Improving navigability on the Kromme River Estuary: A choice experiment application

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Abstract

Navigation of estuaries is a vitally important aspect of boating recreation in South Africa and elsewhere. This paper uses a choice experiment to estimate recreation values of the Kromme River Estuary, a popular estuary along South Africa's east coast. This valuation methodology allows for the identification of preferred management strategies through the trade-offs made by estuarine recreational users. It is found that the level of navigability is the most important predictor of user choice, and argued that more attention needs to be paid than is being to options for improving navigability and methods to fund these interventions. It is concluded that an increase in license fee of R437 would improve recreational value.

Keywords: Estuary, recreational attributes, navigability, choice experiment, willingness-to-pay, conditional logit model, random parameters logit model

1 Introduction

The natural beauty, easy access, and range of environmental services provided by estuaries have attracted recreational, commercial and industrial activities (Day, 1980; Forbes, 1998). South Africa's coastline, which stretches for about 3 000 kilometers (km) from north of Richards Bay on the East Coast to Alexander Bay on the West Coast, has many[1] small estuaries. Not unlike estuaries worldwide, many in South Africa have become a focal point of human settlement, resource use and waste disposal (Hay et al., 2008; Hosking, 2008). There is mounting pressure on estuaries as recreational outlets, which, in turn, has led to their functional deterioration as well as deterioration in the quality of the recreational experience as a whole. A South African estuary system currently facing excess

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[1] Some claim that these estuaries total 289 (Hattingh et al., 2002), while others argue that there are in fact 465 along this stretch (Baird, 2002). In total they cover an area of about 600 km^2 (Baird, 2002).

recreational demand pressure is the Kromme River. The Kromme River Estuary is freshwater starved (Baird, 2002). It faces a trade-off between the demand for abstraction of river inflows into the estuary, and the human demand to maintain an ecologically functional estuary habitat, as well as recreational service flows (Hosking, 2011). The expansion of a canal system, as well as the construction of two major dams on the Kromme River, have restricted the water flow into the estuary and resulted in increased sedimentation. The abstraction of this river water has led to the degradation of the estuarine environment in the form of habitat losses, and a decrease in recreational service yield in the form of reduced navigability (Forbes, 1998). Two options to reduce sedimentation in the Kromme River Estuary and improve navigability are increased instream inflow and dredging. How would these interventions be funded?

This paper argues a license fee increase could be used to fund improved levels of navigability in the estuary, and shows what level of increase would, most likely, be welfare improving.

2 The Kromme River Estuary

The Kromme River Estuary (34°08'S, 24°5'E) is located in the Eastern Cape approximately 80 km west of Port Elizabeth (Scharler and Baird, 2003; Sale, 2007). The estuary flows into St Francis Bay, in the Indian Ocean. This estuary is one of the larger estuaries situated in the Eastern Cape and is classified as permanently open (Figure 1).

The Kromme River catchment experiences rainfall throughout the year. Annual rainfall varies from 700 millimeters (mm) to 1 200 mm (Baird et al., 1992). Temperatures in the immediate area of the estuary range from 14°C in mid-winter to 24°C in mid-summer (Day, 1980). The catchment area of the Kromme system is between 936 km^2 (Baird et al., 1992) and 1 085 km^2 (Day, 1980), and drains a large part of the Langkloof. The Kromme River runs for approximately 95 km, with the last 14 km of the river regarded as estuarine (Heymans, 1992). The Kromme River Estuary occurs in a relatively undisturbed area and comprises approximately 12 km^2 of pristine forest, 80 km^2 of fynbos and 1 462 km^2 of private farmland. Recently there have been a large number of residential developments along the banks of the estuary. There is also a marina canal system which has undergone numerous expansions over the years in order to accommodate more houses with water frontage, and a bridge running over the estuary has been constructed. Dams have been constructed on the upper reaches of the river leading to a reduction in freshwater inflows into the estuary.

3 Navigability on the Kromme River Estuary

Navigation is hazardous on the Kromme River Estuary (Thorpe, 2010). The level of navigability of the Kromme River Estuary is inextricably linked to the extent of in-situ sedimentation taking place. Increased levels of sedimentation lead to the constriction of the river channel, both in terms of width and depth, and the creation of new underwater sandbanks (shoaling). The constriction of the river channel makes navigation difficult, sometimes impossible, especially at low tide. The Kromme River Estuary is a "natural sediment trap." Sediment enters from the tidal head and inlet. In an unmodified system, the net long term rate of sediment buildup is relatively slow because periodic freshwater floods scour the channels and remove accumulated sediment out to sea (Reddering and Esterhuysen, 1983). This sediment balance in the Kromme River, however, has been disrupted through artificial modifications to the estuarine system. Early studies on sedimentation in the Kromme River Estuary expressed concerns at increasing levels of sediment due to reduced freshwater inflows (Reddering and Esterhuysen, 1983; Bickerton and Pierce, 1988). The construction of the Churchill Dam in 1943, and the later completion of the Mpofu Dam (previously named the CW Malan Dam) in 1982, has over time, reduced the freshwater discharge passing through the Kromme River Estuary (Reddering and Esterhuysen, 1983; Baird and Pereyra-Lago, 1992). The MAR for the Kromme River has been estimated at between 105.5 (Reddering and Esterhuysen, 1983) and 116.8 million m^3 (Bickerton and Pierce, 1988). Upstream water abstraction (damming) and resultant sedimentation buildup has reduced the actual annual freshwater inflow into the estuary to approximately 0.011 million m^3. This system is, therefore, almost totally starved of freshwater input (Baird et al., 1992). The dams have a combined storage capacity of approximately 133% of mean annual runoff of the Kromme River. They supply water to both Nelson Mandela Bay and agricultural users.

