaire with respect to the particular property type(s) they dealt with. The agents selected handled a wide range of property types, but were dominated by those concerned with commercial and residential uses.

The aim of the questionnaire was to investigate the perception, by the agents, of the influence that the River Aire had had on property values. The following specific objectives were examined;

- Background information on each agent;
- Their opinion on the water quality in the River Aire in the last 10 years;
- Their perception that the water quality had a beneficial effect on property values;
- Their views on the categories of property that had benefited in terms of marketability, economic enhancement and development potential;
- Their views on the prospects of quantification of these benefits and
- The desired level of water quality needed to allow property values to attain their full potential.

Note agents were only permitted to answer questions which related to the particular property category that they dealt with.

4.3.2 Results and discussion

Satisfactory responses to the questionnaire were obtained from 19 of the agents. These covered all property categories and geographical areas in the vicinity of the river in Leeds (Table 4.1). Most of the agents covered by the survey dealt with more than one category of property (89.4%) and 2 dealt with all five categories.

Table 4.1 Number of agents dealing with each property category

Property category	Number of agents
Residential / Housing	11
Industrial	12
Commercial	14
Retail / Leisure	9
Agricultural / Rural	3

Most agents (58.4%) considered that water quality in the River Aire was at level D, i.e. fair with poor fish stocks (Table 4.2). However, 89.4% considered that water quality had improved in the last 10 years.

Table 4.2 Agent opinion on the present water quality in the River Aire

Water quality code	Number of agents
A*	0
B*	0
C*	4
D*	11
E*	3
F*	1

Note* Appendix VI contains explanation of water quality code

In terms of marketable attributes; economic benefits, and development potential, the opinions of the agents suggest that the water quality improvement of the River Aire is more important for residential and commercial property than industrial; retail and agricultural property (Table 4.3).

Table 4.3 Percent of agents who expressed an opinion on the importance of river water quality to particular property types

Property category	Is it a marketable attribute?	Does it Economically benefit the category?	Does it influence a property developer?
Residential / Housing	100	91	100
Industrial	50	33	25
Commercial	79	79	79
Retail / Leisure	65	56	44
Agricultural / Rural	67	0	33

In general, agents opinion suggested that the greatest level of water quality improvement was required for commercial and residential property (Level B: Good water quality with excellent fish stocks). Water quality did not appear to be as important for industrial and agricultural uses where most agents suggested that water quality did not need to be improved (Table 4.4).

It was not possible to quantify these benefits in economic terms because most agents were not able to provide accurate figures on property values, particularly where retrospective information was required. Furthermore those companies with reliable sources of information, in the form of archived databases, did not hold data with sufficient detail for statistical analysis. Indeed, this was a major limitation on the information. Furthermore, some agents approached in the survey were not able to / or declined to make any comment at all. However, those who were able to raised a number of interesting points, particularly with respect to commercial property.

Table 4.4 Percent of agents who expressed an opinion on the water quality level required to permit property values to attain their full potential

Property category	A	B	C	D	E	F
Residential / Housing	9	64	18	-	9	-
Industrial	-	25	33	42	-	-
Commercial	-	71	7	14	7	-
Retail / Leisure	-	44	22	33	-	-
Agriculture / Rural	-	-	-	67	33	-

National economy

The common theory held by agents and surveyors was that rents and purchase values tend to double over a 10 year period. However, national economic factors have had a marked affect on this pattern in recent years. For example, office space in Leeds city centre is presently quoted at £12-£15 per sq.ft, but in the mid 80s similar accommodation would have been in the region of £25-£30 per sq.ft.

Commerce location

The main factor influencing the location of most enterprise is client proximity. Environmental factors became more relevant when the importance of client proximity to an enterprise has reduced.

Many national companies were able to negotiate office rents at levels which were much lower than quoted prices. This was particularly so for enterprises with large interests in London. Hence, within the same building, different companies may pay differing rent levels although the facilities provided are identical.

New developments

In areas adjacent to the River Aire there are a number of developments which provide first class accommodation for residential, commercial and amenity use. The cost of these developments, combined with their high quality has resulted in properties with values higher than elsewhere in the city.

Comments regarding such accommodation indicated that those residing in these developments chose to do so because of the quality of the accommodation and the city centre location. The influence of the river was uncertain. Furthermore, these new developments had higher rates of occupancy when compared to other properties.

Marketability

Suggestions were made that the quality of the river, and associated improvements, had not been brought to the attention of the public by either the Environment Agency or Yorkshire

Water. Hence, using the improvements in the river as part of a marketing campaign would prove very difficult.

Compounded with this is public confusion in the perception of water quality. While improvements in chemical parameters may be apparent, the public still identified poor water quality with litter which was visible from the accumulations of bankside litter. This perception was reinforced in summer months when odours were apparent.

The amenity value of the river was a marketable attribute. However, with the exception of the city centre, access was restricted and there were deficiencies in the provision of secondary amenity facilities such as car parks. Such issues have also been raised by the Eye on the Aire group (Eye on the Aire, 1992).

4.3.2 Halifax Building Society data

The Halifax Building Society holds a unique database of information relating to the purchase of residential properties. Data were purchased from the Group Statistical Services of the Society for the second part of the property value investigation.

Property value data were selected for a number of post-code sectors in the city of Leeds. Those chosen represented areas that were either adjacent to the river or at a distance away which would act as a control group (Figure 4.1). Data were obtained over a number of annual time periods these being; 1985; 1987; 1989; 1991; 1993 and 1995 and for the following property categories;

- 1 bedroomed flats;
- 2 bedroomed flats;
- 3 bedroomed semi detached houses;
- 3 bedroomed terraced houses and
- 4 bedroomed terraced houses.

These categories were chosen because they provided sufficient data for the post-code sectors and the time periods selected to facilitate statistical analysis.

Comparisons were made between the average property values comparing properties adjacent to the river and the control group using paired t-tests. This was done for each property category and each time period of study. Property price indices were calculated to identify temporal trends in property values adjacent to the River Aire and in the control group. Indices of average property values adjacent to the river as a proportion of the average property value in the control group were calculated.

This form of analysis is termed relative shift analysis. We examined the shift in values of the property / land of interest relative to the shift experienced in the control. Unlike normal controls we have no expectation that this control will remain unchanged. Relative shift has been used in the past to examine land use trends within and without structurally protected flood plain land.

