An Examination of Additively Separable Willingness-To-Pay for Environmental Attributes: Evidence from a Pork Experiment

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May 15, 2005

Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Providence, Rhode Island, July 24-27, 2005

Abstract

This paper examines what is the best method for pork producers to market pork products with environmental attributes. The objective is to examine evidence of whether it is beneficial for pork producers to incorporate multiple environmental attributes into a single product or sell multiple products with a single environmental attribute.

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Introduction

Since the early 1980's, there has been a structural change in the hog industry where individual pork producers have expanded their operations by shifting to larger and larger production facilities in more confined spaces to capture economies of size. With this expansion, there have been rising concerns regarding the effect of pork production on the environment especially with manure management (McBride and Key). These issues can be segmented into two broad areas: managing air quality issues which stem from the by-product of odor from production and managing water quality by storing and utilizing manure in a way that will not contaminate surface and ground water.

In 2003, the United States Environmental Protection Agency (EPA) under the authority of the Clean Water Act released a new set of regulations for non-point source pollution concerning concentrated animal feeding operations (CAFO). These regulations affect pork producers if their operation meets the definition of being an animal feeding operation (AFO) and produces at least 2,500 swine over fifty-five pounds or 10,000 swine under fifty-five pounds.[2] Examining the concentration ratio of pork-to-farms in the top three producing states shows that Iowa, North Carolina, and Minnesota may be heavily affected by the EPA regulations on CAFO's. This is especially true for North Carolina producers that have an average of 18,000 hogs per farm.

This paper examines how consumer's value environmental attributes embedded in the pork products they consume. It focuses on examining what is the best method for

[2] The definition of an AFO is a "lot or facility (other than an aquatic animal production facility) where animals (other than aquatic animals) have been, are, or will be stabled or confined and fed or maintained for a total of 45 days or more in any 12-month period AND where crops, vegetation, forage growth, or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility." (*Managing Manure*, Section 1, pg. 3)

pork producers to market pork products with environmental attributes from the marketing standpoint. The primary objective of this paper is to provide evidence whether it is beneficial for pork producers to incorporate multiple environmental attributes into a single product or sell multiple products with a single environmental attribute.

This paper is split into the following sections. Section two gives a brief state of affairs for the pork industry. In section three, conditions are discussed for a market solution to environmental production externalities. Section four of the paper examines Lancaster model of utility maximization based on characteristics and compares it to the standard utility maximization problem. Section five outlines the experiment that was used to collect the data. This experiment was designed to allow for the direct calculation of the value of the characteristics embedded in the products, specifically environmental attributed embedded in pork products. Section six explains the methodology for examining consumer's willingness-to-pay for pork products with environmental attributes, while the results and implications are presented in section seven. Finally, section eight gives summary and conclusions of this research.

The Current State of the Pork Industry

According to the 2002 USDA Agricultural Census, the pork industry sold approximately 185 million pigs and hogs with a combined sales value of $12.4 billion. The states of Iowa, North Carolina, and Minnesota accounted for over half of this production. At approximately $3.1 billion in sales, 11,275 Iowa farms produced 41.2 million pigs and hogs, making Iowa the top producer of pork in the country with respect to sales. North Carolina ranked second behind Iowa with $2.2 billion in sales and 42

million hogs produced. North Carolina managed to produce this quantity of hogs on 2,300 farms. Minnesota is the third largest producer in the country with the production of 18.6 million pigs and hogs and $1.4 billion in sales, which were produced on 6,390 farms. When examining the average amount of pigs and hogs produced in each of these states, North Carolina had the highest concentration with an average of over 18,000 hogs per farm. Iowa's average number of hogs and pigs per farm was over 3,600, while Minnesota produced approximately 2900 hogs per farm.[3]

Due to the competitive nature of the pork industry, there tends to be no market incentive for producers to produce pork with any consideration of environmental attributes because producers must produce at the lowest cost to stay economically competitive. An argument can be made that by producing pork that mitigates the environmental effects from production that the production cost will decline and make the producer more competitive. If this is true, then a competitive market would ensure that the cost saving management practices and technologies have already been adopted. Since the EPA is adopting further rules on large CAFO's, it can be inferred that the socially optimal amount of environmental protection from CAFO's has not yet been achieved. This leaves two broad avenues for handling production externalities related to manure management in the industry to obtain the socially desired level—a regulatory solution or a market solution.

[3] If all the states in the US are examined for their pork to farm concentration ratio, North Carolina, Iowa, and Minnesota are in the top five with the ranking of first, third, and fifth respectively. Utah has the second highest concentration at approximately 3,900 hogs and pigs per farm, while Oklahoma ranks fourth at 3,220.

