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Water Quality and the Abbotsford Aquifer: Overview and Cost Benefit Analysis of Livestock Waste Disposal Alternatives Using Contingent Value Method

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by

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Water Quality and the Abbotsford Aquifer: Overview and Cost-Benefit Analysis of Livestock Waste Disposal Alternatives using Contingent Valuation Method

1. Introduction

The Abbotsford aquifer is a large underground source of water that is important for domestic, municipal, agricultural, and industrial uses in both Canada and the United States; the aquifer encompasses the districts of Langley, Matsqui and Abbotsford in British Columbia, and Sumas in the United States. Bacterial and nitrate contamination of the aquifer is the result primarily of livestock wastes, and recent boil orders and high nitrate levels in well samples have drawn attention to water quality issues in the aquifer. Although there has been ecoli bacterial contamination on occasion, the major problem is considered to be nitrate pollution. Both forms of pollution are caused by manure management practices, such as stockpiling, overapplication and unsuitable application times.

With federal and provincial funding, efforts have been made to carry out research of the externality problem and undertake analysis of potential alternatives to reduce nitrate leaching. To date, extensive environment-related information on the industry has been identified and analyzed. The following alternative solutions are being considered: adopting adequate on-farm and regional storage facilities; composting manure either on or off-farm; converting poultry manure to cattle feed; and transporting the manure off the aquifer to regions with nutrient deficient soils. Poultry and raspberry farming practices in the study area are also changing to help reduce contamination of the Abbotsford aquifer.

The primary focus in this study will be on nitrate pollution, because efforts to solve this problem will also address that of bacterial contamination. Pollution from pesticides is also a problem, but will not be considered here. The purpose of the current study is to provide an overview of the issues and consider the economics of the alternative methods for reducing the externality impacts of manure on water quality. Since the costs of these alternatives are generally greater than the private benefits, a contingent valuation instrument is used to determine whether the social (private plus off-farm) benefits from alternative livestock handling methods exceed their costs. The off-farm benefits of proposals to reduce contamination (increase water quality) consist of residents' willingness-to-pay for improved water quality. One aspect of the off-farm benefits that will be considered is the damages that are avoided by improving water quality; these damages are the (defense) expenditures of individuals in purchasing water filters and bottled water.

We begin in the next section by examining the background to the problem of water quality degradation from agricultural pollution. Then, in section 3, we consider recommended livestock waste practices for the region, while alternative instruments/ incentives for reducing production externality are described in section 4. The purpose of the research, however, is to determine the benefits of improved water quality. The use of the contingent valuation method (CVM) is reviewed in section 5; included in this review is a theoretical model for measuring the benefits of improved water quality. The survey instrument employed in this study is analyzed in section 6, with the survey itself is found in the Appendix. The conclusions and recommendations ensue.

2. Background

The U.S. Environmental Protection Agency (EPA) determined that agriculture is the largest U.S. source of surface water contamination and a major contributor to groundwater pollution (Napier 1983; Diebel *et al.* 1992b). Water problems include bacteria, salinity, sediment, pathogenic organisms, toxic material, and nutrient (nitrate) pollution. However, pesticides are considered the largest source of toxic pollution in agriculture in the U.S. (Napier 1983). EPA conducted a national survey on pesticides in drinking water wells and discovered that about 52% of community wells have detectable amounts of nitrate, 10% of wells contain at least one pesticide, and 7% may contain both nitrates and pesticides (Diebel *et al.*. 1992b). The U.S. Deputy Minister of Agriculture predicted that water quality will be the leading agricultural issue of the 1990s (Gogerty, 1989); it appears this is true for the Abbotsford aquifer region.

The Abbotsford aquifer covers approximately 100 square kilometres (km) in southwestern British Columbia and an additional 100 square km in Northwestern Washington. It is the largest of the approximately 200 aquifers in the lower Fraser River valley, and is an important source of residential, industrial and agricultural water in the region. In 1981, groundwater supplied forty-four percent of the water for the area between Surrey and Chilliwack on the south side of the Fraser River, and from Maple Ridge to the district of Kent on the north side (Dorcey and Griggs 1991, p.45). Groundwater provided almost all of the water requirements for the residents of Abbotsford, as well as a large portion of water for other uses.

The area above the aquifer is increasingly subjected to the pressures of population growth. Development in all sectors is evident, and this has increased the extent and intensity of the use of the land. On the Canadian side of the border, the trend has been towards the loss of agricultural land to urban expansion. Approximately 20% of the aquifer's surface is now covered by urban areas, with the remainder in agriculture. Aerial photographs from the Canada Land Use Monitoring Program, in addition to recent surveys by the provincial Ministry of Agriculture, Fisheries, and Food (hereafter BCMAFF), identify poultry farms, row crops (primarily raspberries), and pasture as the main agricultural activities. In recent years, there has also been an expanding greenhouse industry. About three quarters of the total area in agriculture is comprised of raspberry farms, with the remainder largely comprised of poultry farms. Because of the intensive nature of many of the Fraser Valley's agricultural production units these figures are deceiving, since there are also a large number of hog and diary farms in the region.

Land use activities on the U.S. side of the aquifer are less intensive than in Canada. Canadian land uses include dairying, raspberry, corn and potato farming, and residential development; satellite imagery reveals less cultivation, more-extensive dairying, and more forested land in the U.S. (Liebscher 1992). The more intensive Canadian agricultural activity reflects the increased value of the land due to its proximity to a major urban centre and the existence of an international boundary that prevents spillover of urban expansion into the U.S.

Since there is potential to develop this agricultural land for other purposes such as housing or recreation, including golf courses, farmer enterprises are more intensive to earn rates of return that are similar to those realized in other land uses.

There are other institutional factors that also impact upon different land use intensities. These include the B.C. Agricultural Land Reserve; the land-use distorting effects of national marketing boards for eggs, broilers and milk; current and historical barriers to agricultural trade between Canada and the U.S.; and the unique characteristics of the food processing industries on the Canadian and U.S. sides of the border.

The two countries also have different methods for improving water quality. The U.S. controls water pollution through the Clean Water Act (1965) and the Federal Water Pollution Control Act (1972), and the Americans have chosen a water improvements' program that pays farmers to maintain registered land according to a management scheme for a 10-year period (registration is binding on any subsequent owner for the duration of the registration) (Castle 1993). The registered land is then restricted from any intensive use, and in some cases must remain fallow.[1] In B.C., the *Code of Agricultural Practice for Waste Management* (hereafter referred to as the Code) was incorporated under the regulations in the *B.C. Waste Management Act*. Prior to this Code, farming operations were exempt from the Act if their management system was standard practice. Further, the *Agricultural Environmental Control Program* was developed jointly by the B.C. Ministry of Agriculture and the B.C. Federation of Agriculture to create guidelines on the siting of waste management facilities and feed lots, so pollution can be reduced (Gram 1990). The Code of Agricultural Practice and the environmental guidelines are discussed further in section 4 below.

The Abbotsford Aquifer

The Abbotsford aquifer is largely unconfined, and is covered with sand and gravel

[1]This program applies primarily to dryland (prairie) agriculture and does not apply directly to the Abbotsford aquifer area in the U.S.

deposits. These features, combined with high precipitation over the winter months, explain why effluent from land use practices readily percolates into the groundwater below. The aquifer's only water inflow is from a small underground stream on its northern end. Since large amounts of water are being tapped by the Abbotsford municipal water system and the fish hatchery on the east side of the aquifer, and because there is no regulation on well drilling on private property, the flow patterns of the aquifer are likely to be affected, and drawdown could occur if water use exceeds the refill rate. Water level drawdown will cause pollution levels to increase, and will augment any problems the aquifer currently has (Dorcey and Griggs 1991, p.25). Since the water from the aquifer flows south into the U.S., Canadian activities related to the aquifer are subject to the Boundary Waters Treaty of 1909. This treaty states that water flowing across the boundary "shall not be polluted on either side to the injury of health and property on the other side"; therefore, water quality is an international concern.

To date, nitrates and pesticides originating from agricultural land use practices have been held largely responsible for the contaminated water (Liebscher *et al.*. 1992), but before poultry or other manure is targeted as the main source of groundwater nitrate contamination, it is important to consider the data gathering process and evaluation of information. Farm practices that have been targeted as causes of groundwater pollution include exposed stockpiling of manure (Gilmour *et al.* 1987; Ritter *et al.* 1984) and overapplication of chemical fertilizer and manure for fertilization and soil enhancement. Since less recognized pollution sources, such as septic field effluent, landfill leachate, leaking underground storage tanks, accidental chemical spills and airport de-icing urea formaldehyde, may also contribute to the pollution, well sampling has recently been extended to include some of these (Liebscher 1992; Canter and Knox 1986).

Pollution of the Aquifer

During the summer of 1993, residents who used water from the aquifer were asked to boil their drinking water due to contamination by ecoli bacteria originating with livestock wastes. While bacterial contamination is certainly a concern, a more long-term problem has been contamination of groundwater by nitrates, originating mainly with livestock wastes. Since 1955, the National Hydrology Research Institute (NHRI) and Environment Canada, along with the

B.C. Ministry of Environment, Lands, and Parks (BCMOE), Agriculture Canada, the B.C. Ministry of Health, and local municipalities, have collected over 450 domestic well and piezometer samples of groundwater from the Abbotsford aquifer region. Sampling locations were on a large grid, but, initially, chemical analyses were confined to traditional inorganic constituents and the frequency with which the water was sampled was highly variable. In 1984, however, a noticeable increase in localized nitrate concentrations raised concern, and sampling was focused on the south Matsqui region where the problem appeared to be most severe (Liebscher 1992).[2]

Nitrates in drinking water pose a health risk to infants, particularly those under six months of age who are on a formula based diet, rather than breastmilk (Addiscott *et al.* 1992). When infants consume too much nitrate they can develop a blood disorder called *methaemoglobinaemia*, also known as "blue-baby syndrome". In infants' digestive systems nitrate converts to nitrite, which, when in the blood, prevents haemoglobin from carrying oxygen. The infant suffers oxygen deprivation, and in severe cases may die. In those infants who already have a respiratory or intestinal infection, the disease can be especially acute (Muia and Thomas 1990).

Although the majority of cases of blue baby syndrome have occurred when water concentrations exceeded 100 mg/L of nitrate (Addiscott 1992), nitrogen levels as low as 10 parts per million (ppm) in drinking water have been linked to *methaemoglobinaemia* (Cogger and MacConnell 1991). Few cases of *methaemoglobinaemia* have been recorded in the United States in recent years, but many are never reported (Cogger and MacConnell 1991, p.247). The long-term effect of nitrate consumption in older infants, children and adults is not known for certain at this time; however, ruminant animals such as cattle and sheep can also develop the disease.

After many years of testing, a recent report by Liebscher *et al.* (1992) stated that:

[2]As of March 1991, regular sampling was extended to pesticides.