4.3.3 Results and Discussion

Residential property values in the control group doubled in the period 1985 to 1995 (Table 4.5). In the same period, values of property adjacent to the river increased by 2.5 times. In

Table 4.5 Property prices and index values for different property categories between 1985 and 1995

Year	Property category	Riverside (£)	Control (£)	Price Index (Riverside/ Control)
1985	1 bedroom flats	17 063	16 745	1.02
	2 bedroom flats	20 143	24 512	0.82
	3 bedroom semi-detached	25 200	26 625	0.95
	3 bedroom terraces	18 776	19 434	0.97
	4 bedroom terraces	33 817	24 276	1.39
1987	1 bedroom flats	17 750	18 267	0.97
	2 bedroom flats	23 150	31 453	0.74
	3 bedroom semi-detached	28 893	29 884	0.97
	3 bedroom terraces	22 260	22 818	0.98
	4 bedroom terraces	26 288	36 678	0.72
1989	1 bedroom flats	38 793	31 713	1.22
	2 bedroom flats	52 600	43 573	1.21
	3 bedroom semi-detached	54 749	58 687	0.93
	3 bedroom terraces	42 406	40 924	1.04
	4 bedroom terraces	58 250	72 948	0.80
1991	1 bedroom flats	38 611	40 088	0.96
	2 bedroom flats	59 000	49 007	1.20
	3 bedroom semi-detached	52 875	60 487	0.87
	3 bedroom terraces	44 206	46 759	0.95
	4 bedroom terraces	76 333	53 833	1.42
1993	1 bedroom flats	35 450	34 531	1.03
	2 bedroom flats	45 169	43 016	1.05
	3 bedroom semi-detached	55 456	59 714	0.93
	3 bedroom terraces	41 797	39 893	1.05
	4 bedroom terraces	82 083	64 190	1.28
1995	1 bedroom flats	41 650	32 400	1.29
	2 bedroom flats	57 312	40 240	1.42
	3 bedroom semi-detached	56 893	53 400	1.07
	3 bedroom terraces	42 401	39 212	1.08
	4 bedroom terraces	75 000	43 795	1.71

both groups most of the increase occurred in the period between 1987 and 1989. This increase in value was not sustained in the following years for property in the control group. However, property values adjacent to the river continued to increase, although not at the same rate, in the following years. It is suggested that environmental quality, including aspects of improved water quality, may have played a role in maintaining rising property values adjacent to the river.

Paired t-test analysis demonstrated that there were no significant differences in property values ($p. < 0.05$), for any of the time periods investigated, between properties adjacent to the river and the control group (Table 4.6). However, probability values were close to significance in 1987 ($p. = 0.15$) and 1995 ($p. = 0.17$). Closer investigation revealed that, in 1987, property values in the control group were higher than those adjacent to the river for all property categories. In addition, property values, in all categories, were higher for property adjacent to the river in 1995. These differences in property values coincide with periods of apparent poor and improved water quality respectively.

Comparative index values also illustrated this trend (Table 4.6). Values for 1985 to 1993 showed that values in the control group and the group adjacent to the river were similar. However, in 1995 property values adjacent to the river were over 30% higher than those in the control group.

Table 4.6 Comparison of average price index values and paired t-test probabilities between property adjacent to the River Aire and the control group between 1985 and 1995

Year	Average Price Index (Riverside/ Control)	Probability (Paired t-test)
1985	1.03	0.42
1987	0.87	0.16
1989	1.04	0.64
1991	1.08	0.84
1993	1.07	0.63
1995	1.31	0.18

A large proportion of the increase in value of property adjacent to the river may be attributed to the residential developments in the city centre. These developments provide high quality residences in pleasant surroundings. However, water quality must be considered to be an integral part of the overall environmental quality of the area.

4.4 River Water Quality and Property Values in Leeds

From the two investigations it is evident that water quality in the River Aire has been, and will continue to be, of economic benefit to property values in its vicinity. This conclusion is supported by information gathered from the opinions of estate agents and data from the Housing Database of the Halifax Building Society.

The opinions of estate agents indicate that the types of property which would most probably benefit from water quality improvement are commercial and residential properties. It was difficult to quantify this in financial terms, because of a number of other influential factors. However, it was clear that occupancy rates of property close to the river was much greater than in other parts of the city (i.e. such property did not remain vacant for long periods of time). Water quality was also considered to be an important marketable attribute for property close to the river. However, there are two constraints on this;

- the Environment Agency must first publicise the improvements and
- further improvements are necessary to allow property to gain full economic benefits.

Data from the Halifax Building Society, on residential property, indicated that there were no statistical differences in property values adjacent to the river compared with the control. However, there was a trend of increasing property values close to the river which had become apparent in recent years. It was estimated that, at present, average property values adjacent to the river are 31% higher than property away from the river. Over a similar period water quality in the River Aire has improved. There is an apparent correlation here although no causation can be proved.

5. SUMMARY AND CONCLUSION

5.1 Background

The aim of this project was to define the benefits of water quality improvement within the corridor of the River Aire as it passes through the Leeds conurbation.

This empirical study forms part of a broader initiative by the Environment Agency to develop techniques and approaches to the assessment of the societal benefits which are normally unquantified in environmental investment appraisals.

5.2 Empirical Studies Undertaken

Predictive river water quality models were assessed to define the feasible scenarios of water quality improvement within the lower reaches of the river resulting from investments in waste water treatment and integrated catchment control.

A contingent valuation survey was undertaken based on a defined corridor between Esholt and Knostrop to quantify the "willingness-to-pay" for water quality improvement. The survey acquired data on the socio-economic and demographic characteristics of the respondent population to enhance transferability of the information acquired. Interviewees were requested to classify present river water quality according to a six part (A to F) ladder which broadly paralleled current Environment Agency classification.

A novel aspect of this survey was the development of a methodology which linked commercially available post code address files with a geographical information system to select the surveyed population.

A parallel survey of property prices, rents and land values was conducted to determine changes in these characteristics that might be attributable to historical water quality improvements.

5.3 Results

The current perception of respondents (80%) was that the River Aire water quality lay in class D (i.e. moderate pollution with poor fish stocks and reduced use potential) or lower. This indicates that the public perception of present water quality is pessimistic.

An 87% response rate was achieved of the random sample selected. These 333 respondents exhibited a mean "willingness-to-pay" of £3.91/month/ household to effect a water quality improvement to facilitate direct contact recreational activities such as swimming with excellent fish stocks (i.e. from a perceived level of D or lower to a new level of A).