Another source of sediment for the Kromme River Estuary is the Sand River[2]. It begins approximately 2 km upstream from the mouth and deposits a small amount of sand into the estuary on the southern bank. This deposit is spread upstream and downstream in the estuary by the tidal currents. This increased sedimentation has been exacerbated by the creation of a large 'sand spit' which provides protection to the marina from strong south easterly gales (Bickerton and Pierce, 1988). Channel constriction due to sedimentation build-up is mainly a problem in the lower part of the estuary – an area of approximately 70.63 hectares or 706 300 m^2, stretching from the mouth to the confluence of the Kromme River and the Geelhoutboom River (Forbes, 1998).

[2] The Sand River initially opened directly into St Francis Bay. Later, it opened into the marshlands on the south bank of the river mouth. More recently, however, these original outlets were cut off by dune stabilisation and the development of the Marina Glades (Bickerton and Pierce, 1988).

4 Management options for improving navigability

4.1 Increased instream flows

It is generally accepted that maintaining a certain level of instream flow is essential to protect and enhance recreation, water quality, and biodiversity (Berrens et al., 1996). In a study conducted by Sale (2007), the value of freshwater inflows into the Kromme River Estuary was estimated by means of a contingent valuation. Consultations with an estuarine expert, Prof T Wooldridge, predicted that an increase of 75.5 million m^3 per annum in freshwater inflows could increase angling fish, mud prawns and foraging birds by 25% (Sale, 2007).

The results of the study showed that the median household willingness-to-pay (WTP) per annum for the suggested increase in freshwater inflows was R287. Taking into account the estimated number of households of 3 200, the total WTP for this suggested increase amounted to R918 400 (Sale, 2007). Dividing the specified change (75.5 million m^3 per annum) by the total WTP figure, indicates a value of R0.012 per m^3 river water inflow per annum (Sale, 2007), or R0.014 per m^3 per annum at 2010 price levels.

An opportunity cost estimate of this water is the price paid by agricultural users for upstream abstraction of this water. This price is the cost levied by the Gamtoos Irrigation Board (GIB). It charges an annual rate per scheduled hectare of R2 200. This entitles the user to a water quota of 8 000 m^3 per hectare per annum (Murray, 2011) which translates into an annual cost of R0.275 per m^3, much higher than the estuary users were willing to pay for river water inflows into the estuary. For this reason, the authors of this paper were led to speculate that the opportunity cost of river inflows into the Kromme estuary will generally exceed the value gained through them (Figure 2).

Figure 2 models the total benefit and cost of instream flow into the Kromme River Estuary. The benefit may exceed the cost up to instream flow level I_0. A small amount of freshwater inflow keeps the estuary functioning at a level that satisfies most recreational use – in the case of the Kromme River Estuary this inflow may be equal to approximately 11 000 m^3 per annum. The maximum MAR for the estuary is 105.5 million m^3. The benefit curve (B) slopes upward from the maximum MAR due to other positive effects, for example, flood events. Beyond I_0 the total benefit of instream flow protection may be below the total cost at every instream flow level. That is why the total benefit of a 75.5 million m^3 increase in freshwater inflows to secure a 25% increase in fish, mud prawn and foraging birds elicits a WTP of R1 057 000, whereas the total WTP for an equivalent amount of water used upstream equals R20 762 500 (a net cost of R19 705 500).

For this reason, alternative options to instream inflow should also be considered for the purpose of improving navigability, such as dredging.

4.2 Dredging

An alternative way of improving navigability of the Kromme River Estuary is to dredge the channel bottom. Dredging involves the use of a machine equipped with a suction device which removes sand and silt from the channel bottom, deepening the waterway. Unfortunately it can come at a cost, for example, damaging prawn habitats. Currently, dredging activities are confined to the canal system in the marina. There are no immediate plans to extend the dredging to the main estuary channel (partly due to the damage it can cause). Assuming an area of 10 000 m^2 requires dredging, and a cost of hiring a dredging outfit of R30 per m^2 (St. Francis Bay Ratepayers Association (SFBRA), 2011), the annual cost (excluding habitat damage) of dredging the main estuary channel would be R300 000, much less than the opportunity cost of instream inflow (but then it also has a narrower benefit). The total cost of dredging including habitat damage would be much higher.

Two big questions are (1) how could this cost be funded, and (2) does the navigability benefit exceed the dredging cost of R300 000. With respect to the first question, we suggest that a potential source of funding for this dredging activity could take the form of an additional tariff imposed on recreational boat users of the estuary. With respect to the second question, we suggest the answer can be revealed through the tariff trade-off boat users of the estuary would be willing to make for improved navigability. This trade-off may be calculated through the application of a suitably designed choice experiment (CE).