"Approximately 60% of the samples collected from the south Matsqui study area have nitrate-nitrogen concentrations that exceed the 10 mg/L maximum acceptable concentration for drinking water as defined in the Health and Welfare Canada *Canadian Drinking Water Quality Guidelines"* (p.i). Environment Canada's 1989 sampling results found 46 out of 73 sample sites with nitrogen concentrations greater than 10 mg/L. The "mean for these samples was 13.08 mg/L, with 0.0 mg/L and 41.5 mg/L as minimum and maximum concentrations detected" (Liebscher 1992, p.35). A field sampling study by Kwong (1986) also reported that much of the groundwater in the south Matsqui and south Abbotsford areas, including parts of the confined and partly confined aquifer, are contaminated with nitrates.

The groundwater in the eastern portion of the aquifer, is generally confined or semi-confined, and is thus partially protected from direct surface contamination. Studies in this area show the presence of nitrates but in lower concentrations than those found to the west (Liebscher 1992). Liebscher further explains: "A compilation of all available nitrate data shows an increasing spread in the range of concentrations over time. The plot of annual means shown on the same figure suggests that the trend is to progressively higher ground water nitrate concentrations over time" (p.37).

It is important to note that, although high concentrations of nitrates have been detected, the true degree of contamination and the extent of contamination from specific sources remains unknown. This is because sampling since 1984 has concentrated on most severely impacted parts of the aquifer (Liebscher 1992, p. 35). In addition, correlations are difficult to make because of the size of the data base, the irregular sampling frequency, and the depth below the water table at which samples were taken.

While a variety of human activities have had an impact on the groundwater quality of the aquifer, the primary focus in this report is nitrate contamination stemming from agricultural land-use practices. Dankin (1991), Liebscher *et al.* (1992), and others identify storage and application practices of poultry manure, on both poultry and raspberry farms, as the primary source of contamination. Finally, hog production also results in livestock wastes that contribute to pollution of the aquifer. These are discussed in more detail below.

Poultry Farming

The Abbotsford region houses the highest concentration of poultry farmers in the province: Approximately 60% of the provincial poultry production is located on approximately 20% of the land above the aquifer. Poultry producers specialize in one product--layers, broilers or turkeys. Since the production and manure management practices of each farm type differ, they are discussed individually.

Layers

Laying hens are usually housed in cages that are suspended over deep (5-10 ft.) manure pits. Manure falls out of the cages directly into the pits, and is stored there until the end of the one year bird rotation cycle. If farmers choose their rotation cycle appropriately, removal of manure will be at the environmentally-optimal, usually in the spring for application on nearby fields.

In general, there are two problems that arise from this industry's manure management practices. These are: (1) farmers rotation cycles do not necessarily end in the spring; and (2) layer manure has a high liquid content. Without mechanical drying or long-term storage, manure of this type will readily leach into groundwater. Because of the high liquid content of the manure, it cannot readily be transported and, thus, drying or storage facilities must be available directly on the farm. Layer operators who do not take these precautions contribute the most to nitrate leaching problems, because they must either stockpile manure or apply it to their land during rainy winter weather.

Broilers and Turkeys

Broiler and turkey farms have much shorter rotation cycles (six and thirteen weeks, respectively)[3] than layer operations, and, hence, very different manure management problems.

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[3]The heavy turkey birds have 17-18 week cycles on average.

The birds are usually housed in barns with sawdust floors, which produces a dry litter. Barns are cleaned at the end of each cycle, so farmers must deal with a constant manure stream; however, the same problems exist with regards to stockpiling and field application as with egg producers, because virtually no broiler or turkey farmer in the region has "adequate" (i.e., covered) storage facilities (Chippersfield 1993b). The problem is only magnified by the fact that broiler and turkey farmers must handle eight and four times more manure, respectively, than layer barn operators.

Recent studies by the Sustainable Poultry Farmer's Group reveal that there is a total of approximately 138,870 tonnes of poultry manure produced in the Fraser Valley each year, and of that 66,603 tonnes comes directly from broilers (an average of approximately 16,000 tonnes every six weeks). Neither layer nor broiler producers tend to have acreage on which to apply the manure, and only 15,129 tonnes/year are kept in adequate storage facilities (Chippersfield 1993a). Those farmers who do not have adequate storage facilities or acreage usually contract to have the manure taken off their farms, but the contractors often resell it to nearby raspberry growers. As a result, manure continues to be applied on land at inappropriate times.

Hog Production

Although not used in raspberry production, hog manure is also a contributor to the nitrate problem in the aquifer. Of all the sows in B.C., seventy percent are located in the Fraser Valley (Agrifood 1989, p.1). Hog manure presents its own handling problems, since it has a very high liquid to solid ratio; only about 20% of the manure is solid enough to be compostable, but, if even half of this were composted, farmers would have 31.5 million litres less to deal with per year (Agrifood 1989, pp.1,9). Since swine producers, like poultry farmers, usually have a very intensive production system and a small land base, finding end uses for waste is difficult. Swine manure handling systems are more expensive than those for poultry, and swine manure is not desirable for field application because of its odour (Stennes 1992a, p.5). Therefore, swine producers face serious manure handling problems.

Raspberry Farming

Raspberries thrive on sandy topsoil and gravel-like subsoil, since this allows for good percolation despite heavy rainfall and prevents root rot. Since this type of soil is found above the Abbotsford aquifer, raspberries continue to be the largest crop, although many blueberries, strawberries and field crops are also grown in the area. There are currently 300 raspberry producers in the Fraser Valley, which indicates the magnitude of the industry.

In general, raspberry farmers do not have facilities to store manure, so manure that is destined for spreading on raspberry plants is left in exposed stockpiles or spread on the land during the winter months. Because of the complexities of south coast weather conditions and the raspberry plants' needs, there are as yet no site-specific nitrogen recommendations (Kowalenko 1993). Manure may be applied at rates that exceed the soil's maximum capacity. With poultry manure available as an inexpensive fertilizer source for raspberry farmers, application rates are highly variable and have been estimated to be in excess of 200 kilograms (kg) nitrate-nitrogen (N) per hectare (ha) (Zebarth 1993). According to the *Berry Production Guide*, it is recommended that only 55 kg N/ha be added yearly. However, Kowalenko (1993) indicates that adjustments for different soil conditions must be made when applying N.

When measuring soil nitrogen content, all nitrogen sources must be considered. The organic matter in the soil contributes to the nitrogen store, but provides little active material. Raspberry canes also contribute about 100 kg N/ha when they are cut down in the fall. Mineralization of the nitrogen into nitrate for use by the plants occurs throughout the year, but is fastest in the early summer when the soil is quite warm and moist; therefore, this is the ideal time to add nitrogen to the soil.

There are also many ways to increase or reduce the mobilization of soil nitrogen. Techniques such as clean cultivating the soil between the rows enhances microbial activity, resulting in greater release of soil nitrate. In contrast to this, weeds or a cover crop grown between the rows may adversely compete with raspberry plants for nitrogen (Kowalenko 1993). While nitrogen may be adequate in the spring, excess manure increases the potential for nitrate leaching.

3. Recommended Livestock Waste Handling Practices

It is generally agreed that minimizing nitrate contamination in the aquifer will require improving agricultural land management practices. Discouraging uncovered manure stockpiling in the fall and winter, and implementing appropriate restrictions on manure application rates and timing, will be particularly necessary in the poultry and raspberry industries (Liebscher 1992, p.68). Research and education are two necessary tools for achieving improvements in water quality; research will give the alternatives to the problem, and extension and education will give farmers the information they need to make informed decisions. However, it is also likely that economic incentives, such as taxes, subsidies or waste emission trading permits, will be needed in the future to enhance the economic efficiency of achieving water quality standards.

The BCMAFF funded the Sustainable Poultry Farming Group (hereafter SPFG), under the auspices of the Canada-British Columbia Soil Conservation Program, to carry out research and analysis of alternatives to current poultry farming practices for the purpose of mitigating the nitrate leaching problem, especially with regards to the development of improved stockpiling techniques. To date, the SPFG has compiled extensive, environment-related information on the poultry industry. Also, a survey sent to all poultry producers in the province allowed the SPFG to compile data on the number and location of farms; individual farm acreage; the number and types of birds produced; the type of feed used; the approximate volume and liquidity of manure produced; and the manure storage and application practices. This analysis of the industry has enabled the SPFG, as well as government, industry and others, to examine alternatives to improper stockpiling and manure application procedures.

Alternatives to both the poultry and raspberry farming practices have been considered; however, the emphasis of the research to date has focused primarily on poultry farming practices. This has included implementing more efficient storage facilities, manure composting, feeding poultry litter to cattle, and transporting the manure off the aquifer (i.e., to Delta or nearby areas with N-deficient soils). Ongoing research may open new options, but currently the alternatives mentioned and discussed below are the only ones that have been investigated. Even so, little information about many of them is available. Therefore, the focus of the discussion in the empirical section is on composting, but even for that alternative the information required for a complete economic analysis is inadequate.

Storage

Under B.C.'s new Code of Agricultural Practice for Waste Management, farmers are advised not to store manure uncovered, or apply it to bare fields during October and November. To comply with this non-regulatory code, some producers may build manure storage facilities or modify their current storage system (see section 4). Since the manure management practices for layers and broilers differ, the facilities required depend on the production type.[4]

The moisture levels in layer manure restrict handling and reduce its usefulness. Fullerton (1991b) provides an estimate of the costs of installing moisture-reducing equipment in an existing layer barn. Assuming a deep pit style barn housing 15,000 birds and producing approximately 780 tonnes of manure per year (at 75% moisture reduced to 65% through in-barn evaporation), total investments of $8,250, $3,672 and $20,000 are required for nipple drinkers, pit drying fans and manure dryers, respectively. If a farmer was to adopt each of the alternatives in turn, it is estimated the manure moisture levels would be reduced from 65% to 55%, 30% and 10%, respectively.

Currently most broiler producers have no storage facilities; therefore, they need to add these facilities to their operations to meet manure guidelines. Stennes (1992b) prepared a simple economic analysis of the capital requirements for adequate broiler barn manure storage facilities. The estimated investment required per farm for a covered broiler storage facility on a concrete

[4]Alternative storage designs and manure handling practices are provided in the *Environmental Guidelines for Poultry Producers*.

slab is $18,000.[5] The per farm estimated investment contribution for a similar, but regional storage facility, is $10,028 per farm enterprise.[6] Farmers would also be required to pay an additional cleaning and unloading cost of $800 every sixty days (the end of each 32,000 bird cycle) (Stennes 1992a).[7] Regional storage facilities would gain economies of scale, thereby reducing the estimated cost to the individual by 45%. This makes regional storage a viable alternative, but the type and size of storage facility that is adopted affects the usability of the manure, so any investment decisions must consider the manure's end-use.

Since storage does not provide an end-use for manure, it is only one component of the required manure management system. Currently, if farmers transport the manure themselves, commercial composting facilities will take it without charge. But, if large amounts of manure get delivered, then these companies will impose tipping fees; fees aid composters in controlling the volume delivered to suit their needs. Since farm manure has value as compost, on-farm or community-based composting is one option being studied as an end use. Other disposal alternatives that are being analyzed are the use of manure as cattle feed, or transporting excess manure to farms in other areas.