A considerable proportion of respondents (48%) recorded a "willingness-to-pay" of zero. This may have been influenced by adverse publicity concerning the Regional Water Company during the survey period and the publics' perception that pollution remediation is outside their direct financial responsibility.

Whilst the existence of 'zero value' responses are common in economic valuation of public goods, it does present certain statistical problems. This was particularly evident in the least squares regression analyses which exhibited generally low explanation. Partly to address these problems, further analyses were conducted using logistic regression, logit and probit analyses.

Using a dichotomous choice procedure followed by integration of the bid curve resulted in a estimated "willingness-to-pay" of £8.68/month/household, higher than the open-ended questionnaire derived figure of £3.91/month/household. Other studies have also observed generally higher "willingness-to-pay" estimates from dichotomous procedures.

Assuming the true "willingness-to-pay" is bounded by these figures (i.e. £3.91-£8.68) and using the total household number in the surveyed corridor (i.e. 25,000) this would indicate a gross figure of £97,750- £224,500 per calendar month to effect water quality improvement as defined above. It should be noted that this does not include the broader catchment residents which might have an interest in water quality in the River Aire.

If it were assumed, for example, that all City of Leeds residents were willing to pay the lower monthly contribution this would generate a revenue of approximately £800K per month. Some wider regional projections of "willingness-to-pay" monthly totals are presented in Table 5.1.

Table 5.1 Speculative projections of regional monthly "willingness-to-pay"(£)

	Open-ended Average WTP (£) Minimum-end	**Average WTP(£)**	**Closed-ended and Integration Procedure WTP (£) Maximum-end**
Per household values	3.91	6.45	8.98
Corridor values (25,000 households)	97,750	16,125	224,500
City values (200,000 households)	782,000	1,290,000	1,796,000
Agency region values (2,500,000 households)	9,775,000	16,125,000	22,450,000

Whilst property values in the City of Leeds doubled in the period 1985 to 1995, values in the surveyed corridor exhibited a 2.5 fold increase, principally due to residential development in the city centre. The displacement of industrial land uses with prestige residential and commercial activities suggests increasing importance of water quality to the property sector in the central zone of the city of Leeds.

5.4 Conclusions

This project has demonstrated the feasibility of initiating empirical investigations to define the "willingness-to-pay" of the population for environmental improvements through the application of widely accepted contingent valuation methods.

Linking of post code address information with geographical information systems offers an effective means of sample selection and survey design in contingent valuation analysis.

Building society, and other data sources, offer considerable potential for assessing the relative movement in property values adjacent to and distant from sites of environmental quality change although the present investigation was unable to isolate the contribution of water quality to this observed trend in the Leeds area.

Notwithstanding the proportion of zero value returns, the survey has demonstrated a significant financial commitment of the surveyed population to effect water quality improvements in this historically polluted urban watercourse.

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Appendix I

WATER QUALITY IMPROVEMENT SURVEY
QUESTIONNAIRE
RIVER AIRE

SECTION I: LOCATION AND USE OF RIVER AIRE

1). Approximately how far is your home from River Aire or any tributary of Aire?
______________ meters/km (yards/miles) please delete as appropriate.

2). How do you use the River Aire? Please put a tick in the **first box** for all uses that apply to you and to members of your household during the last five years (1991 through 1995). Please tick the **second box** if you **would** use the river for this purpose assuming a suitable water quality.

Group A			**Group B**		
☐	☐	House boating	☐	☐	Private abstraction
☐	☐	Swimming	☐	☐	Livestock drinking water
☐	☐	Angling	☐	☐	Draining excess water
☐	☐	Irrigation	☐	☐	Private discharge
☐	☐	Canoeing	☐	☐	Flood alleviation
☐	☐	Sailing	☐	☐	Nature appreciation
☐	☐	Water contact activities	☐	☐	Disposal of liquid wastes
☐	☐	Water skiing	☐	☐	Bird watching / Wildlife
☐	☐	Walking by the river	☐	☐	Other (specify______________)

If "yes" to any item in **GROUP A**, continue in **section II**, otherwise go to **section III**.

SECTION II. WATER CONTACT ACTIVITIES.

3). How often did you or anybody in the immediate family contact water (i.e. immersion) in the river during 1995?

Activity in Group A	**How often**
______________________	______________ week/month/year
______________________	______________ week/month/year
______________________	______________ week/month/year
______________________	______________ week/month/year

4). Can you describe the nature of your (and/or your immediate family's) contact with the water (circle appropriate number).

1. Water contact with your skin
2. Immersion of your head
3. Swallowing water
4. Other (please specify ____________________________________)

5). Did you or anybody in the immediate family experience any disease, as a result of water contact? (Circle your answer)

yes   no (go to section III) ____

If **"yes"**

Type of disease ______________________

How many days ______________________

How often ______________________

SECTION III. POTENTIAL SOURCES OF WATER POLLUTION IN THE RIVER AIRE.

6). Now we would like your **opinion** concerning the significance of various sources of water pollution. Using a scale among 1 and 5, please give a **significance rating** for each of the potential sources of water pollution given below. A value of **"1"** means that the item is **not a significant source** of water pollution in your opinion and a value of **"5"** means that it is a **very significant source** of water pollution.

Potential sources of water pollution	Ranking
• Sewage treatment plant waste	________
• Water treatment plant waste	________
• Industrial waste	________
• Run-off from roads and storm drains	________
• Run-off and leaching from landfills	________
• Run-off from fertilizers, manure & pesticides applied to farms	________
• Run-off from developments (parking lots, building sites etc.)	________
• Illegal dumping of wastes in water (litter)	________
• Leaking underground storage tanks (gasoline tanks etc.)	________
• Household waste	________
• Drainage from mines (coal, iron etc.)	________
• Other (please specify:______________________)	________

SECTION IV. WATER QUALITY IN THE RIVER AIRE.

These next questions relate to the surface water quality that you have observed or know about in the River Aire. For this purpose, we will use a **Water Quality Ladder,** which considers different water quality standards used by the National Rivers Authority (NRA).

WATER QUALITY LADDER

A	**Good water quality**	- Very clean, suitable for all uses (include. swimming)
B		- Clean, suitable for most uses (excellent fish stocks)
C	**Fair**	- Slight pollution, suitable for recreation (eg. canoeing)
D		- Moderate pollution, reduced uses (poor fish stocks)
E	**Poor**	- Dirty, water uses very restricted (fish stocks absent)
F	**Bad water quality**	- Very Dirty, no suitable water uses

Please consider the last year (1995) for all water quality questions.