The first way to handle environmental externalities from pork production is by the government directly regulating producers with or without the blessing of the producers.[4] This is the current method that the EPA is using to induce large pork producers to mitigate their effect on the environment from their production. According to Stavins, using these types of command-and-control policies can have different cost effects on producers and tend to be inefficient ways at handling externalities (2000).

The second way of handling production externalities is for pork producers to produce hogs with environmental attributes and market those attributes to consumers.[5] In the document, *Managing Manure*, EPA outlines information on production technologies and management practices that could lead to greater production efficiency of CAFO's that would further protect water quality affected by these facilities. For this to be a viable solution there must be demand for pork products with environmental attributes.

Conditions for a Market Solution to Production Externalities

A necessary condition for the viability of a market solution, i.e., niche marketing pork products with environmental attributes, is for producers to be able to cover all the associated additional costs required to produce pork with environmental attributes. If this is possible, the producer needs to identify the best way to market the environmental attributes embedded in the product. This implies that the producer needs to understand

[4] An industry may request the government to enforce regulations that the industry has developed for many reasons. One major reason is to mitigate any future regulations that government may impose with little or no input from the industry.

[5] Throughout this paper, pork with embedded environmental attributes is discussed. Pork with embedded environmental attributes is defined as pork that has been produced in a production system that has less of an impact to the environment in comparison to what would be termed the typical system. This does not imply that pork production in general is harmful to the environment; rather, it means that the pork discussed in this paper was produced in a way that attempts to mitigate effects on the environment due to production.

how the consumer values pork with embedded environmental attributes. Does the consumer prefer a product that has a bundle of environmental attributes, or is it better to produce pork with a single environmental attribute? The producer is primarily interested in whether the cost of adopting a certain production technology to attain greater environmental sustainability will be compensated by increased revenue from producing a product with environmental attributes.

It is not a priori obvious whether consumers would prefer to purchase one good with multiple attributes, or multiple goods with single level attributes. Neither is it obvious that consumers would want pork products with embedded environmental attributes. Since pork production is primarily produced far away from the typical consumer of pork products, the consumer does not usually get any direct benefits from purchasing pork that has environmental characteristics. Even though consumers may not receive a direct benefit from consuming pork with environmental attributes, they may receive what Andreoni termed a warm-glow effect from giving (1990).

If consumers value products with environmental characteristics, then what mix of environmental attributes would they prefer? By bundling multiple environmental attributes into a single product, the consumer is forced to potentially purchase a product that has some characteristics that are not desirable or not bundled in the correct proportions. On the other hand, if you sell goods that have only a single level attribute, the consumer would be forced to purchase multiple products if they wanted to consume the multiple environmental attributes.

Modeling the Valuation of Characteristics

The standard consumer maximization problem posits that consumers attempt to maximize their utility given a budget constraint. Within this theory the consumer derives utility from the consumption of goods which have a bundle of characteristics. Utility is derived from the direct consumption of goods where the focus is on the good itself rather than the characteristics.

Lancaster (1966) points out that one of the biggest drawbacks to examining consumer behavior in the standard way is that it becomes difficult theoretically to evaluate new commodities that consumers have no experience with. The key underlying difference between standard utility theory and Lancaster's view of utility theory is that Lancaster believes utility is derived from characteristics embedded in a product rather than the product itself which is a bundle of characteristics. Lancaster views the product as a vessel that delivers attributes.

Lancaster bases his model on three primary assumptions. The first assumption is that the good is a mechanism to carry attributes, where attributes provide the direct utility to the person. He next assumes that most goods possess multiple attributes, and each attribute is shared in multiple goods. His third assumption is that goods consumed together can provide different attributes than goods consumed separately. This allows for goods when consumed together to provide more utility than if they were consumed separately.

A typical consumer in Lancaster's model can be represented by the following choice problem:

$$\underset{\mathbf{x}}{Max} \quad U(\mathbf{C})$$
$$subject\ to: \mathbf{px} \leq M$$
$$\mathbf{C} = \mathbf{f(x)}$$

The nx1 vector **C** represents the characteristics that the consumer derives utility from, where the utility function U(•) represents a continuous twice differentiable function mapping characteristics to utility which is assumed to have the standard convexity properties. Income is represented by M, while the 1xq price vector **p** represents the prices of the qx1 vector of commodities **x** the consumer can purchase. The **f(•)** function maps the attributes of the bundles consumed into characteristic space. Both the vectors **x** and **C** are assumed to be positive.

The biggest advantage to using Lancaster's model is that it focuses on attributes of the products rather than the product itself. This motivates a hedonic approach to analyzing the price of the goods based on valuing each of the attributes in the product.