Composting

There has been growing interest in converting raw manure into compost. The compost could be used for bulk fill in landscaping or landfill, processed and packaged as an odourless soil conditioner for home owners, or used in crop production. Composting requires processing and marketing and, therefore, also investment and planning. Insight into the economics of composting animal manure in the Fraser Valley region versus current manure-handling practices are provided in a study by Fullerton (1991a) and an information circular from the BCMAFF.

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[5]This is calculated assuming a 32,000 bird/cycle operation, with a six month capacity of 360 m^3 of litter.

[6]This calculation is done assuming 5 broiler operations with 32,000 birds/cycle; total cost is $50,140.

[7]This additional cost is applicable to either alternative.

(1993), entitled *The Economics of Composting.*

The costs of composting facilities vary depending on the type of building adopted, the composting system used, and the amount and type of manure processed. The total investments are estimated to range from $40,000 for a basic composting facility, up to $190,000 for a deluxe system. Assuming a facility composting 2,000 tonnes of manure annually, production costs are estimated to be between $18.86/m³ and $39.14/m³, or $36-$70/tonne. Compost production costs rise as the level of investment increases; with investments divided equally between machinery and buildings, an investment of $100,000 could produce compost for approximately $20.00/m³ ($36/tonne), but with an investment of $200,000 the costs would be $26.00/m³ ($46.85/tonne) (Fullerton 1991a). These figures are indicative of diseconomies of scale, suggesting that smaller compost facilities are more efficient. However, given sale prices of compost in the U.S. (see below), this seems unlikely. This means that the scale of composting facilities considered by Fullerton (1991a) is likely too small relative to the size required to achieve lowest per unit composting costs (or economies of scale). Additional study is certainly warranted.

Costs and compost quality are also affected by the active compost period--21 or 49 days (BCMAFF 1993)--and the composting procedure used--windrows, aerated windrows, or aerated bin composing (BCMAFF 1993). Composting using these methods converts nitrogen, giving it a better nutrient balance and a more stable form; the composted manure is not an ideal fertilizer, but is simply a good soil conditioner (Agrifood 1989).

Not included in production costs are the marketing costs. The information circular on composting expresses handling (including bagging), transportation and marketing costs as a proportion of final revenue. But expressing costs as a proportion of revenue is misleading since it implies that these costs fall as revenue falls. That is, even if the same amount of compost is produced and sold, the handling, transportation and marketing costs are assumed to fall whenever prices fall. Suppose that revenues are $25/m³ and marketing costs are 30% of revenue, or $7.50/m³. If price fell to $20/m³ for reasons unrelated to marketing costs, then marketing costs would fall to $6/m³ by the proportionality assumption. If production costs were constant at $13.50/m³, and there were no costs other than those of production and marketing, then composting would continue to be economically feasible under the reduced price only if the marketing costs also fell. With the higher price of $25/m³, profits are $4.50/m³; with a price of $20/m³, composting results in a loss of $0.50/m³ if marketing costs remain at $7.50/m³, but there is a net revenue of $0.50/m³ if marketing costs fall in accordance with price declines. Of course, the assumption that marketing costs decline with a reduction in price is untenable.

Whether composting is economically viable from a private perspective depends on the availability of markets for the product and the price that is received (i.e., revenue). It is estimated that, in the Fraser Valley, "approximately 27.8 million litres of product could be sold by 1997" (Ference & Associates 1989), but such a market is inadequate to absorb all of the compost that could be generated from livestock wastes in the Valley; nor is it known whether this amount of compost from livestock wastes could be sold in the Valley if competing sources of compost are available. Competing sources include backyard and municipal composting facilities. Other markets include the U.S. states of Washington and Oregon. However, as an import into the U.S., manure is treated the same as sewage sludge and requires an import permit as a controlled material; a permit is required for each shipment, with restrictions on packaging and pathogenic control having to be met (Agrifood 1989). Because of these regulations, it is unlikely that much compost will be sold across the border. Further, exported compost will need to compete with that produced in the U.S., which is also moving toward the construction of more compost facilities. Alberta has been considered another market for composted material, but the size of that market is limited and transportation costs are likely to pose an obstacle to economic viability.

The information circular indicates that farmers might expect revenues of $11.95-$26.53/m³ ($21.50-$47.75/tonne), depending upon the quality of the compost produced (which, in turn, depends on the composting method employed). For the high price scenario, it is estimated that producers could achieve a net revenue of about $2/m³ or$3.60/tonne. For other price scenarios, expected revenues do not cover composting costs. Further, marketing costs are not included in these calculation and it is likely that even the lower estimates of expected revenues from composting are optimistic. BCMAFF (1993) assumes a price for the final product that is simply too high. A Kansas study comparing the use of compost with nitrogen fertilizer (Berends *et al.* 1993) employs a price of US$6 per ton (about C$8/tonne) for compost; this is the actual price charged farmers in the Kansas study area by a commercial compost dealer. The lowest price considered by BCMAFF (1993) exceeded C$20/tonne. Berends *et al.* (1993) found compost not to be competitive with nitrogen fertilizer, despite the low cost of compost in their study, although compost did increase the organic matter of soils. Further, as composting of livestock wastes, household wastes and other wastes in both Canada and the U.S. becomes more popular, especially at the municipal level, the supply of bulk compost will increase, thereby reducing price. While prices for bagged compost will be higher, costs are also increased and market saturation continues to be a problem.

Finally, composting could be economically viable for some private composters if they are able to charge tipping fees that cover losses in the production and sale of the compost. However, tipping fees can only be charged if livestock producers are required by law to dispose of their manure in a manner that makes this a competitive alternative to other methods of disposal, and on-farm composting is more expensive for the individual than transporting manure to a regional facility and paying tipping fees. Tipping fees may make composting profitable from a private perspective, but this does not also mean it is economically efficient from the standpoint of society. Tipping fees simply constitute a redistribution of income against the livestock producer, but any requirements that change the "rules of the game" and increase costs to livestock producers have a negative impact on their incomes.

Our review of the available evidence regarding the costs and benefits of composting indicates that composting is not generally viable from a private perspective and constitutes a risky investment at best. Although there will undoubtedly be exceptions, it is unlikely that on-farm composting or large, commercial-scale composting will develop without some form of government intervention either via regulations or financial incentives (subsidies, taxes, *etc.*). Public intervention to bring about composting of livestock wastes can be justified only if the on-farm plus off-farm (or external) benefits of composting exceed the costs. In a later section, we provide an estimate of these external benefits.

Utilization as Cattle Feed

Cattle ranchers and feed lot operators are possible end users of poultry manure. Broiler litter has been used in cattle feed for over 35 years in the United States. Poultry litter is corrosive; if it is to be used as feed, proper equipment must be installed to store it. Upright, air-tight silos lined with polyethylene are the best storage facility because oxygen cannot enter the mixture and raise the temperature to undesirable levels. With the right additives, manure stored in this way can provide high-quality feed for ruminants. Currently, broiler litter can be used as cattle feed in Canada; however, it cannot be sold for this purpose (Chippersfield 1993b).

Provided that Canadian regulations on its use are met, and the poultry manure is of reasonably good quality, large amounts could be profitably used in beef feed production (Overcash, Humenick and Miner 1983; National Research Council 1981). The nutritional value of the product is high, and with well-developed regulations, the risks of herd sickness are negligible (Ruffin and McCaskey, undated). However, it is extremely important that the general public be convinced that this feed source is acceptable, or they may reduce purchases of beef and seriously harm the industry.

Transporting Manure Off the Aquifer

Farmers also have the option of transporting manure off the aquifer to farms with nutrient-deficient soils. Delta soils are low in nutrients and require fertilization; therefore, Delta's approximately 8,000 acres of agricultural land would be suitable for poultry manure application. The SPFG is currently marketing four types of manure, each with a different blend of manure and sawdust, for about $50.40/m^3$ ($90.80/tonne). It would cost a poultry farmer, with 32,000 birds producing about 200 tonnes of manure per year, approximately $2,380 per year to transport the manure from North Matsqui to the Delta region. This is a cost of about $40.63 per tonne (Stennes 1992a, p.2). Transportation costs are subject to change due to fluctuations in fuel prices and new environmental regulations. Further, costs of inputs, blending, marketing and so on need to be added to transportation costs, and the opportunity costs of using manure need to be considered, in order to determine economic viability. Ideally, if there was adequate demand for the manure, end-users would pay for its delivery, but, given Delta farmers have other alternatives, the poultry farmers will have to cover the difference in costs.

Alternative Raspberry Management Practices

Until recently, little attention was focused on the raspberry farmers. Since poultry manure was identified as the primary source of nitrate contamination, it was initially thought that only poultry farming practices had to be corrected, and funding was allocated primarily in this area. But poultry farmers in the Abbotsford region generally contract out the removal of manure; therefore, storage and application problems reside with the removal contractors or the purchasers of the manure. Since the local raspberry producers are often the end users of this manure, it has now been recognized that they also need education on proper storage and application procedures, and research on their production systems.

Soil scientists have examined nitrogen management in raspberry production to determine optimal application rates on raspberry crops in order to improve recommendations for manure and nitrogen management practices. Preliminary research indicates that substantially less manure nitrogen is required than what is currently recommended as minimum levels to maintain yields (Bomke 1991; Sands 1993; Chippersfield 1993b).

Although nitrogen testing is important to determine correct application rates, it is not routine for any of B.C.'s agricultural crops. Kowalenko (1993) suggests that a fall soil nitrate test should be used to adjust nitrogen amendments over a period of a few years so that yields are acceptable. If farmers could be convinced, or were required to test their fields and apply the amount of fertilizer recommended, reduced nitrate leaching could be achieved.

4. Instruments and Institutional Alternatives

The problem of the aquifer is one of production externality, where agricultural production has an adverse effect on water users. In response, the provincial government has supported the development of voluntary guidelines regarding livestock waste management practices. The government has the choice of a variety of economic instruments, including standards, permits and charges, to encourage change; the guidelines currently in place are believed to be the best alternative in the short run, but if farmers do not comply mandatory measures may be necessary.

Current Regulations

The *Agricultural Waste Control Regulation* and the *Code of Agricultural Practices for Waste Management* suggest methods for the handling and storing of manure from any agricultural industry in B.C.. The Code is a starting point for a voluntary system for reducing pollution and the adverse environmental impacts of agricultural practices. Enforcement of the Code is through a "peer inspection system". The Agricultural Environmental Protection Council (hereafter AEPC), which consists of farmers and local environment and BCMAFF officials, responds to environmental complaints about farm management practices. The AEPC investigates the complaint, discusses it with the farmer, and with guidance from the BCMAFF and the industry, develops a recommendation for corrective measures, according to the Code. If the farmer chooses not to adopt the new measures, the matter is turned over to the BCMOE for potential prosecution under the *Waste Management Act*. Lack of well-trained, readily-available and industry-oriented inspectors is a major problem with the peer-watch system, since complete enforcement cannot be assured.