7). Circle the letter which best reflects your view of River Aire **current water quality**.

A B C D E F _____
Good Bad

8). Is this water quality suitable for :

Swimming?	yes	no	_____
Fishing and wildlife?	yes	no	_____
Recreational (boating etc.)?	yes	no	_____
Livestock uses?	yes	no	_____
Crop uses?	yes	no	_____

9). What water quality level would be **acceptable** to you for the water in River Aire? (Circle your answer)

A B C D E F _____
Good Bad

10). Would this acceptable water quality be suitable for:

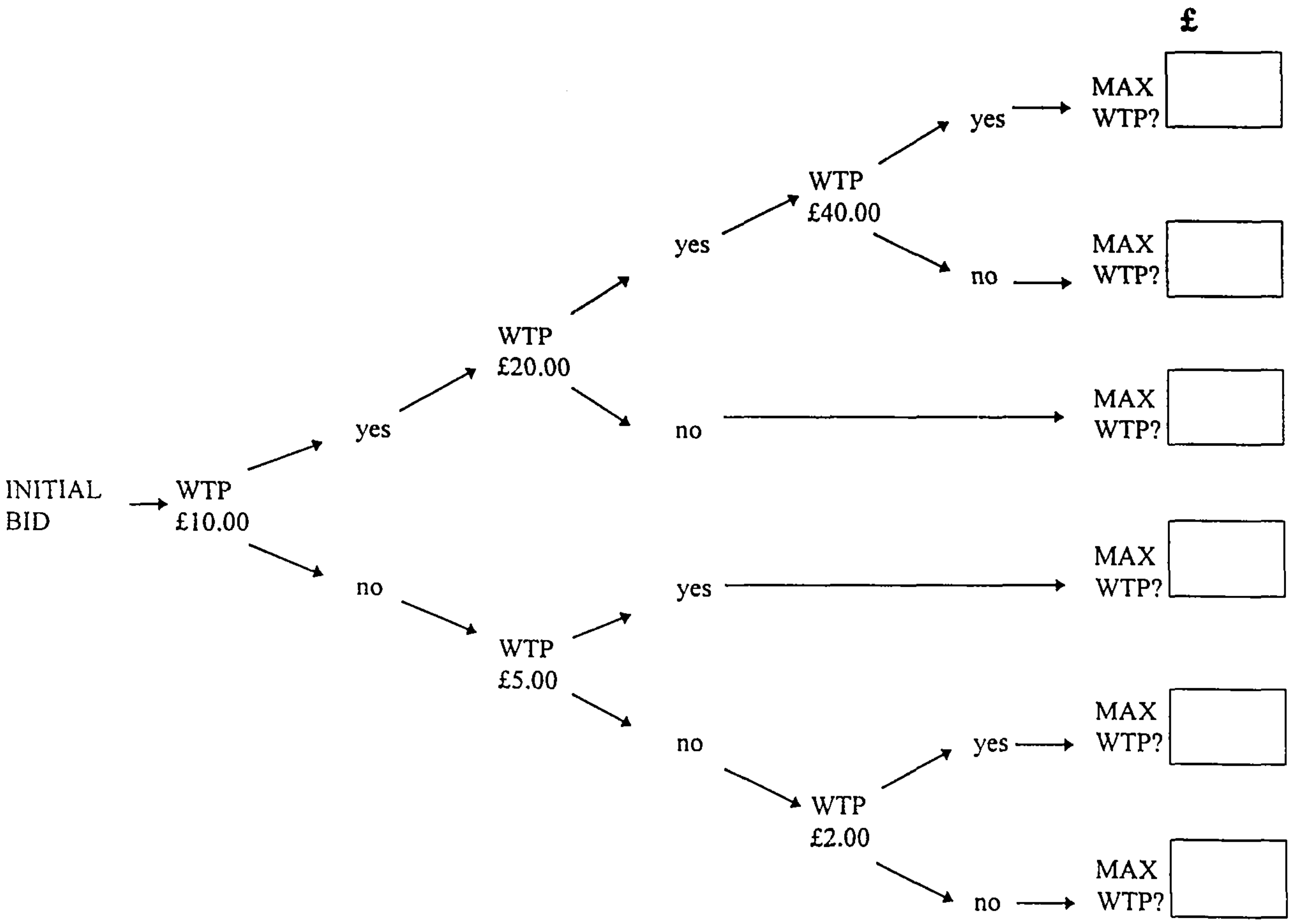
Swimming?	yes	no	_____
Fishing and wildlife?	yes	no	_____
Recreational (boating etc.)?	yes	no	_____
Livestock uses?	yes	no	_____
Crop uses?	yes	no	_____

<u>Interviewer: Please now show water samples and river photographs to the respondent giving examples of good and bad water quality.</u>

Note in the next section we will be asking questions relate to your willingness to pay for certain changes in the water quality of the River Aire. **This is a hypothetical situation and does not imply that you will receive a bill or payment from any government body or other organization.** We want to get an estimate of the value that you place on changes in water quality.

11). Assume that the **current water quality** level that you indicated in Q#7 is to be changed to the **best** level, that is to level A. If you indicated that the current water quality is already A then assume that this level will be maintained indefinitely.

Would you be **willing to pay** £10 each month over the coming year as more taxes for this level of change to be achieved and/or maintained?



If you answered £0.00 to Q#11 please answer next question. Otherwise please go to section V.

12). Why did you answer £0.00? Please circle appropriate number:

1. I do not make use of the river nor do I expect to use it.
2. I do not think it is appropriate to place a money value on water quality improvement.
3. I am not comfortable of placing a money value on water quality improvement.
4. Water quality improvement or environment conservation is not in my agenda.
5. Other (Please specify)______________________________

SECTION V. ABOUT YOUR LAND

13). Do you own the property you live? (Circle answer)

yes no

If yes,

- Area of the land (acres) ____________________
- Approximate value (£) ____________________

14). Do you think that the value of the property you own or rent has been **changed** during the last **five years**?

yes no

If yes,

Why? (Circle appropriate number(s))

1. General trend of land value in the area
2. People and businesses are moving out of the area
3. Bad/good river water qualities affect the value of the land
4. Other (pl. specify _________________________)

Give approximate percentage change of land value ________%_____
Enter + or - sign in the space to indicate the increase or decrease of land value.

15). Would you think that your property value would increase, as a result of:

- Improvement in River Aire corridor (circle) yes no
- Better river water quality (circle) yes no

16). **For properties within 100 meters of the river (only).**

What premium do you pay in terms of monthly payments in mortgage or rent for your riverside location?