5 A literature review of choice analysis

The CE technique is an appropriate method to analyse choice with respect to environmental goods and services (Adamowicz, 1995; Bennett and Adamowicz, 2001; Hanley et al., 2001; Hensher et al., 2005). Previous international applications to analyse choice in wetland settings include: Opaluch et al. (1999) on the protection of selected natural resources in the East End of Long Island; Economics for the Environment Consultancy (EFTEC) (2002) on the value of benefits derived from a revised bathing water quality directive in England and Wales; Carlsson et al. (2003) on values placed on selected characteristics of the Staffanstorp wetland area in southern Sweden; Eggert and Olsson (2004) on improving coastal water quality on the Swedish west coast; Windle and Rolfe (2004) on assessing community preferences for the protection of the Fitzroy Estuary in central Queensland; Birol et al. (2006) on estimating the value of changes in social, ecological and economic functions provided by the Cheimaditida wetland in Greece; Nam Do and Bennett (2007) on estimating wetland biodiversity values for the Mekong Delta in Vietnam; Luisetti et al. (2008) on the values of managed realignment coastal policies on the east coast of England; and Kragt and Bennett (2009) on catchment management issues in the George catchment, north-eastern Tasmania.

In South Africa, there have only been a few attribute valuation studies reported. The Water Research Commission (WRC) commissioned a study in 2008 (Project K5/1413/2) to generate information on guiding the allocation of river water to South African estuaries and to investigate the factors that explain WTP for river inflows into South African estuaries (Oliver, 2010). This study applied a CE to the Bushmans Estuary, in the Eastern Cape Province, and compared the results with those of an application of a CVM done by Van Der Westhuizen (2007). Welfare measures derived from the CE study were about 30% less than the welfare measures derived from the CVM study (Oliver, 2010). Reasons cited for this difference included different samples of users, as well as the possibility of embedding bias in the derived CVM estimates.

These studies lend support to the use of the CE for the purposes of valuing selected recreational services provided by the Kromme River Estuary. This method forces the recreational user to make trade-offs among estuarine attributes, and reveal which of these are most important. This information is vital in the context of resource management decision making, where scarce resources need to be allocated between competing recreational demands.

6 The choice experiment methodology

A frequently used tool for modeling the behaviour of individual choice is the discrete choice model based on the hypothesis of random utility (Bateman et al., 2002; Hensher et al., 2005). The random utility model (RUM) allows the researcher to analyse choices among many alternatives. The individual's decision to select one alternative, as opposed to other substitute alternatives, is treated by the RUM as a stochastic, utility-maximising choice (Louviere et al., 2000; Haab and McConnell, 2002). The total utility derived from selecting alternative i may be described by the utility function,

$$U_{iq} = V_{iq} + \varepsilon_{iq} \tag{1}$$

where:

U_{iq} represents utility derived for consumer q from option i,

V_{iq} is an attribute vector representing the observable component of utility from option i for consumer q, and

ε_{iq} is the unobservable component of latent utility derived for consumer q from option i (Nam Do and Bennett, 2007).

Assuming a linear additive form for the multidimensional deterministic attribute vector (V_{iq}):

$$Viq = \beta_{1i} f_1(s_{1iq}) + ... + \beta_{ki} f_k(s_{kiq}) \tag{2}$$

where:

β_{ki} are utility parameters for option i, and

s_{iq} represents $(1 - k)$different attributes with differing levels.

Equation 1 may be expanded to:

$$U_{iq} = \beta_{1i} f_1(s_{1iq}) + ... + \beta_{ki} f_k(s_{kiq}) + \varepsilon_{iq} \tag{3}$$

This RUM is converted into a choice model by recognising that an individual (q) will select alternative i if and only if (iff) U_{iq} is greater than the utility derived from any other alternative in the choice set A. Alternative i is preferred to j iff $P\left[(V_{iq} + \varepsilon_{iq}) > (V_{jq} + \varepsilon_{jq})\right]$, and choice can be predicted by estimating the probability of individual (q) ranking alternative i higher than any other alternative j in the set of choices available (Louviere et al., 2000; Nam Do and Bennett, 2007).

This model may be estimated using a conditional logit (CL) model (Louviere et al., 2000; Haab and McConnell, 2002). The CL model assumes that ε_{ij} is independent and has a type I extreme value distribution. The probability, $Pr(iq)$, that individual q chooses alternative i out of n alternatives is given by

$$\Pr(iq) = \exp(V_{iq}) / \sum_{i=1}^{n} \exp(V_{iq}) \tag{4}$$

where:

$\exp(\cdot)$ = the antilog function.

One of the assumptions of the CL is independence of irrelevant alternatives (IIA) (Haab and McConnell, 2003; Hensher et al., 2005). The IIA assumption requires that the relative probabilities of choosing between any two alternatives be unaffected by the introduction or removal of other options (Haab and McConnell, 2002). If the IIA assumption is violated, the observed and unobserved components of utility can be dependent on one another and the error term exhibit serial correlation, leading to biased estimates (Nam Do and Bennett, 2007). The CL model also assumes that the coefficients of variables that enter the model are the same for all consumers, i.e. that there is homogeneity in preferences across respondents (MacDonald et al., 2005; Ben-Akiva and Lerman, 1985; Louviere et al., 2000). This homogeneity implies that consumers that exhibit the same socioeconomic characteristics, for example, level of income, will value the good in question in an equal manner. Preferences are, however, often heterogeneous in nature. If there is a violation of these assumptions, a random parameters logit (RPL) model may be preferred (Hensher et al., 2005). A generalised version of the RPL choice model is (Louviere et al., 2000):

$$P(j|\mu_i) = \frac{\exp(\alpha_{ji} + \theta_j \mathbf{z}_i + \delta_j \mathbf{f}_{ji} + \beta_{ji} \mathbf{x}_{ji})}{\sum_{j=1}^{J} \exp(\alpha_{ji} + \theta_j \mathbf{z}_i + \delta_j \mathbf{f}_{ji} + \beta_{ji} \mathbf{x}_{ji})} \tag{5}$$

where:

α_{iq} is a fixed or random alternative specific constant (ASC) with $i = 1$, 2....,n alternatives and $q = 1$,....,n individuals; and $\alpha_i = 0$,

δ_i is a vector of non-random parameters,

β_{iq} is a parameter vector that is randomly distributed across individuals,

μ_q is a component of the β_{iq} vector,

$\mathbf{Z}_q$ is a vector of individual-specific characteristics, for example, income,

$\mathbf{F}_{iq}$ is a vector of individual-specific and alternative-specific attributes,

$\mathbf{X}_{iq}$ is a vector of individual-specific and alternative-specific attributes, and μ_q is the individual-specific random disturbance of unobserved heterogeneity.

The RPL can take on a number of different functional forms and incorporate a number of assumptions. The most popular assumptions are normal, triangular, uniform and log-normal distributions (Bhat, 2000; Bhat, 2001). It can be difficult to determine which variables to distribute and which distributions to choose. Some applications only randomise the cost variable (Layton, 2000), whereas others randomise all non-price variables and leave cost as non-random (Anderson, 2003). The latter choice is favoured for two reasons. Firstly, the distribution of the marginal WTP for an attribute is simply the distribution of that attribute's parameter estimate, and secondly, it allows the cost variable to be restricted to be non-positive for all individuals (Carlsson et al., 2003).

6.1 Choice experiment design

The first step in the development of a discrete CE is the identification of the attributes of interest and the specification of levels for each attribute chosen (Ryan et al., 2001; Hensher et al., 2005; Yacob and Shuib, 2009). In order to identify the attributes of interest, informal interviews were conducted with members of the SFBRA, the Kromme River Trust, and the Kromme River Joint River Forum. They were asked to list their concerns with regards to the recreational use of the estuary, and rank them in order of importance. This information, together with that provided by estuarine experts, led to the development of a pilot questionnaire. The four attributes defined included three qualitative attributes relating to the effects of different management options in relation to the quality of estuarine services and the estuarine environment, and one quantitative attribute which specified the cost/price of the option. Importantly, one of the attributes identified as critical was the navigability of the estuary (Table 1).

Focus group discussions led the researchers to classify each of the three non-monetary attributes into two different levels. These qualitative attributes were set in order to assess the change in the level of welfare associated with the choice of one option over the other. The cost variable was expressed by four different Rand values, anchored by the existing boat license fee of R169 per annum (2010/2011). A '*status quo*' or '*no change*' option was not included in this study, as it can lead to '*status quo*' bias and the need to increase sample size (Bateman et al., 2002).

The written description of the monetary attribute, or cost variable, was:

"It is assumed that the cost of providing these recreational use alternatives is ***partly*** *covered by the Kromme River Estuary's boat license holders. We ask you to imagine that all boat license holders will contribute equally by means of a fixed annual sum added to the existing boat license structure, and this annual sum will then be directed back to the Kromme River Estuary. This annual sum can take four different values, namely R169 (boat license payment for 2010/2011 year), R254, R338 and R676."*

A full factorial design (2x2x2x4 = 32) was generated using SPSS, yielding 32 different treatment combinations or alternatives. These alternatives were randomly allocated to 32 different questionnaires containing four choice sets each. For each choice set, the respondent had to choose between two alternatives or scenarios, each including a cost price (license fee). An example of a choice set is provided in Table 2.

The development of the questionnaire followed the design steps proposed by Hasler et al., (2005). These steps include (1) the collecting of introductory information from the respondent through the use of an introductory section, (2) the setting out of the CE with relevant descriptions of the attributes and levels, (3) the provision of follow-up questions, which allow for reliability and validity checks, and (3) the collection of socio-demographic information from the respondent.

6.2 Sample design

Sample design entailed four distinct steps: selecting the target (sample) population, determining who to sample (the sample frame), determining the appropriate sample size and choosing the method of respondent selection and elicitation of response technique. The target population included all individuals who, at the time of the survey, made use of the Kromme River Estuary for recreational purposes, as well as those individuals who had high potential to make use of the estuary for recreational purposes in the future. A sample frame for the estuary could not be compiled, as the population does not reveal itself until it visits the estuary. Given the inability to adequately define a sample frame, the sample select process was followed using underlying knowledge of the specific target population. This form of non-list sampling can be used when the target population refers to visitors to a beach, or in this case, an estuary (Bateman et al., 2002; Dillman et al., 2009). Time of survey is very important when attempting to sample the recreational users of an estuary, as they ideally need to be sampled when they are actually engaged in carrying out the recreational activities. This requires on-site sampling, and is known as an intercept survey (Bateman et al., 2002). An intercept survey selection strategy was adopted where every n^{th} recreational user to the estuary was approached for participation, and the overall number guided by the proportions thought to make up the true underlying population of users.