The AEPC is currently writing guidelines for each segment of the food production industry (broilers, layers, dairy, hogs, field crops, *etc.*). These guidelines go well beyond the issue of siting feed lots to include waste disposal, water use and so on. The Soils and Engineering Branch of the B.C. Ministry of Agriculture, Fisheries and Food, in co-operation with the B.C. Federation of Agriculture (BCFA) and the Poultry Industry of B.C., has also recently developed the *Environmental Guidelines for Poultry Producers in British Columbia* (1992). These guidelines describe in detail how poultry farmers should handle and store manure.

In the short run, the current guidelines are beneficial, since farmers must already begin to adjust their manure handling practices, and alternatives can continue to be explored. If in the long run farmers have still not adopted the waste management practices, the government can employ a variety of alternative economic instruments, some of which are discussed below.

Research and Education

Research continues to play an important role in trying to understand the dynamics of manure, manure application and storage procedures. Recently, research has provided a much better understanding of the dynamics of soil nitrogen in response to the unique weather conditions of south coastal British Columbia. Bomke (1991) examined effective manure management practices for the purpose of protecting ground and surface waters. In addition to the timing and rate of manure application, consideration was given to cash crops, nitrogen immobilizers, and balanced fertilization techniques as alternative mechanisms to control nitrate leaching. However, these "nitrogen capture systems" are site specific and additional research and development will be required so tools like the " B.C. Nitrogen Model" can be applied, and a meaningful "spring nitrate soil test" can be developed (Bomke 1991).

Current studies at Agriculture Canada's Aggasiz Research Station include research on quantifying denitrification losses from manured soils. These denitrification losses represent a loss of plant available nitrogen and reduce the amount of nitrate available for leaching (Zebarth, *et al.* 1993). As a result of studies on the proper application and storage procedures for ensuring safety from the leaching of nitrates into the groundwater, heavy manure applications to the same fields every year should be avoided and farmers should test their soil at least every two years to ensure a proper nutrient balance is maintained.

Extension is the tool that brings research and practice together and should not be ignored. To assist producers, the Aggasiz Research Station, the Sustainable Poultry Farming Group, and the Soils and Engineering Branch of the BCMAFF provide up-to-date information on optimal use, manure storage practices, and methods and timing of manure application. Although compliance with the Code is voluntary, extension activities need to take into account demand for changes in environmental practices.

Permits

Farming has always been considered a way-of-life, so farm pollution was never controlled like that of other industries. Unlike any other industry in Canada, farmers do not require a permit for livestock waste disposal. However, the new Agricultural Waste Control regulation does begin to control B.C. farmers so that they do not dispose of waste improperly, although permits are not required.

If a permit system were developed, it would give farmers the legal right to dump a certain amount of waste, while exceeding this limit would result in fines. Enforcement, political acceptability, and identifying waste permit allotments are obstacles to the use of permits. One benefit is that tradeable permits could enhance allocative or economic efficiency. With a system of tradeable waste emission permits, farmers with the highest waste disposal costs would purchase permits from other farmers, and those whose with lower costs would dispose of their wastes by an approved method not requiring a permit. Thus, the pollution target could be reached at the lowest cost. Since people are often angered if an industry is given the "right" to pollute, the current method using regulation allows government and industry to work together to find an alternative to the less politically acceptable use of permits.

Charges/Fines/Taxes

If producers do not conform to the current regulations, government could impose a charge, fine or tax. This consequence is implied by the Waste Management Act regulations; however, because of their political unacceptability and the difficulty of enforcement, it is unlikely that charges will be implemented. From a behaviourial or psychological standpoint, charges are believed to be viable alternative instruments because they provide negative reinforcement for the purpose of behaviour modification. If the farmers do not properly store or apply the manure, then they pay. From an economic perspective, however, the farmer's objective is to maximize profit while minimizing costs, so charges, fines or taxes are incorporated in the cost/profit decision function of the individual farm. Thus, we cannot be certain that the farmer will not stockpile manure or apply manure in an unacceptable manner. Rather, he/she will pollute to the point where the marginal cost of doing so (e.g. charge) equals the marginal benefit. Therefore, if pollution continues to be unacceptable, charges must be adjusted upwards.

Political acceptability is an important issue if one of these methods is used for dealing with pollution. Farmers argue that the "level playing field" no longer exists because their cost of production is increased due to the pollution charges, while their competitors in the U.S. and Mexico can still pollute. Because of the increased cost of production, price of local produce would rise, and consumers would substitute imported products for local production. This would reduce farmers' comparative advantage and, since global competition is such a politically sensitive issue, this is not acceptable. Also, administration of such a program could be costly.

The waste management regulations facing the farmers on the Abbotsford aquifer mark the beginning of an inevitable transition taking place in the market. The regulations define the new "arena" in which the farmers must work. Government and industry's joint efforts to identify alternative uses for the manure signal potentially new profit maximizing alternatives. Thus, through government regulation, the previous farming practices that created the externality are beginning to change, and new market alternatives are being developed that provide farmers with the necessary information and incentive to complete the change. In the future, we will likely see greater reliance on market instruments and on farm management. For the short term, however, regulation and subsidization of farmers to improve waste handling and disposal are likely.

5. The Contingent Valuation Method (CVM)

It is clear from the discussion in previous sections that livestock producers are unlikely to implement practices that reduce the externality impacts of waste disposal unless they are induced to do so via economic incentives or regulation. While regulation is currently the preferred choice of decision makers, there appear to be incentives and means to avoid compliance. This is not meant to suggest that agricultural producers are not concerned about their impact on others, only that the costs they incur are often borne solely by those producers or might be perceived as a threat to their farm enterprise. In addition, recent legislation might be viewed as a shift in property rights to the environment from the livestock producers to urbanites who are encroaching upon farmland as a result of rapidly increasing populations in the region.

Whatever the reasons, it is clear that no alternatives to current livestock waste disposal practices are preferred by the farmer on economic grounds. Composting is the best option for disposing of livestock wastes, at least from an environmental point of view, but it is not economic. However, it might be possible to justify composting on the basis of its social costs and benefits. The social costs of composting are equivalent to the private costs; they are equal to the production, handling, transportation and marketing costs of composting. The social benefits include the revenue obtained from sales of compost plus the benefits to water users of improvements in water quality brought about as a result of composting. In order to measure these benefits, a contingent valuation device is employed. In this section, we first provide a theoretical framework for CVM analysis, including thereby a model for deriving WTP estimates. This is followed by a discussion of surveys and the means of eliciting contingent values. The survey instrument and results used in this study are examined in the following section.

Theoretical Model

Consumers are assumed to maximize their utility, which is a function of the amounts of market goods (x) that they consume and the quantity of the public good that is available, which, in this case, is the quality of the water, denoted by Q. Given a choice, consumers prefer higher water quality for drinking and other consumptive purposes. The budget constraint is given by the household's income. The household's economic problem is represented by the following:

$$Max_x \ u(x, Q)$$
$$s.t. \ m = px,$$

where m is household income, **p** is a vector of prices, and **z** is a vector of social and other factors that affect utility. The latter are dropped from the remaining analysis for convenience, but they do enter the empirical estimation. For given water quality Q^0, the household achieves utility level u_0, as indicated in Figure 1.

The indirect utility function is:

$$v(p,Q,m) = \max_x \{u(x,Q) \,|\, px - m = 0\} = u(x(p,Q,m),Q).$$

The associated expenditure function is:

$$e(p,Q,u) = \min_x \{px \,|\, u(x,Q) \geq u^0\} = px(p,Q,u) = v^{-1}(p,Q,m).$$

The indirect utility function and the expenditure function are assumed continuous and twice differentiable in **p**, Q and m. The indirect utility function is non-decreasing and quasi-concave in Q; the expenditure function is non-increasing and convex in Q. Since prices remain fixed throughout the analysis, we drop price as a variable in the remaining analysis.

Hicksian compensated measures are used to evaluate welfare changes from increments or decrements in the availability of a public good, in this case increments and decrements in water quality (e.g., Boadway and Bruce 1984; Johansson 1987; Hoehn 1992). These welfare measures and the contingent valuation method that is used to elicit them are required for assessing natural resource damages and evaluation of projects (i.e., in cost-benefit analysis) (Hoehn 1992). In the case of groundwater, for example, the Hicksian compensating variation (CV) gives the maximum amount that the household is willing to pay (WTP) for an improvement in water quality from Q^0 to Q^1 (Figure 1). Likewise, the Hicksian equivalent variation (EV) is the minimum amount that the household would be willing to accept (WTA) as compensation to forgo the improvement in water quality (Figure 1). Notice that CV assumes individuals have a right to water quality Q^0, while EV assumes they have the property right Q^1.

In this study, a contingent valuation instrument is used to elicit the respondents' WTPs; therefore, we focus on measurement of compensating variation. For household k, the compensating variation of the improvement in water quality from Q^0 to Q^1 is given by:

$$CV^k(Q^1,Q^0,m_k) = m_k - e(Q^1,v(Q^0,m_k)).$$

A Taylor series expansion about Q^0 and the mean income level, $\overline{m}$, gives the following expression for CV:

$$CV^k = CV(Q^0,Q^0,\overline{m}) + (Q^1-Q^0)\frac{\partial CV}{\partial Q} + (m_k-\overline{m})\frac{\partial CV}{\partial m} + \frac{1}{2}(Q^1-Q^0)^2\frac{\partial^2 CV}{\partial Q^2} + \frac{1}{2}(m_k-\overline{m})^2\frac{\partial^2 CV}{\partial m^2} + (Q^1-Q^0)(m_k-\overline{m})\frac{\partial^2 CV}{\partial Q\,\partial m} + R,$$

where R refers to remaining terms. Then the willingness to pay of the k^{th} household for the improvement in water quality can be written as:

$$WTP^k = \alpha_0 + \alpha_1\Delta Q + \alpha\Delta Q^2 + \alpha_3(m_k-\overline{m}) + \alpha_4(m_k-\overline{m})^2 + \alpha_5\Delta Q(m_k-\overline{m}) + \varepsilon_k,$$

where $\alpha_0 = CV(Q^0,Q^0,\overline{m}) = 0$ since the CV of no change in water quality must be zero; $\alpha_1 = \partial CV/\partial Q$; $\alpha_2 = \partial CV/\partial m$; $\alpha_3 = 1/2\ \partial^2 CV/\partial^2 Q$; $\alpha_4 = 1/2\ \partial^2 CV/\partial^2 m$; $\alpha_5 = \partial^2 CV/\partial Q\partial m$; and $\epsilon = R$. The empirical model is completed by adding social factors describing attitudes, age, household makeup and size, and so on.