£__________ per month.

SECTION VI. ABOUT YOU

17). How old were you on your last birthday? __________years.

18). Gender:(Please circle) Male Female

19). Including yourself, how many people are living in your household? ______

20). How long have you lived at this location? _________ years.

21). What is the highest grade or level of regular school that you have completed including college, vocational or technical training? (Please circle)

1. none
2. CSE
3. GCSE/O' level
4. Advanced level
5. Diploma, vocational or technical training
6. Bachelors degree
7. Masters degree
8. Professional

22). Please circle the category that comes closest to your household's gross income (£) from all sources (wages, investments, and part-time jobs) in 1995? (Circle correct answer)

1 = under £8000	2 = 8000 - 10000	3 = 10000 - 15000
4 = 15000 - 20000	5 = 20000 - 25000	6 = 25000 - 30000
7 = 30000 - 35000	8 = 35000 - 40000	9 = more than 40000

23). Are you a member of any environmental group or organization?

yes no

24). We have now concluded the questionnaire. If you have any questions or comments relating to this survey or the water quality in the River Aire, please use the space below.

____

____

____

____

Thank you very much for your time. The Environment Centre at the University of Leeds and the National Rivers Authority appreciate your input and cooperation.

Appendix II

SAMPLE SIZE SELECTION

1. $\text{SEM} = \frac{\sigma}{\sqrt{n}}$

SEM = Estimated standard error of the mean
σ = Standard deviation
σ, and summary statistics such as median and total willingness to pay (TWTP) are decreasing function of the sample size.

We are interested in the likely magnitude of the relative error (the percentage deviation from the true mean) rather than the absolute magnitude of the error. In order to achieve an acceptable degree of precision in sample statistics, such as the mean WTP amount, CV studies require large sample sizes. This is mainly due to the large variance in the WTP responses. Sampling theory provides a framework within which to think intelligently about the problem.

2. The estimated coefficient of variation "v" in CV studies almost always fall between 0.75 and 6.00. Therefore, an initial estimate for "v" of at least 2 is advisable (Mitchell & Carson, 1986). Since we have a prior estimate of "v" , where

$$v = \frac{\sigma}{TWTP}$$

now we can estimate the sample size, as a rough approximation.

$$n = \left[\frac{Zv}{\Delta}\right]^2$$

where,
Δ is the percentage distribution between the true willingness to pay (TWTP) and the estimated willingness to pay (EWTP). Past experience suggests that the reasonable value for Δ lie between 0.05 and 0.3.
Z is the standard value; the confidence intervals are of the form $t\,\Delta$ EWTP, where t is the standard t variate. The use of two sided 95 percent ($1-\alpha$) confidence level gives us the Z value of 1.96.

3. Thus, we have,

$$n = \left[\frac{1.96 \times 2.0}{0.20}\right]^2 = 384.$$

This sample size presume that **Simple Random Sample** method was used to select the respondents.

Appendix III

THE ECONOMETRICS OF THE CV MODEL.

A regression line could be fitted to these data by using one of several econometric techniques. One may define a linear relationship and make it hold identically by introducing an additive disturbance term e_i, as in

$$Y_i = \alpha + \beta X_i + e_i \; 5 \qquad \text{III.1}$$

It is necessary to assign complex properties to the e_i to restrict the Y_i to the observed values 0 and 1. Thus, e_i cannot have the simple properties that are the main appeal of the regression model. The solution to the problem is to regard Y_i as a discrete random variable and to make the probability of $Y_i = 1$ not the value of Y_i itself. This leads to a probability model that specifies the probability of a certain response as a function of the activator.

$$P_i = \Pr(Y_i = 1) = P(X_i, \theta) \; 6 \qquad \text{III.2}$$

and

$$Q_i = \Pr(Y_i = 0) = 1 - P(X_i, \theta) = Q(X_i, \theta) \; 7 \qquad \text{III.3}$$

where,
Pr( ) = the probability of the event
P( ) = probability as a function of certain argument
Q( ) = compliment of P( )
Q = vector of parameters that govern its Behaviour.

The regression equation, therefore, is specified as

$$P(X) = \alpha + \beta X \; 8 \qquad \text{III.4}$$

which is the Linear Probability Model (LPM), and the estimation of a, and b can be made by the linear regression model.

Suppose that we have $n_i > 1$ observations on the discrete choice Behaviour of the ith individual, where i=1,...,N. Each individual under consideration is characterized by a vector x_i containing values of explanatory variables. We observe n_i trials corresponding to each vector x_i. Let y_i equal the number of occurrences of one of the alternatives and, therefore, proportions of the occurrences of a particular event Z in n_i trials is

$$P_i = X'_i\beta + \varepsilon_i \quad i = 1,\ldots,M$$ III.5

Thus the full set of observations can be written in matrix form, as

$$P = XB + E\,9$$ III.6

If the sample proportions p_i are related to the true population R_i by,

$$P_i = P_i + \varepsilon_i \quad i = 1,\ldots,M\,10$$ III.7

where P_i is the probability of that particular event Z, given the values x_i, then the error term e_i has zero mean and variance $P_i(1-P_i)/n_i$. The covariance matrix of e is then,

$$\Omega = E(ee') = \begin{vmatrix} \frac{P_1(1-P_1)}{n_i} & 0,\ldots & & 0 \\ 0 & \frac{P_2(1-P_2)}{n_2},\ldots & & 0 \\ 0 & & 0 & ,\ldots\frac{P_M(1-P_M)}{n_M} \end{vmatrix} 11$$ III.8

The appropriate estimator for B in equation (III.6) is

$$B = (X'\ \Omega^{-1}\ X)\ X'\ \Omega^{-1}\ P\,12$$ III.9

which is the generalized least square estimator (GLE). The true population P_i is generally unknown but is consistently estimated by p_i. Thus the GLE provides the values for estimated W, which is the consistent estimator obtained by replacing P_i in equation (III.7) by p_i. The estimated B is asymptotically normally distributed, and a consistent estimator of the covariance matrix, which may be used as a basis for hypothesis testing. The predictor $p_i = x_i{'}b^*$ is interpreted as a predicted probability.

However, the main drawback of this model is that nothing ensures that the estimated p_i will fall in the unit interval. Probabilities are, of course, restricted to the interval from 0 to 1. As a result, the LPM imposes harsh and quite possibly arbitrary constraints on the values the regression coefficients may assume. As long as the linear assumption is maintained, least squares estimation with a correction for heteroscedasticity and some care in interpretation in small samples is viable.