In the context of the CE, sample size is often determined through the use of both probabilistic and non-probabilistic sampling techniques, known as 'rule of thumb' approaches (Hensher et al., 2005). Probabilistic sample size approaches are very often abandoned in favour of 'rule of thumb' approaches due to practical considerations – budget and time constraints often supersede theoretical preference (Hensher et al., 2005). A 'rule of thumb' approach was used to calculate the minimum sample size i.e. a sample of 50 respondents is acceptable if each respondent faces 16 choice sets (Bennett and Adamowicz, 2001). This translates into a sample of 200 respondents if they are being offered 4 choice sets each. In total, 244 completed questionnaires were collected. The personal interview method was adopted as it affords the interviewer the best opportunity to encourage the respondents to cooperate with the survey. The interviewer is also given an opportunity to explain complex information and valuation scenarios to the respondent – which is very important in the CE setting (Mitchell and Carson, 1989). The questionnaire was administered on-site by seven trained interviewers during December, 2010.

7 Results

7.1 Sample features

The only socio-economic information available for the Kromme River Estuary was that gathered by Forbes (1998) and, more recently, by Sale (2007). Both the Forbes (1998) and Sale (2007) studies captured data on the recreational users of the Kromme River Estuary. Comparison with the Forbes (1998) data was possible for residential location and number of days visited, whilst the Sale (2007) study provided information about the average recreational user's education and income per annum. This study captured a similar composition of resident/visitor information with respect to the selected socio-economic characteristics. The results are summarised as follows:

- The majority (59%) of visitors travelled from areas more than 50km away from the estuary.
- The majority (64%) of recreational users surveyed were over the age of 35.
- The majority (65%) of recreational users surveyed were male.
- The average gross annual income for the sample was R447 000.
- Of the respondents sampled, 29% had a matric qualification with university exemption.
- All occupational categories are well represented in the sample of respondents, with the exception of plant and machinery operators/assemblers (0%), agricultural workers (0.4%), and elementary occupations (0%).

7.2 Choice model specification

Three different choice model specifications were estimated as part of the Kromme River Estuary CE: a CL Model, HEV model and an RPL model. The LIMDEP NLOGIT Version 4.0 statistical programme was used to make all the estimations. The three models estimated showed the importance of choice set attributes in explaining respondents' choices across the two different options: option A and option B[3]. For the two option choice sets, with four attributes, the

[3] ASCs were not included in the models for two reasons: the alternatives were unlabelled and a status quo alternative was not included in the choice sets.

utility functions were expressed as follows:

$$Option\ A : V_A = \beta_1\ Navigability + \beta_2\ Congestion + \beta_3\ Jetskiing + \beta_4\ Cost$$

$$Option\ B : V_B = \beta_1\ Navigability + \beta_2\ Congestion + \beta_3\ Jetskiing + \beta_4\ Cost$$

The model provides an estimate of the effect of a change in any of these attributes on the probability that one of these options will be chosen. All model estimates are provided in TABLE 3. All the coefficients[4] in these models have the correct signs[5], a priori, and three of the four coefficients are significantly different from zero at the 99% confidence level. The probability that an alternative would be chosen was reduced: the lower the level of navigability; the higher the amount of boat congestion; the higher the amount of jet skiing activity; and the higher the environmental quality levy.

The navigability coefficient of the CL model can be interpreted by estimating its odds ratio, i.e. by calculating the antilog[6] of the coefficient. An increase in the level of navigability will result in a 4.7% increase in the probability of a respondent choosing this option.

In order to address a potential source of bias, i.e. non-identical distributed random components and constant variances, an HEV model was also estimated (see TABLE 3). Like the CL model, the results of this model indicate that all the coefficients have the correct signs a priori. Three of the four coefficients are significantly different from zero at the 99% confidence level: 'Navigability', 'Congestion' and 'Cost'. The odds ratio calculation for the navigability coefficient in the HEV model indicated that an increase in the level of navigability will result in a 4.3% increase in the probability of a respondent choosing this option.

The RPL model addresses another potential source of bias, i.e. heterogeneity of preferences amongst respondents. TABLE 3 reports the RPL results for two models. In the first RPL model, two of the recreational attributes were treated as random variables; 'Navigability' and 'Congestion.' The 'Jet Skiing' and 'Cost' variables were specified as fixed.[7] The cost variable was specified as fixed, and non-randomly distributed, because the distribution of the marginal WTP for an attribute is simply the distribution of that attribute's coefficient. In other words, preferences relating to the use of jet skis/wet bikes and the cost were assumed to be homogenous, whereas the two variables assumed to be random represent

[4] A variable coefficient estimated by a discrete choice model reveals the relationship between the decision makers' choice and the variable of interest. A positive (negative) coefficient shows that decision makers prefer a quantitative increase (decrease) or a qualitative improvement (deterioration) of the attribute.

[5] The sign of a coefficient is used to test whether the relationship between variables correspond to a priori expectations.

[6] Finding the antilog entails calculating the value of 10 to the power of the coefficient's value.

[7] The 'Jet Skiing' variable was not made a random variable because during an initial estimation where it was specified as a random parameter its standard deviation coefficient was statistically insignificant.

heterogeneous preferences. A normal distribution[8] was initially selected for both the random parameters specified.

The results of the first RPL model indicate that all the coefficients have the correct signs a priori. Two of the four coefficients are significantly different from zero at the 99% confidence level: 'Navigability', and 'Cost.' The odds ratio calculation for the navigability coefficient indicated that an increase in the level of navigability will result in an 89.3% increase in the probability of a respondent choosing this option.