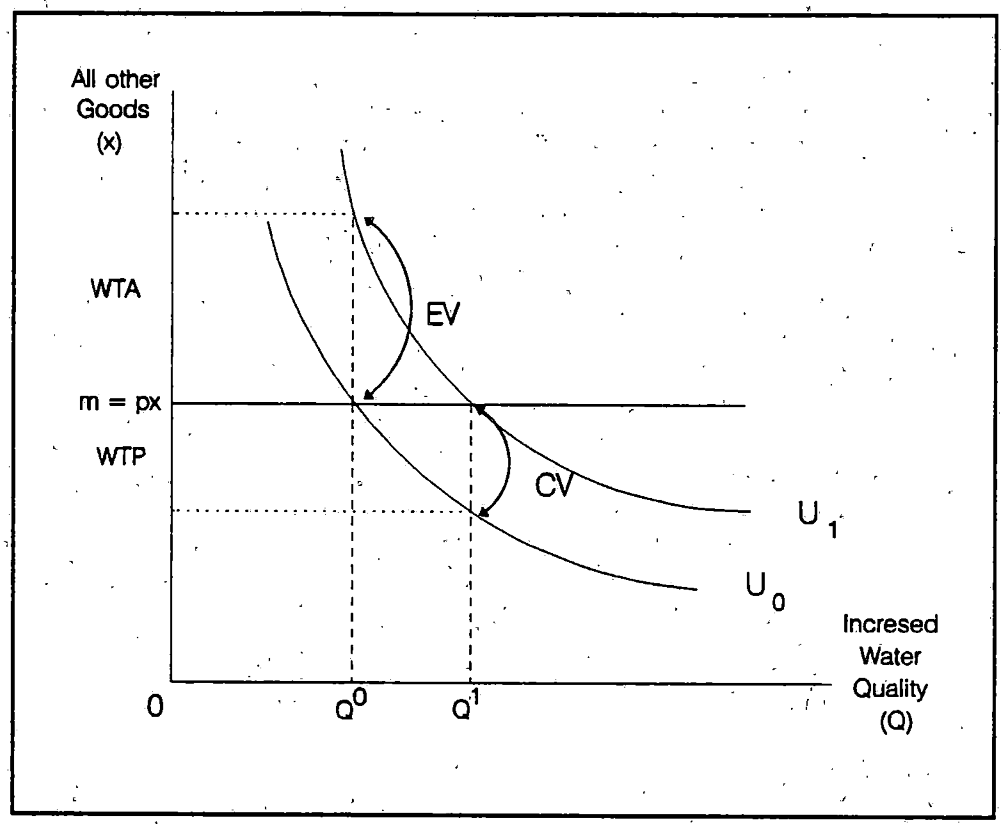

Figure 1: Welfare Measures Related to Changes in Water Quality

Designing Surveys: Asking about WTP

Data on willingness to pay for improvements in water quality are determined from contingent valuation questionnaires. Individuals are essentially asked to reveal the maximum amount they are WTP for a hypothetical change in water quality. Due to the hypothetical nature of WTP questions, it is important that surveys be appropriately designed and implemented.

McMeiken (1973) points out that researchers and bureaucrats have opinions that differ from those of the general public about what is important when accessing situations and creating policy. Therefore, survey studies are important because they indicate to scientists and politicians where research efforts should be focused. Two important issues when using surveys to determine public perception are their construction and analysis. Surveys must be designed so respondents understand the questions and feel comfortable answering candidly. Survey analysis is also crucial, since these results are then used in policy making and further research.

Survey development is difficult. It includes extensive testing and requires that certain criteria be followed. Metuchen (1974) discusses the best survey design method, pointing out that surveys should always include return addresses, that people will only answer a survey if they feel it applies to them, and that people may be concerned with anonymity, especially if income or personal questions are asked in the survey (p.54). He also point out, that followups should always be used, since they usually increase the response rate, thereby increasing the validity of the results (Metuchen 1974, p.69).

Another aspect of survey analysis concerns survey errors. Since survey responses are opinions, they can be influenced by different people, situations, and scenarios. Trying to reduce error as much as possible is a goal of every researcher. These authors address the types of error that can occur, and make suggestions useful for survey development. It is recommend that, even when respondents do not answer all questions, surveys should not be eliminated, but the general response of that particular class of respondent should be taken to fill in the missing information. Other concerns with contingent valuation are: strategic bias, where respondents think that they can influence the final results; design bias, where the information influences the conclusions; instrument bias, which causes respondents to provide biased answers because of the payment vehicle; and starting-point bias, where the responses are influenced by the choices given in the question.

Sundeman and Bradburn (1982) consider problems in survey analysis; they state that income is often deflated because of tax risks, or inflated to make respondents appear more wealthy (p.18). Since our survey was mailed and returns were anonymous, it is likely that there will be no problems with income being altered. Another point that the authors make is that some respondents find ranking difficult and, therefore, only indicate their first choice (p.164). A ranking question was included in the current survey (see Appendix) despite this concern, but it appears that it was a poor choice of methodology, because it was badly answered or often left out altogether. Sundeman and Bradburn (1982, p.249) also stated that a long question should not be followed by a short one, or it may be overlooked; although our pretest group answered the question on gender, it is most likely survey respondents left it out because they did not see it, despite its being labelled as part of the question above it.

It is important of course to identify the group that is being targeted. Important questions that need to be considered include the following (Winnpenny 1991): Who is a user of the amenity? Who are the gainers and losers from the proposed change? Is the sample a good representation of the user group? Variation in responses to WTP questions comes from natural variation across populations, from improper survey design, from improper population representation, and from the time of year when the survey is done (Reiling *et al.* 1990, p.129). For example, it may have been inappropriate to survey respondents at the time of an order to boil water; likewise, groundwater is generally at its worst at the end of the summer, so this would be an inappropriate time of year to ask people about their WTP for improvements in water quality (Musser *et al.* 1992). Maddala (1983), and Sellar, Stoll and Chavas (1985), describe probit and logit models appropriate for analyzing dichotomous choice responses, while Maddala describes the Heckit model for testing for sample selectivity when zero WTP responses are excluded in the regressions.

There are different ways to set up the contingent valuation question, and there are different types of error that can be encountered with each method. With the dichotomous choice (take-it-or-leave-it or closed) model, different respondents are asked whether or not they would be willing to pay $x (with x randomly varying between respondents) for the same improvement in an environmental amenity (Winnpenny 1991; Cooper and Loomis 1992). A variant of this approach asks individuals a second question, requiring them to provide an upper (if they answered yes) or lower (if no) bound on their responses. This increases the statistical accuracy of the subsequent welfare measures (Kannien 1993).

Another approach is to provide an open-ended willingness-to-pay question, where the respondent fills in the value. Research indicates that, when people are faced with this type of choice, 25% felt they could not give accurate answers, while if they were given choices 9.2% felt their answer lacked accuracy (Sellar, Stoll and Chavas 1985, p.165). Nonetheless, it appears that open-ended formats generate lower values of WTP than do closed formats (Kealy and Turner 1993).

A third approach is contingent ranking where a set of outcomes with different combinations of goods and payment requirements are given. The respondent identifies the most preferred combination. Measurement biases are discussed in great detail, including some which are not mentioned in other literature. These include importance bias, where the person feels the item being valued must be important, simply because a study is being done on it, and position bias, where people are affected by how a question is positioned in the survey. Important points that are mentioned about survey construction include leaving provocative questions, like those about income, until the end or people may choose not to complete the survey.

Mitchell and Carson (1989) discuss the benefits of using WTP over WTA compensation. WTA values generally decline over time and, although they are a valid welfare measure, people appear to reject the implicit property right in WTA studies. This is indicated by preposterous WTA values. WTP and WTA may vary by several orders of magnitude, although economic theory suggests that they should vary by little. This difference may be due to difference in property rights (Knetsch 1989).

There is also an ongoing debate concerning the usefulness of CVM-derived values in the assessment of environmental damages and, hence, cost-benefit analysis. Smith (1990, 1992), Randall (1993) and others argue that CVM values are meaningful and can safely be used in cost-benefit analysis. Others have attempted to statistically adjust CVM values by combining them with travel cost or other choice-based information (Cameron 1992a, 1992b). But others have recently argued that values obtained from contingent valuation devices have no economic meaning and cannot be used in cost-benefit analysis (Desvousges *et al.* 1993; Cambridge Economics 1992; Kahneman and Knetsch 1992a, 1992b; Editors of the Harvard Law Review 1992). This debate is ongoing and is not entered into here.

As mentioned above, one check on CVM responses is to use other measures of welfare in addition to WTP. In this study, we employ defense expenditures (purchases of bottled water and water filtration systems) as a lower bound on the WTP estimates. In order to be meaningful, WTP responses must exceed respondents' defense expenditures. We also employ the results of fuzzy pairwise comparisons to WTP in order to obtain a better feel for the range of values obtained from the contingent valuation model. Respondents were asked to provide information on purchases of bottled water and were also asked to make fuzzy comparisons among four items. Defense expenditures and fuzzy pairwise comparisons are discussed in greater detail below.

6. Abbotsford Water Quality Survey

A survey of residents in the Abbotsford region was conducted during May 1993. The survey was be sent to 343 households, with 18 returned as undeliverable. Similar studies in the region have had survey response rates of between 30-45%, with the majority of the surveys being returned by people of higher education levels. Reminder notices were sent to all those in the sample approximately 3 weeks after the first mailouts. Eighty-nine completed surveys were returned, providing a response rate of 27.4% for deliverable surveys. This is an adequate return rate for analytical purposes. Since groundwater problems have been highly publicized and have received extensive media attention, above average returns were expected. However, the below average return rates can be explained because the same methods of phoning and reminding respondents that have been used in other survey work could not be used due to the UBC Ethical Review process--mailouts and returns had to be kept completely confidential and "harassment" via repeated follow-up would not be permitted. Funding limitations prevented the use of an outside consultant to conduct the survey, as is now done with most CVM surveys.

The main objective of the survey was to elicit respondents' willingness-to-pay for improvements in water quality. In addition, respondents were asked about purchases of bottled water, in-home water filtration systems, and their WTPs for preserving agricultural land and preventing golf course development on agricultural land. In addition, respondents provided background and personal information, likert-scale responses to opinion questions, and revealed their preferences for four items using fuzzy pairwise comparisons (discussed below). Not all sections of the survey were analyzed for this study. A copy of the questionnaire is provided in the Appendix.

The survey instrument was pretested on a group of 20 students. As a result, questions related to bottled water, in-house water filters, and water's quality attributes were amended for better clarity. Minor re-wording of other questions also occurred.

Summary of Survey Data

A summary of the personal and background information is found in Table 1. On average, respondents were 41.3 years old and had an average education level of one year of post-secondary education, which is reasonably close to the Statistics Canada 1986 average education level of just over 12 years. Hence, it can be assumed that there is no educational bias between respondents and the general populace in the study region. Statistics Canada's 1991 census indicates that average family size in the region is 2.9, which corresponds with the average of 3.0 for the current survey.[8] There was an average of only 0.385 children under age five, which is understandable considering the average age of respondents.