There are a variety of reasons why the assumption that a probability model is linear in the independent variables is frequently unrealistic. If the model is incorrectly specified as linear, the statistical properties derived under the linear assumption generally will not hold. The parameters being estimated may not even be relevant. The only apparent solution to this problem is to specify a nonlinear probability model in place of the LPM.

This approach considers the larger value of the index that will occur, as the greater probability of the event. It is assumed that a monotonic relationship exists between the value of index and the probability of the event occurring. Therefore, the true probability function would have the characteristic shape of a cumulative distribution function (CDF). The most commonly used CDFs are the normal and logistic. In practice, the normal density leads to the Probit model while the logistic density yields the Logit model.

For a variety of reasons, however, the logistic and normal curve specifications are used frequently as alternatives to the linear specification of the probability model.

The Logit Model

The Logit model is based on the logistic CDF and is frequently used as an alternative to the Probit model. The logistic CDF given below closely approximates that of a normal random variable and has some convenient properties.

$$P_i = \Pr(I_* \leq X_{i'}\beta) = F(X_{i'}\beta) = \frac{1}{[1+\exp(-X_{i'}\beta)]} \quad 13 \qquad \text{III.10}$$

Using the Taylor series expansion and the probability expansion, the probability function can be rewritten as:

$$\begin{aligned} L &= \ln\left(\frac{p_i}{1-p_i}\right) = \ln\left(\frac{P_i}{1-P_i}\right) + \frac{e_i}{P_i(1-P_i)} \\ &= X_{i'}\beta + \mu_i, \qquad 14 \qquad \text{III.11} \\ &\textit{since } \ln\left(\frac{P_i}{1-P_i}\right) = X_{i'}\beta \end{aligned}$$

Probit and Logit parameters can be estimated using the Maximum Likelihood Estimation (MLE) method. MLE is an alternative to OLS in many situations. Generally, exact (small sample) properties of the MLE (unbiasedness, efficiency, normality) cannot be established. The MLE typically exhibits the asymptotic (large sample) properties of unbiasedness, efficiency, and normality. A minor drawback of MLE on Probit and Logit is that the likelihood estimation is nonlinear and cannot be estimated. The result, is that algebraic solutions are not obtainable. Instead, approximation by standard iterative algorithms are widely used.

Appendix IV.

MULTIPLE REGRESSION MODEL WITH ALL INDEPENDENT VARIABLES (listwise deletion of missing data):

Analysis of variance for multiple regression equation (Full model)

Variance due to	DF	Sum of Squares	Mean Square	F-ratio	P value
Regression	9	894.46	99.38	1.44	-
Residual	168	11589.35	68.98		

Coefficients, standard error and significance values for variables in the multiple regression equation

Variable	Coefficient	Standard error	Significance
Constant	0.39	5.90	0.95
Acceptable water quality	0.99	0.89	0.27
Gross income	0.97	0.37	0.01
Duration lived	0.14	0.35	0.70
level of education	-0.27	0.36	0.46
household size	-0.64	0.54	0.24
Age of the respondent	-0.33	0.55	0.55
Value of the property	0.01	0.29	0.97
Distance to the River Aire	-0.72	0.72	0.32

Other relevant statistics:

Multiple R	0.27
R Square	0.07
Adjusted R Square	0.02
Standard error	8.30

Dependent variable: Maximum willingness to pay.

MULTIPLE REGRESSION MODEL WITH ALL INDEPENDENT VARIABLES (Mean substituted for missing data):

Analysis of variance for multiple regression equation (Full model)

Variance due to	DF	Sum of Squares	Mean Square	F-ratio	P value
Regression	10	1323.64	132.36	2.71	-
Residual	322	15742.90	48.89		

Coefficients, standard error and significance values for variables in the multiple regression equation

Variable	Coefficient	Standard error	Significance
Constant	-1.52	3.80	0.69
Acceptable water quality	0.03	2.92	0.99
Gross income	0.86	0.22	0.00
Duration lived	-0.07	0.20	0.73
level of education	-0.07	0.24	0.78
household size	-0.35	0.29	0.23
Age of the respondent	-0.02	0.31	0.94
Value of the property	-0.01	0.17	0.95
Distance to the River Aire	-0.73	0.46	0.11

Other relevant statistics:

Multiple R	0.28
R Square	0.08
Adjusted R Square	0.05
Standard error	6.99

Dependent variable: Maximum willingness to pay.

Appendix V.

RECORD OF ESTATE AGENTS & PROPERTY SURVEYORS QUESTIONED:

Name of agent / surveyor	Address of agency	Postcode
Towler	37, Great George St, Leeds	LS1 3BB
Denby, Beevers & Taylor	1, Oxford Place, Leeds	LS1 3AX
Paxtons	33, Great George St, Leeds	LS1 3BB
Levine & Co.	29, St Pauls St, Leeds	LS1 2JT
Grenville, Smith & Duncan	17, Park Place, Leeds	LS1 2SJ
Robinson & Gregory	19, York Place, Leeds	LS1 2EX
Adair Davy	5, King St, Leeds	LS1 2HH
Weatherall, Green & Smith	29, King St, Leeds	LS1 2HP
Mawsons	6, Park Place, Leeds	LS1 2RU
Knight, Frank & Rutley	10, Park Place	LS1 2RU
St Quentin	6, Park Place	LS1 2RU
Leeds Executive Service	100, Wellington Street, Leeds	LS1 4LT
Regus	Prospect House, 32, Sovereign St, Leeds	LS1 4BJ
Headingley Estates	34, The Calls, Leeds	LS2 7EW
Durham, Roberts & Co.	4-10 New Station St, Leeds	LS1 5DL
Staintons	134, Lower Wortley Road, Leeds	LS12 4PQ
Brooklands	19, Town St, Armley, Leeds	LS12 4UX
W.H. Brown	Oakwood: Records Dept	LS8 7PU
Black Horse	113, New Road Side, Horsforth, Leeds	LS18 4QD
Gibson Twaites	3, Oxford Place, Leeds	LS1 3AX
Richard Ellis	Aquis House, Greek Street, Leeds	LS1 5RU
David Price	Refuge House, 5, Bedford St, Leeds	LS1 5PZ
Anthony Sharpe & Co.	10, Butts Court, Leeds	LS1 5JS
DTZ Debenham Thorp	3, The Embankment, Sovereign St, Leeds	LS1 4BP
Whitegates	32, North Lane, Headingley, Leeds	LS6 3BF
Baker, Stollery & Wrightson	Gelderd Link, Gelderd Rd, Leeds	LS12 6EU
Spencers	Duncan Street	LS1 2RZ
Manning	20, Otley Road, Leeds	LS6 2AD
Castlehill	21, Otley Road, Leeds	LS6 3AA
Ridings Estate Agents	27, Kirkgate, Leeds	LS1 2RU

Appendix VI.