In the second RPL model, a uniform distribution was selected for both the random parameters specified. All coefficients have the correct signs a priori. However, only the 'Cost' coefficient is significantly different from zero at the 99% confidence level. The 'Navigability' and 'Congestion' coefficients are significant at the 95% confidence level.

Allowing preferences for two recreational attributes ('Navigability' and 'Congestion') to vary across respondents shows that there is unexplained heterogeneity in respondent preferences. Both the standard deviation coefficients are statistically significant, indicating statistically dissimilar preferences for these attributes across respondents. In other words, the random variables specified in both RPL models indicate that respondents are divided on their views regarding the need to increase estuary navigability, and reduce boat congestion.

The RPL models indicate the presence of unobserved heterogeneity. However, they fail to explain the sources of the heterogeneity (Adamowicz and Boxall, 2001). One way to detect and account for unobserved heterogeneity is to include interactions of various respondent-specific characteristics with choice specific attributes in the utility function. This enables the RPL model to elicit preference variation, whether it is from unconditional taste heterogeneity (random) or conditional heterogeneity (individual characteristics). This can improve model fit (Revelt and Train, 1998).

In a model given in APPENDIX A, a series of respondent-specific control variables were included in the RPL specification.[9] These variables were: resident type, respondent type, gender, age, where the respondent lives, occupation, income and education. The inclusion of these variables did not improve the estimates. In this case, complete reliance was placed on the fixed mean and standard deviation of the parameter estimates, with the latter representing all sources of preference heterogeneity around the mean (Hensher et al., 2005).

7.3 Estimation of WTP values

Implicit prices are calculated by determining the marginal rates of substitution between the attributes, using the coefficient for cost as the "numeraire" (Hanemann, 1984). The ratios of the attribute in question to the cost coefficient can

[8] Other options include a uniform distribution, a triangular distribution, and a log-normal distribution (Hensher et al., 2005).

[9] These were specified in LIMDEP NLOGIT Version 4.0 as "Heterogeneity around the mean" variables. During estimation, these variables were interacted with the two random variables selected, namely Navigability and Congestion.

be interpreted as the marginal WTP for a change in each of the attribute values (Hanemann, 1984). More specifically, the marginal WTP value represents a change from one attribute level to another. In the case of the Kromme River Estuary, the marginal WTP values represent: a change from the current level of navigability to a pre-settlement level, a change from seeing and hearing few boats to seeing and hearing many boats, and a change from no jet ski or wet bike access to the potential use of jet skis and wet bikes on the estuary. Table 4 reports the implicit prices, or marginal WTP, for each of the Kromme River Estuary's recreational attributes estimated using the Delta method (Wald procedure)[10] in LIMDEP NLOGIT Version 4.0 (Greene, 2007). For comparisons, estimates were calculated using all four models.

The differences in the WTP estimates among the four models are not particularly large, except for the WTP figures reported for the second RPL model estimated. Confidence intervals for the CL and both RPL models are overlapping for all attributes however the CL model shows a narrower range.

8 Discussion and recommendations

The level of navigability on the Kromme River Estuary is a negative function of the level of estuary sedimentation, inter alia. Two management options to improve navigability are: increasing freshwater inflows and dredging the main estuary channel. If the total mean annual run-off (105.5 million m^3 per annum) was made available to the estuary it probably would be navigable at any tide. This amount of run-off could possibly restore navigability to pre-settlement levels.

However, this option is unattractive because the demand value for upstream abstraction is higher than it is for the freshwater that flows into the estuary. The water abstracted is used mainly for domestic and agricultural consumption. Two big storage dams located on the Kromme River are a physical testimony to this value. Improving navigability through dredging, on the other hand, may be a much lower cost option.

A marginal WTP value of freshwater inflows was derived from the demand response to improving the level of navigability from its current state to a pre-settlement one and may be calculated from the results of the choice experiment reported above. The marginal WTP value was estimated to be R437 per household per annum. Like the Sale (2007) study, the minimum navigability improvement value may be estimated by the product of the marginal WTP and the number of registered boat owners[11] for the Kromme River Estuary over the 2009/2010 period: (R437 x 1 100 = R480 700); more than the R300 000 we estimated the required dredging cost would be. Notwithstanding the low cost

[10] This procedure automates the process of estimating standard errors for non-linear functions, such as marginal rates of substitution (Suh, 2001).

[11] During the 2009/2010 year the number of motorised water craft registered for use on the Kromme River Estuary was 1 100 boats. This number does not include those that obtained temporary registration for water craft usage on the estuary during peak periods.

of dredging, environmental damage costs, such as habitat lost, still need to be investigated. If these costs are high, then the total cost of dredging may become prohibitively expensive.