Respondents have lived in their homes for an average of 7.0 years and in the area for 15.2 years, so they should be aware of water quality issues. Also 89.2% of respondents own their homes, and 13.8% have land in the Agricultural Land Reserve (ALR). If these owners have a farm enterprise, their views towards agricultural pollution and water quality may be affected by the fact that they own farmland. Hence, this variable is included in the WTP model below.

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[8]Only some census data are available for 1991. Where possible, 1991 data is used; otherwise we rely on 1986 census data.

According to the 1986 census, average household income in the study region was $46,493 in 1992 dollars, which is not too different from the average household income of survey respondents--approximately $44,620.[9] Respondents average monthly rent or mortgage payment was $600 (assuming owners paid some property taxes).

Two scaled scores were constructed from the opinion questions. Because perceptions regarding externality might be important to individual behaviour or their willingness-to-pay, opinion questions 2 and 10 were combined into a single scaled score. The scaled score takes on a value of 1 when externality from farm operations is perceived to be at its highest, and a score of zero at its lowest. Likewise, the opinion question regarding belief about water quality was scaled to take on values between 0 and 1. The averages for these scaled scores are also provided in Table 1, and these indicate that there is greater concern over water quality than general farming externalities.

Questions pertaining to residential sewage and septic systems were included along with those on water quality; a summary of responses is provided in Table 2. Sewage disposal questions are important because poorly maintained septic fields are believed to contribute to aquifer nitrogen-nitrate pollution. Of respondents, 40.6% indicated that they have a septic system, while the remainder believed they were connected to municipal sewers. (One respondent admitted that they did not know what type of sewer system they had.) Of those who knew they had a septic system, only 55.2% had cleaned their system within the last four years (as required), 10.3% cleaned it in the last 5-10 years, 3.5% had not cleaned their system in 10 years, 20.7% did not know when their system had last been cleaned, and 10.4% had never cleaned their system. In conclusion, only one-half to three-quarters of respondents who own a septic system maintain it according to acceptable practices.

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[9]The 1986 income ($35,572) was converted to a 1992 basis using the index for average hourly earnings.

Table 1: Summary of Personal and Background Information

Item	Mean	Coefficient of Variation
Age of respondents	41.3 years	43.5%
Female respondents	27.6%	163.5
Family size	3.0	44.5
Number of children under five	0.385	182.1
Own their homes	89.2%	35.0
Length of time living in neighbourhood	15.2 years	91.8
Length of time living in current home	7.0 years	107.4
Education	13.14 years	19.3
Household income	$44,620	61.1
Scaled scores:		
- Concern about water quality	0.5371	61.5
- Concern over externality from farming	0.3516	85.0

Table 2: Water Quality and Sewer Maintenance

Item	Mean	Coefficient of Variation
Respondents with septic system	40.63%	121.8%
Length of time since septic system last cleaned	approx. 8 yrs	49.5
Perceived water source	municipal-don't know	46.1
Respondents using bottled water or filters	36.9%	131.7

Water filtration systems and water bottle purchases are indicative not only of a minimum WTP for improved water quality, but also perceived water quality. Of respondents, 37% had purchased bottled water within the last year, and 27% owned some type of water purification filter. This indicates that there is some concern over local water quality, but it is generally not considered to be a serious problem. Respondents paid an average of $69.59/year on defensive expenditures (see below).

Willingness-to-Pay for Improved Water Quality

The WTP model for improved water quality was developed in an earlier section. Respondents were not asked to provide their WTP in an open-ended format, but, rather, were asked to identify their location on the supply curve for water quality (see Appendix). The average WTP for all respondents was $63.86/year, and it was $70.85/year for those who indicated that they were on groundwater or did not know whether they were on groundwater. However, because the supply curve was presented to respondents, it was not possible to include quantity--the measure of water quality--in the regression. However, income and income squared were included in the ordinary least squares (OLS) regression as required by the economic theory. Socioeconomic variables (such as education and age) were also included in the regression, as was the scaled opinion question regarding water quality. The regression results are provided in Table 3.

The estimated regression equations were used to predict possible values for willingness to pay. These indicate that those with land in the ALR are willing to pay more than those owning no agricultural land, perhaps because they see themselves as contributing to nitrogen-nitrate pollution. WTP ranges from about $78 to $90 per year for those without land in the ALR, and $114-125/year for those with land in the ALR (ignoring regression A3). These values are generally higher than the average stated WTPs, except for regression A3 (where predicted WTP was less than stated WTP).

Table 3: Regression Analysis of Willingness-to-Pay for Improved Water Quality

	WTP of all respondents			WTP of those on ground-water or who do not know their water source		
Item /Model	A1	A2	A3	W1	W2	W3
Income	5.56 (1.22)	8.64 (2.50)		1.3205 (0.24)	4.1962 (1.06)	
Square of Income	1.53 (1.04)		2.69 (2.41)	1.335 (0.81)		1.61 (1.32)
Belief about water quality	-31.73 (-1.39)	-28.2 (-1.25)	-35.34 (-1.56)	-67.66 (-2.34)	-66.73 (-2.32)	-68.61 (-2.43)
Own ALR land	24.10 (1.15)	25.81 (1.23)	-24.65 (1.17)	42.53 (1.71)	44.98 (1.84)	42.66 (1.74)
Constant	69.37 (4.76)	73.94 (5.31)	66.32 (4.60)	96.19 (4.70)	101.80 (5.315)	95.57 (4.77)
R^2	0.1646	0.1480	0.1418	0.2287	0.2142	0.2274
Predicted WTP ($/yr): if ALR land / no ALR land	114.38 / 90.28	114.71 / 88.90	55.35 / 80.00	123.19 / 80.66	125.56 / 80.58	120.93 / 78.27

*Where A regressions include all the respondents independent of their water source, and W regressions include only those who do not know their water source, or who know they are using well water.

Fuzzy Pairwise Comparisons

Fuzzy logic is increasingly used to control everything from washing machines to cement kilns and subway systems (Klir and Folger 1988; Kosko 1992; Kosko and Isaka 1993), to aggregate communities for regional analysis (Harris, Stoddard and Bezdek 1993), to determine planting strategies in agriculture (Flick and van Kooten 1993), and so on. While the use of fuzzy logic has had a slow start in North America, it has recently started to become more popular as a result of success by the Japanese in developing products that use this technology. In the current research, fuzzy pairwise comparisons are used to determine the value of water quality to respondents in the Abbotsford region.

Fuzzy pairwise comparisons were first used by van Kooten, Schoney and Hayward (1986) to study farmers' goal heirarchies for use in multiple-objective decision making. As noted by these authors, the fuzzy pairwise method results in a ratio scale (p.43) that can then be used to value nonmarket goods and services if one of the items in the set is traded in the marketplace. Fuzzy pairwise comparisons require that all items to be ordered are compared in pairwise fashion; thus, there are n(n-1)/2 pairwise comparisons that need to be made.

A measure of the intensity of preference between two items, A and B, is made by marking on a line, with endpoints denoted A and B, the degree of preference for one over the other; a mark placed at the centre of the line indicates indifference. A measure of the intensity of the preference of item A over item B is determined by measuring the distance from the left-hand-side endpoint (where A is assumed to be located) to the respondent's mark, where the line is of unit length (at least after normalization). Denote this distance by r_{AB}. If $r_{AB} < 0.5$, then A is preferred to B; if $r_{AB} > 0.5$, then B is preferred to A; and if $r_{AB} = 0.5$, A is equally preferred to B. Of course, $r_{AB} = 1 - r_{BA}$.

Van Kooten, Schoney and Hayward (1986) develop a measure indicating the intensity of preference of one item over another. Once all of the pairwise measures r_{ij} are obtained, the measure of intensity for the item is determined as:

$$m_j = 1 - \left(\frac{\sum_{i=1}^{k} r_{ij}}{k-1} \right)^2 ,$$

where the numerator in the second term on the right-hand-side of the equation is the Euclidean norm and the denominator, $(k-1)^{1/2}$, is its maximum value; k is the number of items that are ranked by the fuzzy pairwise comparison. Finally, suppose we obtain the following measures: $m_A = 0.2$; $m_B = 0.6$; $m_C = 0.3$; and $m_D = 0.75$. Further suppose that item C is valued at \$100. Then, by independence of irrelevant alternatives (one's preference of an orange over an apple does not depend on whether or not one has to determine preference of an orange or apple over a grapefruit), item C is valued at \$250 (\$100 x 0.75/0.3).

In the questionnaire, respondents were asked to make fuzzy paired comparisons over the following four items:

1. reducing one's commuting time to work by one-half,
2. improving the availability and quality of one's drinking water,
3. preventing the development of a golf course on agricultural land, and
4. a 33-inch, split-screen, stereo colour television set with remote control.

For the 40th respondent, the following matrix of normalized distances was constructed.

Item	1	2	3	4
1	0	0.2121	0.9697	0.1212
2	0.7879	0	0.5606	0.4242
3	0.0303	0.4394	0	0.3485
4	0.8788	0.5758	0.6515	0

The matrix indicates that 1P2, 1P4, 2P4, 3P1, 3P2 and 3P4, where P denotes "preferred to". Using the above formula, the preference intensity scores are as follows: m_1=0.4227,

m_2=0.3904, m_3=0.6757 and m_4=0.2863. This individual ranked "preventing development of a golf course on agricultural land" highest, followed, in order, by a reduction in commuting time, improved water quality, and the colour television. He or she also valued improved water quality 1.36 times (0.3904/0.2863) as much as the television set.

The average scores of all respondents for these items, and their coefficients of variation, are provided in Table 4. These indicate that the respondents ranked the four items presented them in the following order: improved water quality, halving commuting time, preventing golf course development on agricultural land, and the television. Improved availability or quality of drinking water was considered to be 2.1 times more important than the television by the group as a whole.

Table 4: Intensity of Preference for Fuzzy Pairwise Ranked Items

Item	Mean	Coefficient of Variation
Halve commuting time	0.4605	32.1%
Improve water quality	0.6528	24.1
Prevent golf course development	0.4395	39.9
33" colour television	0.3026	41.1

The value of the television varies according to brand and where it is purchased, with prices ranging from about $900 to almost $2,000, but it is perceived prices that are important. Upon asking a number of individuals about their perception of price, we found that their average price for such an item was about $1,350; answers of less than $1,000 were common. Hence, we employ values of $1,350 and $900, and annualize these simply by dividing by 10--the approximate useful life of a T.V. The subsequent values are then multiplied by 2.1 to obtain an estimate of the value of improved water quality based on fuzzy pairwise comparisons. This provides an estimate of approximately $189-$280/year for water quality improvements.

The fuzzy scores for the four items in Table 4 were regressed on a number of explanatory variables using seemingly unrelated regression, which is the same as independent OLS regression using the same regressors. The explanatory variables used in the regressions were the scaled attitudinal scores, education, income, whether or not the respondent had land in the ALR, whether or not the respondent owned their place of residence, and time spent commuting. The regression results are presented in Table 5. Using these results, the predicted fuzzy scores for each of the items were calculated depending on whether or not the respondent owns land in the ALR and their place of residence. The predicted preference intensities are provided in the bottom rows of the Table.