PROPERTY VALUE SURVEY QUESTIONNAIRE

Q1a Name of contact (optional) or reference point: ....

Q1b Name and address of Estate Agent (optional): ....
....
....
....
Tel. ....

Q2 Which of the following categories of property do you deal with? (Please place a tick in the appropriate boxes).

Housing/Residential	❑	Retail	❑
Industrial	❑	Agricultural/Rural	❑
Commercial	❑	All	❑

Q3 Which of the following districts of Leeds do you deal with? (Please place a tick in the appropriate boxes).

LS1	City Centre	❑	LS13	Moorside/Rodley	❑
LS3	City Centre	❑	LS15	South of Temple Newsham	❑
LS4	Burley	❑	LS18	Horsforth/Woodside	❑
LS5	Kirkstall/Hawksworth	❑	LS19	Rawdon Carr/Wellroyd	❑
LS9	Cross Green	❑	LS26	Woodlesford	❑
LS10	NE Hunslet/Stourton	❑	LS28	Calverley/Calverley Wood	❑
LS11	North Holbeck	❑			
LS12	Armley/Upper Armley	❑		All of the above districts	❑

Q5 In your opinion, how would you classify (A-F) the present water quality in the River Aire as it passes through Leeds? (Please place a tick in the appropriate box).

Excellent	Very clean, suitable for all uses (incl. swimming)	A	❑
Very good	Clean, suitable for most uses (excellent fish stocks)	B	❑
Good	Slight pollution, suitable for recreation (eg. canoeing)	C	❑
Fair	Moderate pollution, reduction in suitable uses (poor fish stocks)	D	❑
Poor	Dirty, water uses very restricted (fish stocks absent)	E	❑
Bad	Very dirty, no suitable water uses	F	❑

Q6 In your opinion, in which of the following catagories of property, in the vicinity of the River Aire in Leeds, is the river water quality considered to be a marketable attribute? (Please place a tick in the appropriate boxes).

Housing/Residential	❑	Retail	❑
Industrial	❑	Agricultural/Rural	❑
Commercial	❑	All	❑

Q7a In your opinion, has the water quality in the River Aire in Leeds improved in the last 10 years?
YES / NO

Q7b If YES, has this had a beneficial effect upon property values close to the river (Approx 200 meters)?
YES / NO

Q8 In your opinion, would future improvements in water quality have a beneficial effect on the value of the following catagories of property close to the River Aire in Leeds? (Please place a tick in the appropriate boxes).

Housing/Residential	☐	Retail	☐
Industrial	☐	Agricultural/rural	☐
Commercial	☐	All	☐

Q9 In your opinion, for the catagories you ticked in Q8, what degree of water quality improvement would be required in order to influence an increase in property values? *(NB. Use the classifications listed in Q5 to help you make your choice (A-F)).*

Housing/Residential	☐	Retail	☐
Industrial	☐	Agricultural/rural	☐
Commercial	☐	All	☐

Q10 Please indicate, as accurately as is possible the property values within 200 meters of the River Aire over the last ten years. *(NB. Only give values for the catagories you ticked in Q2).*

Category	1996	1994	1992	1990	1988	1986
Housing/Residential						
Industrial						
Commercial						
Retail						
Rural/Agricultural						

Q11 How have you measured these property values?

£ / sq. foot	☐	£ / sq. meter	☐
£ / sq. yard	☐	£ / hectare	☐
£ / acre	☐	£ / sq. km	☐
£ / sq. mile	☐	Other	☐

Please specify....................

Q12 In your opinion, in which of the following catagories of land/property development is the water quality a factor in influencing a developer?

Housing/Residential	☐	Retail	☐
Industrial	☐	Agricultural/rural	☐
Commercial	☐	All	☐

Appendix VII
Recreation and Amenity Use of the River Aire in Leeds

VII.1 Background

Relatively little is known about the recreation and amenity value of the River Aire. Clearly, however, there are strong interconnections between these uses and the value that residents of the River Aire corridor place upon environmental water quality improvements. The work presented here, to characterise the recreation and amenity use of the river, was conducted as an additional part of the original R&D contract between the Environment Centre, at The University of Leeds, and The Environment Agency.

VII.2 Introduction

Rivers are an important focus for recreation and amenity. As such, they have value to the public. However, it is difficult to measure this value in monetary terms because of the problems associated with the worth of goods in common ownership. In such circumstances it may be appropriate to identify alternative methods of assessing the value of the environmental resource through, for example, the level at which the common resource is utilised. Unfortunately, although the River Aire provides a focal point for amenity and recreational activity for the public of Leeds, little is known regarding either the types or the levels of activity which take place on, or adjacent to, the river. In this part of the study the nature and intensity of the public use of River Aire in Leeds was examined to assess the recreation and amenity value of the river.

VII.3 Methods

A survey was conducted in which a number of attributes of recreational activity and amenity use of the river were recorded. These included;

- activities (angling, walking, canoeing, cycling, jogging, nature appreciation, boating, eating and other activities);
- individuals (sex and approximate age group) and
- groups (size, type e.g. family, activity and age/sex composition).

The survey was carried out at 10 locations along the river (Table VII.1). Sites were selected to cover the whole length of the main river corridor used in the CVM survey. Criteria for selection of particular locations were based primarily upon aspects of public access. Hence most survey locations were either close to bridges (e.g. Apperley Bridge) or places of specific amenity value (e.g. Kirkstall Abbey).

Table VII.1 Location and National Grid Reference of recreation and amenity survey sites

Site number and name of location	NGR reference number
1. Apperley Bridge	419500 438100
2. Calverley (at Ring Road)	422000 436900
3. Newlay footbridge	423900 436900
4. Kirkstall Abbey (Car Park)	425500 436300
5. Kirkstall Abbey (at Rugby Club)	426000 435400
6. City Centre 1 (Water Lane Lock Gates)	429800 433100
7. City Centre 2 (Yorkshire Water offices)	430000 433100
8. City Centre 3 (at Brewery Wharf)	430300 433100
9. South Accommodation Road Bridge	431400 432400
10. Knostrop (Skelton Grange Power Station)	433100 431100

The exercise was carried out on 4 occasions; twice to represent weekday activities and twice to represent weekend activities. These were;

- 2 September (Monday);
- 8 September (Sunday);
- 13 October (Sunday) and
- 14 October (Monday).