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TABLE 1
Estuary management attributes and levels used in the CE

Indicator/attribute	Levels	Description of levels
Level of estuary navigability	Ideal navigability	The estuary is completely navigable at any tide
	Current navigability	Parts of the estuary are not navigable at low tide. At mid to high tide, it is navigable only with detailed knowledge of fluctuating channels
Boat congestion	Hear and see few boats	The recreational user sees and hears a few boats
	Hear and see many boats	The recreational user sees and hears many boats
Potential use of jet skis/wet bikes	Unbanned, with enforced regulation	Let jet skis and wet bikes use the estuary, but in a regulated manner with very strict law enforcement
	Banned	Keep the ban on jet skis and wet bikes in place

TABLE 2
Example of a choice set

Attribute	**Option A**	**Option B**
Level of estuary navigability	**Ideal navigability**	**Current navigability**
Boat congestion	**Hear and see few boats**	**Hear and see few boats**
Potential use of jet skis and wet bikes	**Unbanned, with enforced regulation**	**Banned**
Cost to you(R)	**R169**	**R338**
I would choose (TICK ONE BOX ONLY):	√	□

TABLE 3
Estimation results of the CE

Variables	**CL**		**HEV**		**RPL Model 1**[2]		**RPL Model 2**[3]	
	Coefficient	**Std Error**	**Coefficient**	**Std Error**	**Coefficient**	**Std Error**	**Coefficient**	**Std Error**
Navigability	.672167**	.096057	.632440**	.09912	1.950906**	.722367	2.383288*	.965053
Congestion	-.467298**	.097580	-.424775**	.09849	-1.608222*	.693198	-1.984012*	.864568
Jet Skiing[1]	-.053177	.097113	-.044222	.08477	.122747	.182631	.1552595	.185983
Cost[1]	-.001539**	.000252	-.001405**	.00026	-.003332**	.000627	-.0034440**	.000616
	Standard Deviation of Random Parameters							
Navigability					3.356599*	1.556617	6.310501*	2.677684
Congestion					5.288879*	2.176638	9.526799*	3.695197
No. of Respondents	244		244		244		244	
No. of Choice Sets	976		976		976		976	
Pseudo R^2	.081		.085		.094		.091	

Notes: **indicates that parameter is statistically significant at the 5% level*
*** indicates significance at the 1% level*

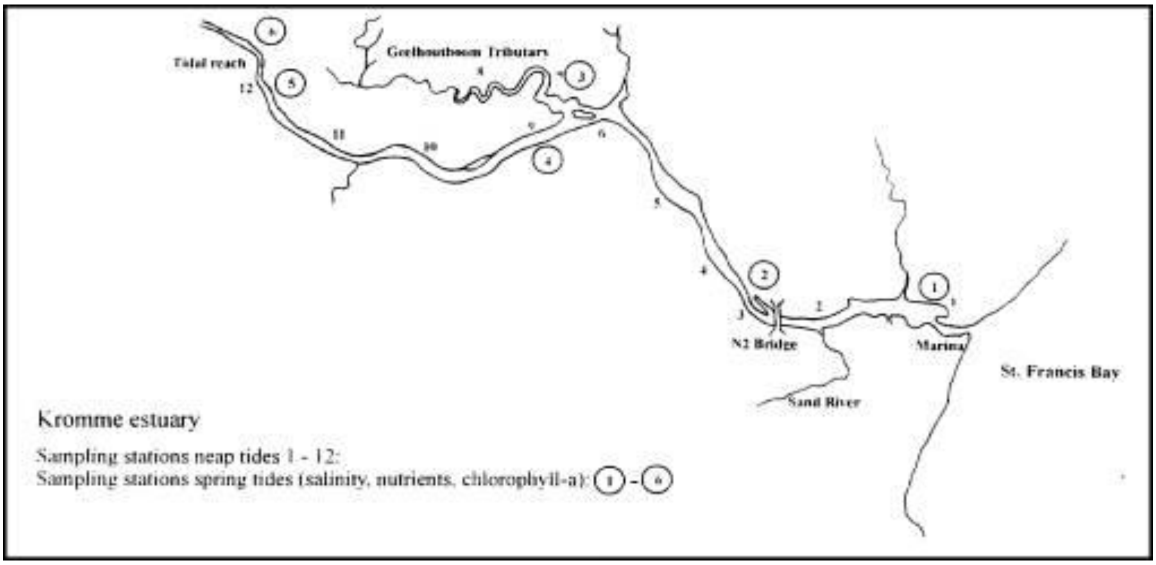
1. *Jet skiing and Cost were specified as non-random parameters in both the RPL models.*
2. *The random parameters were normally distributed in Model 1.*
3. *The random parameters were uniformly distributed in Model 2.*

TABLE 4
Marginal WTP (MWTP) for attributes (Rands)* and 95% confidence intervals (CI)**

Attributes	CL (Rands/annum)	HEV*** (Rands/annum)	RPL Model 1 (Rands/annum)	RPL Model 2 (Rands/annum)
Navigability	437 (256; 617)	450	586 (231; 940)	692 (211; 1173)
Congestion	-304 (-463; -144)	-302	-483 (-841; -124)	-576 (-1023; -129)

**Please note that implicit prices were not calculated for the Jet Skiing attribute as the estimated coefficients were statistically insignificant in all four models (see Table 3 above).*
***Confidence intervals in parentheses.*
**** Confidence intervals not calculated for HEV due to the presence of fixed parameters.*