From the predicted preference intensities for the ranked items, it is possible to calculate respondents' intensity of preference for water quality relative to the 33" color television. These depend on ownership of land in the ALR and ownership of their residence. Those owning both land and their residence valued improvements in water quality by a factor of 1.836 over the television, or about $248/year. Those who owned their place of residence by did not own land in the ALR valued improvements in water quality at $193/year, while those who owned no property whatsoever valued it at $242/year.[10] If individuals perceive the price of the television to be lower than $1,350, say only $900, then improvements in water quality are valued at $165, $128 and $161, respectively. In general, improvements in water quality are valued higher by those with ALR land, as was the case for WTP.

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[10]The other case was not included because there were no respondents who had land in the ALR and did not also own their place of residence.

Table 5: Regression Analysis for Intensity of Preferences and Predicted Intensities

Item/Fuzzy Score	Halve Commute Time	Improve Water Quality	Prevent Golf Course Develop.	33" TV
Income	-0.0176 (-1.66)	-0.0182 (-1.65)	-0.0128 (-1.06)	0.0148 (1.51)
Dummy=1 if own land in ALR	0.1787 (2.67)	0.0164 (0.14)	-0.2142 (-2.88)	-0.0700 (-1.14)
Dummy=1 if own place of residence	0.0707 (1.08)	-0.0787 (-1.16)	0.0163 (0.21)	0.0277 (0.45)
Quality score	-0.0536 (-0.84)	-0.2138 (-3.24)	0.2525 (3.48)	0.0671 (1.14)
Externality score	0.0246 (0.36)	0.1447 (2.07)	-0.1916 (-2.46)	-0.0060 (-0.09)
Open space score	-0.0992 (-1.04)	-0.0377 (-0.38)	0.0725 (0.66)	-0.0481 (-0.54)
Time spent commuting	-0.0620 (0.94)	-0.0110 (-1.61)	0.0071 (0.95)	-0.0036 (-0.59)
Education	0.0256 (2.86)	-0.0082 (-0.89)	0.0018 (0.17)	-0.0230 (-2.78)
Constant	0.1247 (0.82)	0.9083 (6.03)	0.2637 (1.59)	0.5979 (4.47)
R2	0.3658	0.3981	0.4416	0.269
Predicted Scores ALR land own residence				
1 1	0.2710	0.5198	0.2088	0.2831
1 0	0.2003	0.5985	0.1925	0.2554
0 1	0.0923	0.5034	0.4230	0.3531
0 0	0.0216	0.5821	0.4067	0.3254

In conclusion, the fuzzy pairwise comparison approach provides an estimate of $128-$284 per year for improvements in water quality in the Abbotsford region.

Defense Expenditures

A third method was used to determine the accuracy of the WTP measure. Respondents were asked to complete a table indicating the brands and amounts of bottled water purchased in the previous month (April 1993), as well as to indicate the brand of any water filter they might own. Some respondents did not answer this question, although they indicated that they did purchase bottled water or own a filter; in addition, taxes on purchases of bottled water or water filters were not included in the analysis. As a result, the true stated defense expenditure is likely underestimated. Further, since some respondents purchased only small bottles of water, they can be excluded from the defense expenditure calculation, since this appears to indicate that they do not perceive their residential water quality to be a problem, but rather would purchase this water anyway, despite improvements in the aquifer's water quality. Finally, since filters are often permanent and have little or no maintenance requirements, a 25-year life was assumed unless the manufacturer indicated otherwise.

Sixty-two of the 89 respondents to the Abbotsford survey are on ground water, and these are the only ones considered in the determination of defense expenditures. The calculations indicate that respondents paid an average of $69.59/year (with standard deviation of $147.47) to avoid using well water (drawn from the aquifer) for drinking purposes. As expected, this is less than their stated WTP, as determined above. A regression of defense expenditures on income and family size is provided in Table 6. It indicates that households may have been more willing to purchase bottled water or water filters as the number of individuals affected by poor water quality increased. Household income levels do not appear to affect purchases, however.

In conclusion, defense expenditures of about $70/year serve as a lower bound estimate of the benefits of improved water quality.

Table 6: Regression Analysis of Defense Expenditures in the Abbotsford Region of B.C.

Item	Estimated Coefficient	t-statistic
Constant	15.619	0.207
Income	9.935	0.629
Income squared	-8.629	-1.872
Household size	35.049	1.688
R^2	0.1489	

Cost-Benefit Analysis of Composting

Storing manure and transporting it off the aquifer were considered alternative means of dealing with animal wastes. From earlier sections, we can provide some crude calculations of these costs for broilers and layers. Storage costs for broilers are approximately $8.75/tonne, which includes investment costs and cleaning and handling costs; for layers, costs are much higher--$25.65/t. To these costs, one must add transportation costs of about $40.63/t. Hence, total costs range from about $50/t to $70/t. If manure can be sold for more than this (some manure is sold for about $90/t), then no public intervention is needed. However, these calculations do not take into account marketing costs, wastes from animals other than chickens, and sales of manure to local vegetable and berry producers (who now apply the manure at more appropriate times of the year). However, it is unlikely that storage and transportation will solve the problem of nitrogen-nitrate pollution entirely. In that regard, composting has been identified as the preferred alternative.

Earlier it was shown that composting is not feasible from a private perspective. The appropriate question is the following: Is composting economically feasible from society's point of view? In order to answer that question, it is necessary to employ social cost-benefit analysis. Given the nature of the available data, it is only possible to calculate whether or not it is feasible to compost all animal wastes; it is not possible to determine the socially-optimal amount of wastes to compost, as that would require additional research. However, if it can be demonstrated that composting is socially feasible, then the next problem is that of designing incentives (and institutions) that encourage livestock producers to compost.

Estimates of the amounts of livestock waste produced in the Abbotsford region are provided in Table 7. The total costs of composting these wastes in any given year are determined by multiplying total annual waste produced by the cost of converting that waste into manure. From Table 7, the total amount of animal waste produced each year is about 890,000 tonnes. For compost costs of $36-$70/t, the total annual cost of reducing this to compost is between $32.0 and $62.5 million. Assuming that revenues are $8-$15/t, or $7.1-$13.4 million per year, the shortfall is $18.6-$55.4 million.

In 1991, there were 29,840 private households in the Central Valley Regional District. In drawing our random sample, 90 out of 343 households (or 26.24%) were in regions where groundwater was used for drinking purposes, while 62 out of 89 respondents (69.66%) indicated that they were on groundwater. Hence, some 18.28% of households, or about 5,500, in the Central Valley Regional District are on groundwater. For comparison, according to the latest Census, the 1991 population of the District of Abbotsford was 18,864. Almost all residents in the District are on groundwater. Assuming 3 individuals per household, then some 6,300 households are on groundwater. We use the latter figure in our calculations.

Table 7: Estimated Production of Animal Wastes in the Central Fraser River Valley Regional District

Animal	Total Number[a]	Total Waste (kg/day)[b]
Cattle	35,666	1,153,201
Pigs	90,069	459,352
Sheep	1,776	1,954
Horses	884	20,332
Goats	1,044	2,714
Rabbits	323	65
Mink	54,044	140,514
Poultry	7,221,298	673,988
Total (tonne/day)		2,452

[a] Statistics Canada, 1991, *Census of Agriculture, British Columbia, 1990*. Catalogue #95-393.
[b] Manure production per animal figures from Hagen (1990)

Multiplying the number of households by defense expenditures of $70/year per households results in a lower bound estimate of the benefits of improved water quality of $0.44 million. This number is very close to the average stated WTP of $70.85 per household ($0.45 million). However, based on WTP estimate from table 3 of $78-$90/year per household, the estimate of benefits is somewhat higher--$0.49-$0.57 million. If WTP estimates for those who own ALR land are used ($114-$125/year), then the benefits of improved water quality are $0.72-$079 million. Finally, using the results from the fuzzy pairwise comparisons gives benefits of $128-$284/year per household. The total benefits of improved water quality would then be $0.81-$1.79 million.

It is clear that the social benefits of composting do not exceed the social costs. Rather, the social benefit likely amounts to a maximum of about $2/tonne of livestock wastes produced. That is, before composting can be considered economically feasible from a social point of view, private revenues from composting (or any other alternative means of manure disposal) must be very close to private costs. Otherwise, public subsidies to reduce livestock pollution are not worth undertaking.

7. Conclusions

The research in this study indicates that pollution of the Abbotsford aquifer is not as serious a problem as originally thought. The value that users of groundwater attach to improvements in the quality of their drinking water are inadequate to cover the losses that agricultural producers are likely to incur in preventing the pollution. The general conclusion is that public subsidies to agricultural producers will simply encourage an activity (composting) which costs more than it benefits society. Subsidies would simply result in increased inefficiency and a waste of taxpayer money. The same can be said about taxes or regulations that force producers to compost their wastes. These will encourage economic inefficiency from a social standpoint and have the effect of driving some producers to bankruptcy. This will be aggravated in some sectors if, and when, marketing boards no longer provide them with the protection they would otherwise have.

It should be noted that these conclusions are based on an "all-or-nothing" scenario, where all or none of the livestock wastes are composted. There may well be some benefits from providing subsidies to producers to enable them to clean up the worst cases of pollution. There may be benefits to research that aims to optimize the rates and timing of manure applications so that less nitrates enter the aquifer. Indeed, research and extension efforts that change management practices at low cost may do more to reduce pollution than large investment schemes that seek to establish regional manure storage and/or composting facilities. It is our recommendation that more effort be directed at improving on-farm management practices, both for livestock and field crops.

A second caveat is also in order. Information about the actual costs of composting, potential markets for compost and composting techniques is sparse; further research into any of these areas is certainly warranted. The same is true of alternatives such as storage and optimal application, storage and subsequent transportation to other regions, the off-farm costs of manure applications (i.e., negative impacts of smell), using manure as cattle feed, and so on. Finally, it is necessary to determine how other government programs affect disposal of livestock wastes and use of water. For example, how does the feed freight subsidy affect the location of livestock production facilities? How do input rebates and input subsidies (if any), and the tax system itself, influence decisions by field crop producers (e.g., berry and grain producers) to apply manure *vis á vis* chemical fertilizers, for example? Farm-level research (e.g., mathematical programming) is required to suggest how these factors interact in production decisions.

The contingent valuation approach was used in this study to estimate the off-farm benefits from improved water quality arising from a reduction in the level of improper disposal of livestock wastes. However, the use of CVM in cost-benefit analysis has been questioned by a number of researchers (e.g., Kahnemann and Knetsch 1992a, 1992b; Cambridge Economics 1992). The design of the survey used in this study could likely be improved upon, as indicated by the low response rate. In this regard, a telephone survey of more than 100 households has been implemented, with funding provided by the current sponsors--UBC's Sustainable Development Research Institute and Environment Canada (see Athwal 1993). This research is scheduled for completion in the next several months. It will provide a useful check on the conclusions reached here, although preliminary results indicate that our conclusions will be supported.