The survey was repeated over four time periods throughout the day;

- Period 1 9.30 a.m. to 11.30 a.m.;
- Period 2 12.00 p.m. to 2.00 p.m.;
- Period 3 2.30 p.m.to 4.30 p.m. and
- Period 4 5.00 p.m. to 7.00 p.m.

VII.3 Analysis and discussion

The results of the four surveys are summarised in Table VII.2 and Figures VII.1 to VII.4. The survey illustrated that the range and intensity of activities taking place by the river are greater on Sundays than during the mid-week at all sites. Indeed, the sum total of recreation/amenity visitors to the river was 1.86 times greater on Sundays in comparison to mid-week visits. It is apparent that a large proportion of the population have commitments during weekdays which preclude their participation in recreational persuits at that time. This is clearly not the case at the weekend when more people are able to take part in recreation and amenity activities more easily.

Daily peak activities were dominated by the middle time periods monitored (i.e. 12.00 p.m. - 2.00 p.m. & 2.30 p.m. - 4.30 p.m.), when activities were 1.61 times greater than those of mid-morning and early evening, for both mid-week and weekend surveys. Furthermore, closer examination of these data suggested that mid-week activities peaked between 12.00 p.m. and 2.00 p.m., while weekend activities were more intense in the mid-afternoon period (i.e. 2.30 p.m. - 4.30 p.m.).

The most popular sites were those which possessed amenity facilities (Kirkstall Abbey (Site 4), Granary Wharf (Site 6) and Brewery Wharf (Site 8)) or adjacent to residential areas (Newlay footbridge (Site 3)). Less popular locations were Calverley Bridge (Site 2), which has amenity facilities but is remote, and South Accommodation Road (Site 8) and Knostrop (Site 10), which are adjacent to industrial areas.

The most common activity taking place in the vicinity of the river is walking. Other activities were also popular, such as cycling and jogging, particularly at sites in suburban locations. The results of the CVM demonstrated that improvements in water quality would increase participation in these types of non-contact activities. The activity of walking would increase by 1.42 times and those who would use the river for nature appreciation would more than double.

Angling was the most common water contact activity which was observed at most locations within the Leeds city boundary. However, few people were observed canoeing even at the Leeds Canoe club facilities (Site 5). The CVM survey suggested that improvements in the water quality of the river, with the associated reduction in health risks to the public, would increase participation in these water contact recreation activities. Those who would participate in angling and canoeing would increase by 2.5 and 8.25 times respectively.

Clearly, such large increases in those who would participate in both non-contact and water contact activities puts great emphasis on the value of the water quality attributes of the River Aire as a recreational and amenity resource. Furthermore, a combination of the CVM approach with levels and intensity of amenity use would provide the basis for the economic analysis of recreational activity and the role of water quality as a factor enhancing this value for the River Aire in Leeds.

Table VII.2 Summary of River Aire amenity and recreation survey results

Monday September 2nd

	Angling	Walking	Canoeing	Jogging	Cycling	Eating	Nat. Appr.	Boating	Other	Total
Site 1	0	62	0	29	20	5	0	0	0	116
Site 2	0	20	0	2	0	2	0	0	0	24
Site 3	0	137	0	15	21	3	0	0	2	178
Site 4	11	151	0	13	14	8	6	0	4	207
Site 5	0	14	3	0	4	0	0	0	0	21
Site 6	2	223	0	1	11	3	0	6	6	252
Site 7	17	327	0	8	16	5	7	12	13	405
Site 8	6	358	0	0	1	0	0	4	0	369
Site 9	6	49	0	4	26	0	0	8	0	93
Site 10	1	0	0	2	9	0	0	0	0	12
Total	43	1341	3	74	122	26	13	30	25	1677

Sunday September 8th

	Angling	Walking	Canoeing	Jogging	Cycling	Eating	Nat. Appr.	Boating	Other	Total
Site 1	1	178	0	56	10	0	4	0	0	249
Site 2	0	51	0	8	0	4	3	0	3	69
Site 3	4	258	0	28	33	1	4	0	54	382
Site 4	13	351	0	16	34	0	0	0	0	414
Site 5	0	2	1	10	1	0	0	0	0	14
Site 6	14	335	2	3	7	0	0	12	6	379
Site 7	12	148	0	11	14	0	0	15	1	201
Site 8	17	393	0	3	18	2	2	15	0	450
Site 9	14	61	0	6	32	0	0	15	6	134
Site 10	15	11	0	0	54	0	1	0	0	81
Total	90	1788	3	141	203	7	14	57	70	2373

Sunday October 13th

	Angling	Walking	Canoeing	Jogging	Cycling	Eating	Nat. Appr.	Boating	Other	Total
Site 1	1	174	1	19	81	0	4	0	4	284
Site 2	0	51	0	1	1	0	2	0	0	55
Site 3	7	334	0	25	60	0	62	0	5	493
Site 4	15	560	0	10	47	69	0	0	11	712
Site 5	0	4	6	2	0	0	0	0	0	12
Site 6	9	1159	0	5	67	111	172	3	114	1640
Site 7	2	174	0	0	21	0	3	45	0	245
Site 8	0	732	0	5	8	0	0	0	0	745
Site 9	32	85	0	2	33	1	0	21	0	174
Site 10	0	35	0	7	17	1	6	4	0	70
Total	66	3308	7	76	335	182	249	73	134	4430

Monday October 14th

	Angling	Walking	Canoeing	Jogging	Cycling	Eating	Nat. Appr.	Boating	Other	Total
Site 1	0	21	0	6	15	0	1	0	1	44
Site 2	0	14	0	3	0	0	0	0	2	19
Site 3	0	225	0	14	33	0	0	0	0	272
Site 4	16	193	0	2	4	10	0	0	0	225
Site 5	0	4	1	0	0	0	0	0	1	6
Site 6	0	452	0	8	14	13	111	0	17	615
Site 7	0	88	0	6	12	1	2	7	27	143
Site 8	0	410	0	5	4	5	0	7	2	433
Site 9	0	34	0	0	5	0	0	6	0	45
Site 10	0	146	0	2	8	2	0	0	0	158
Total	16	1587	1	46	95	31	114	20	50	1960