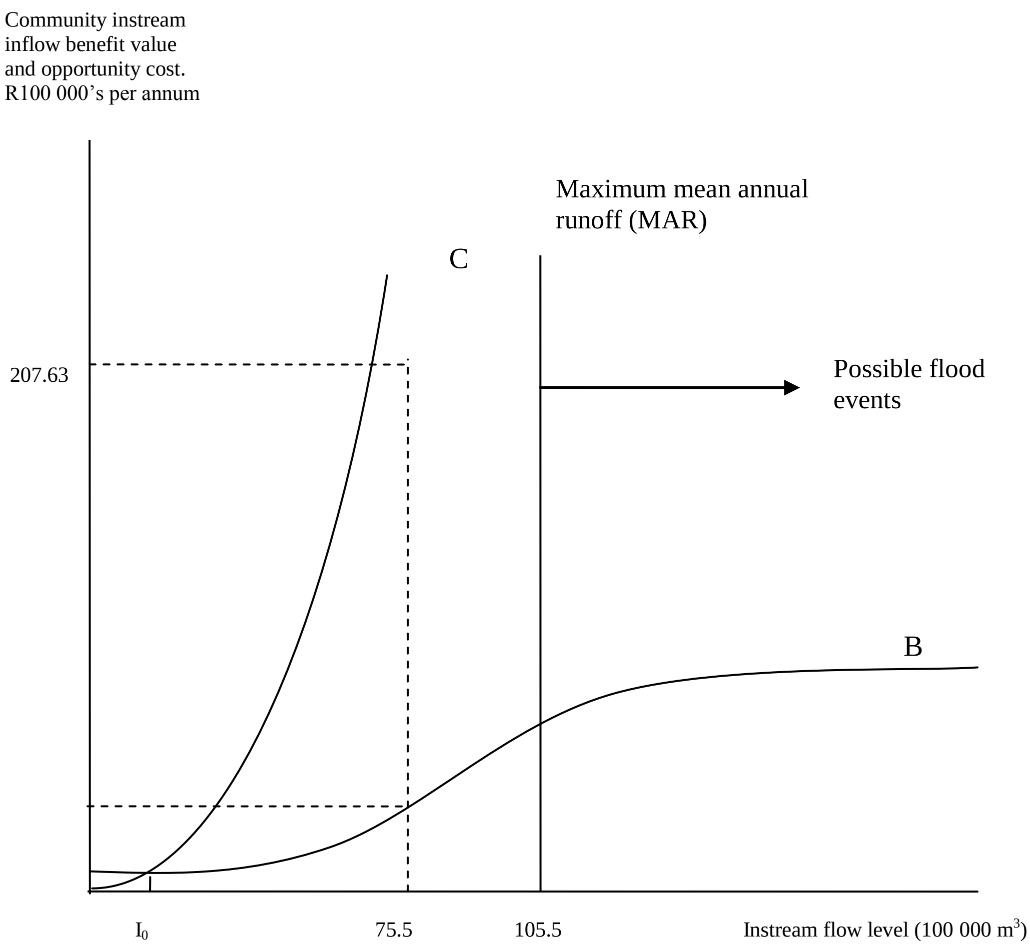
Figure 1
The Kromme River Estuary



Source: Whitfield et al., (2011)

Figure 2

Costs and benefits of instream flow protection for the Kromme River Estuary



APPENDIX A: RANDOM PARAMETERS MODEL – ATTEMPTS TO EXPLAIN HETEROGENEITY

DEPENDENT VARIABLE: CHOICE

INDEPENDENT VARIABLES:
NAVIGABILITY (RANDOM: UNIFORM DISTRIBUTION)
CONGEST (RANDOM: UNIFORM DISTRIBUTION),
JETSKIS (NON-RANDOM)
COST (NON-RANDOM)

INDEPENDENT VARIABLES INTERACTED WITH:
RESIDENT TYPE (LIV), GENDER (GEN), AGE, HOMETOWN (LIV1)
OCCUPATION (OCC), INCOME (INC), EDUCATION (EDU)

ESTIMATION RESULTS

Variable	Coefficient	Standard Error	b/St Er	P[|Z| > z]
Random parameters in utility functions				
NAVIG	3.97614137	2.57397202	1.545	.1224
CONGEST	.32451470	2.78921517	.116	.9074
Non-random parameters in utility functions				
USEJET	.15652081	.18818384	.832	.4056
COST	-.00341745	.00061790	-5.531	.0000
Heterogeneity in mean, Parameter: Variable				
NAVI: RES	.27576904	.39603677	.696	.4862
NAVI: GEN	.00044965	.70857616	.001	.9995
NAVI: AGE	-.01091321	.02660452	-.410	.6817
NAVI: LIV	-.01041100	.06513371	-.160	.8730
NAVI: OCC	.15158140	.14208494	1.067	.2860
NAVI: INC	.14151045	.10802049	1.310	.1902
NAVI: EDU	-.51325632	.34196534	-1.501	.1334
NAVI: LIV1	-.08180610	.20451836	-.400	.6892
CONG: RES	.05468433	.53522029	.102	.9186
CONG: GEN	.37689383	.88233535	.427	.6693
CONG: AGE	-.02682220	.03324031	-.807	.4197
CONG: LIV	-.06381171	.09322796	-.684	.4937
CONG: OCC	-.21929895	.18236255	-1.203	.2292
CONG: INC	.02478229	.11753002	.211	.8330
CONG: EDU	.01895687	.39192311	.048	.9614
CONG: LIV1	-.03534087	.25030421	-.141	.8877
Derived standard deviations of parameter distributions				
UsNAVIG	6.21427085	2.84470406	2.185	.0289
UsCONGES	9.39370944	3.84989387	2.440	.0147