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APPENDIX

Abbotsford Water Quality Survey: Questionnaire

March 31, 1993

Dear Sir/Madam:

The Department of Agricultural Economics at the University of British Columbia is studying conflicts in the urban-rural fringe. We are hoping that you will contribute to a part of this research by completing the enclosed questionnaire, which takes about 15 minutes to complete.

The questionnaire deals with transportation, open space, preservation of agricultural land, and water quality in the lower mainland region. We are attempting to gain insights into how citizens perceive conflicts among different objectives, and their willingness to accept higher or lower levels of public goods and services (e.g., more or less open space). We ask several questions of a more personal nature, such as what income category your household falls in, and what you are willing to pay for various levels of public goods and services. However, we assure you that your replies will be kept in strict confidence. We hope that you answer all of the questions because our economic models require this information and our conclusions are weakened without it. Your views are also lessened when questions are left unanswered.

Background information is provided on the first page of the survey, but the questionnaire can be completed without this information.

There are no right or wrong answers; we are only interested in your views, and these will be kept confidential.

Thank you in advance for you cooperation.

Sincerely yours,

Rita Athwal/Anke Hauser/Julie McAuley
Research Assistant

SURVEY
Decisions for the Future: Agricultural Land Preservation and Waste Disposal in the Lower Mainland

Preserving Agricultural Land

The government of British Columbia created the Agricultural Land Reserve (ALR) in 1973 in order to preserve agricultural land for future generations. However, in certain areas of the province, particularly the lower mainland, population growth has put increasing pressure on these lands. Consequently, some lands have been removed from the ALR for urban development and for recreation (e.g., golf courses). Farmers have complained that urban encroachment and the rules of the ALR prevent them from having viable farming operations in some cases (e.g., fields are fragmented and there are problems of vandalism). Urban residents might feel that the ALR contributes to higher property values by restricting the availability of building lots. Thus, commuting times increase (as citizens move further from their work to find affordable housing) and living standards are lowered. Others would argue to the contrary, indicating that preservation of agricultural land leads to a better environment. One thing is clear, however; it is not possible to achieve a better environment without some sacrifices. The amount to be sacrificed depends upon urban housing densities, whether or not golf courses are permitted, whether preservation of wildlife habitat on private farmland is an objective, etc.

Water Quality and Agricultural Wastes

The main water quality issue in the Greater Vancouver Regional District (GVRD) appears to be one of turbidity (murky water). Some believe that this is due to logging in the water shed from which the GVRD obtains its water; others dispute this. However, faced with this problem, as well as water shortages due to drought, the GVRD intends to improve water purification, including the development of additional sources of water. Home owners can expect a increase of 35% on their water bills. This is in addition to added charges to upgrade sewage treatment (an increase of 64% on sewage bills is expected). Rents will also rise to reflect these increases.

The water quality problem in the Central Fraser Valley Regional District is related to agricultural wastes. Water users rely primarily on water from underground aquifers that have become contaminated with nitrogen/nitrates and pesticides (e.g., 1,2,2 tichloroprpoane used to kill a worm-lie creature that attacks raspberries) in underground water reservoirs. Scientists believe that animal wastes are the major contributor to pollution in the Abbotsford region, for example. Each day some 2,500 tonnes of waste need to be disposed of. Composting is the most benign method for disposing of wastes, but it costs about $20/tonne.

It should be noted that water quality is not so low that it constitutes a health threat. Scientists only suggest that we need to be careful and that it is possible to do better than currently.

Section 1: Opinion Questions

Please indicate your agreement or disagreement with respect to each of the following statements. (Please circle the number that best represents your response to the statement indicated).

	Strongly Agree				Strongly Disagree	No Opinion
There is a need to preserve open space in British Columbia	5	4	3	2	1	0
Smell and other farm nuisances are a problem	5	4	3	2	1	0
Water quality in my area is adequate	5	4	3	2	1	0
Government needs to impose strong regulations on fertilizer use and handling of livestock wastes, regardless of cost to farmers	5	4	3	2	1	0
Agricultural land needs to be preserved to ensure future supplies of food	5	4	3	2	1	0
Constructing golf courses on agricultural land constitutes wise economic use of such land	5	4	3	2	1	0
Preserving agricultural land increases residential property values	5	4	3	2	1	0
The Agricultural Land Reserve is effective in preserving agricultural land	5	4	3	2	1	0
Open space should never be sacrificed for urban development	5	4	3	2	1	0
Air and water pollution from farming lower residential property values	5	4	3	2	1	0

Please indicate your preference for each of the paired items listed by placing an X on the line between them. For example, the following indicates that item B is somewhat preferred to A.

	Indifferent	
Item A	____________________|_x____________________	Item B

For the following, please mark the line with an X to indicate your preference.

	Indifferent	
Half my Commute Time to Work	____________________|____________________	Item B
Item A	____________________|____________________	Item B
Prevent golf course on Agricultural Land	____________________|____________________	Half my Commute Time to Work
54", Split-Screen, Stereo Television	____________________|____________________	Half my Commute Time to Work
Item A	____________________|____________________	Prevent golf Course on Agricultural Land
Item A	____________________|____________________	Item B

Section 2: Background Information

1. (a) How long have you lived in this area? ______ years

   (b) How long have you lived in your current residence? ______ years

2. Do you own land in the Agricultural Land Reserve (ALR)? (Please circle one)

   YES   NO

If YES: How many acres do you own in the ALR? __________ acres

What is its approximate, current value? $ __________

How much money do you think you would gain if the land was taken out of the ALR? $ __________

3. Do you rent or own your current place of residence? (Please circle one)

   rent   own

4. What is your monthly rent or mortgage payment (including taxes)?

____ less than $500	____ $500 to $750	____ $750 to $1,000
____ $1,000 to $1,250	____ $1,250 to $1,500	____ $1,500 to $1,750
____ $1,750 to $2,000	____ $2,000 to $2,2500	____ more than $2,250

5. Suppose the government decided to permit various forms of development to occur on the Agricultural Land Reserve.

(a) Would you be willing to pay $ _____ per month in added rent or mortgage payments to prevent ALR land from being developed for residential housing?

YES NO

(b) Would you be willing to pay $ _____ per month in added rent or mortgage payments to prevent ALR land from being developed as golf courses?

YES NO

If you work outside the home, please answer the following.
Otherwise proceed to the next page.

6. How much time do you spend commuting to your place of employment each day? (Please check one)

____ less than 5 minutes ____ 15 to 20 minutes ____ 30 to 40 minutes

____ 5 to 10 minutes ____ 20 to 25 minutes ____ 40 to 50 minutes

____ 10 to 15 minutes ____ 25 to 30 minutes ____ over 50 minutes

How long is your commute? (Please check one)

____ less than 10 kms. ____ more than 10 but less than 20 kms.

____ more than 20 but less than 30 kms. ____ more than 30 kms.

Section 3: Sewage and Water Quality

1. What type of sewer system do you have? (Please check one)

____ city sewer ____ septic tank ____ don't know

If you have a septic tank, when was it last cleaned? (Please check one)

____ within last 4 yrs ____ within 5-10 yrs ____ more than yrs ago

____ never ____ don't know

2. What is the source of your drinking water? (Please check one)

____ private well ____ municipal water from Fraser R. or its tributaries

____ municipal well ____ municipal water from mountain resevoir

____ municipal water but don't know source ____ other (specify)____________________

3. Do you use any of the following special filters in your household to improve water quality?
(Please check appropriate choice)

____ N.S.A ____ Water Pick ____ Brita ____ other (specify) ____________

4. Have you purchased any bottled water in the last five years? (Please circle).

YES NO

If YES, please complete the following table to the best of your ability since we are interested in knowing about purchases of bottled water; otherwise go to the next section.

Brand Name of Bottled Water	Container Size	Number Purchased per Month	Brand Name of Bottled Water	Container Size	Number Purchased per Month
Evian	300ml.		Perrier	300ml.	
	750ml.			750ml.	
	1 litre			1 litre	
	4 litres			4 litres	
	Other ____			Other ____	
Canadian Springs	300ml.		Polaris	300ml.	
	750ml.			750ml.	
	1 litre			1 litre	
	4 litres			4 litres	
	Other ____			Other ____	
Clearly Springs	300ml.		Glacier Springs	300ml.	
	750ml.			750ml.	
	1 litre			1 litre	
	4 litres			4 litres	
	Other ____			Other ____	
Other (specify) ____	300ml.		Other (specify) ____	300ml	
	750ml.			750ml.	
	1 litre			1 litre	
	4 litres			4 litres	
	Other ____			Other ____	

5. Well testing in the Abbotsford region indicate that approximately 60% of the samples taken from wells in some regions exceed the 10 mg/L maximum acceptable concentration of nitrate-nitrogen for drinking water as defined in Health and Welfare Canada's *Canadian Drinking Water Quality Guidelines*. According to an Environment Canada study, elevated ntrate concentrations also signal the potential for contamination from other pollutants. Concentrations of some pesticides for which Canada guidelines do not exist exceed Washington State water quality standards for ground water. Wastes from farm animals have been identified as one (perhaps major) source of ground and surface water pollution. Cleaning up such wastes is expensive.

Composting offers a solution to the problem of animal wastes. for various levels of nitrogen-nitrate concentrations, we have made some rough calculations of the probable costs of cleaning up the pollution via composting. Are you prepared to pay the amounts indicated to clean up farm animal wastes, assuming charges would show up either on your annual water bill or through an increase in rent?

Please place an X under YES or NO in each row to signify whether or not you would be willing through higher water bills or rent to make the payment indicated.

An answer is required in each row.

Water Quality Objective (Nitrate Concentration)	Remark	Estimated Annual Cost to Achieve Objective ($/year)	Are You Willing to Pay?	
			YES	NO
12 mg/L	May be current level	$ 0		
10 mg/L	Current gov't standard	$ 28		
8 mg/L		$ 57		
6 mg/L		$ 85		
4 mg/L		$113		
2 mg/L		$142		
1 or less mg/L	Future gov't target	$170		

Section 5: Personal Information

1. a) What is your age? (Please check one)

___ 25 or under ___ 26-35 ___ 36-45

___ 46-55 ___ 56-65 ___ over 65

b) Are you: ___ Male ___ Female

2. a) Including yourself, how many individuals are there in your household? ___

b) If you have any children **under the age of 5** in your household, how many?

___ children under 5 years of age

3. What is your level of education? (Please circle)

Secondary (Grade): 8 9 10 11 12

Post Secondary (Years): 1 2 3 4 5 6

4. What was your **family's (household's)** approximate gross (before tax) income in 1992? (If a farm, income after farm expenses but before personal expenses.) **Please check one.**

___ less than $30,000 ___ $50,001 to $60,000 ___ $80,001 to less than $90,000

___ $30,001 to $40,000 ___ $60,001 to $70,000 ___ $90,001 to $100,000

___ $40,001 to $50,000 ___ $70,001 to $80,000 ___ more than $100,000

THANK YOU FOR TAKING THE TIME TO FILL OUT THIS QUESTIONNAIRE

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