Data Collection and Methods

There have been many studies that have used experimental auctions to value product attributes. Hoffman et al. (1993) and Menkhaus et al. (1992) investigated willingness-to-pay for beef that is sold in different packaging under different information sets. Hayes et al. (1996) did various experiments to obtain consumer's willingness-to-pay for food safety attributes. Melton et al. (1996a, 1996b) studied consumer's willingness-to-pay for pork chops with different visual characteristics. Roosen et al. (1998) examined what consumers would pay for apples with reduced pesticides. Rousu et al. (2004) examined what consumers would be willing-to-pay for differing tolerance levels of genetically modified attributes embedded in canola oil, tortilla chips, and russet potatoes.

Unlike previous studies of this nature, this research focuses on examining the value of environmental attributes when they are bundled together. To facilitate this research, data were collected by using a second-priced sealed-bid auction segmented into five bidding rounds.[6] In the first three rounds of this auction, participants bid only on the physical attributes of the product, such as color and marbling, where the participants had no other information except for the previous round's bids. For the fourth round, the participants were informed of the specific environmental attributes associated with the respective products. Changes in bids would reflect the value of the respective environmental attribute. In the fifth round, the implications of the environmental attributes were further explained and the participants bid one final time.

Ten products with varying levels of environmental attributes were auctioned. Six products had a single environmental attribute, two products had two environmental attributes, one product had three environmental attributes, and one product had no identified environmental attributes. Single attribute products were examined with environmental attributes at a high level and a low level, while multiple attribute products were evaluated only at high level attributes. The attributes examined were related to air quality and water quality, where water quality attributes were segmented into surface water and ground water attributes.

The products used to elicit bids were two-pound packages of uniformly cut, boneless, 1¼ inch pork loin chops. The packages were arranged in a row and placed on

[6] Hoffman et al. (1993), Menkhaus et al. (1992), Coppinger et al. (1980), Cox et al. (1985), Shogren et al. (1994a), and List and Shogren (1999) explain the benefits and drawbacks of using a multiple-round Vickrey auction versus a single-round Vickrey auction.

ice in one of three white coolers. Each package was labeled as Package i, where i = 1,.., 10. Before the experiment began, the participants were invited up to the front of the room to visually inspect the packages of pork chops. After the participants viewed the packages, they were allowed to simultaneously bid on them for three rounds. After each round, the highest bid and the number of the highest bidder was posted. Following the third round each participant was told that one package was a "typical package" with no specific environmental attributes, while the other nine packages were assigned varying levels of environmental attributes listed in Table 1.

Three hundred twenty-nine observations were gathered from six different locations across the United States: Ames, Iowa; Iowa Falls, Iowa; Manhattan, Kansas; Raleigh, North Carolina; Burlington, Vermont; and Corvallis, Oregon. A random sample of individuals drawn from local telephone numbers from the area being studied was used to obtain participants for the study. Each experiment lasted approximately two hours at each site. The first experiment was conducted at 9:00 a.m., the second at 11:30 a.m., and the third at 2:00 p.m. To discourage collusive behavior being formed within the auction, the participants were instructed that a three dollar penalty would be assessed if they were discovered talking to other participants. Each participant was given a randomly generated number to use as his/her identity during the experiment to maintain his/her anonymity. Following Fox (1994), each participant was paid forty dollars for participating in the experiment. As done in Fox et al. (1995, 1996) and Roosen et al.

(1998), an attempt was made to control for wealth effects.[7] The method used in each experiment to control for wealth effects was a random drawing of one bidding round and one product from that selected round to be the product sold at the end of the experiment.

Econometric Model and Testing Procedure

In the spirit of Lancaster's approach to the consumer maximization problem where he focuses on product characteristics, the following regression is estimated using ordinary least squares:

$$(1) \quad Bidsr4 = \alpha_0 + \alpha_1 * Bidsr3 + \alpha_2 * LowAir + \alpha_3 * HiAir + \alpha_4 * LowGrndWat + \alpha_5 * HiGrndWat + \alpha_6 * LowSurWat + \alpha_7 * HiSurWat + \alpha_8 * HiAirGrndWat + \alpha_9 * HiAirSurWat + \alpha_{10} * HiAirGrndSurWat + e,$$

where Bidsr3 and Bidsr4 are vectors of bids for the ten products in the auction from round three and four respectively. LowAir, HiAir, LowGrndWat, HiGrndWat, LowSurWat, and HiSurWat represent vectors of dummy variables where a one denotes that the product being bid upon was a single-level attribute package that had the low or high air quality attribute, the low or high ground water quality attribute, and the low or high surface water quality attribute respectively. HiAirGrndWat and HiAirSurWat represent vectors of dummy variables for the products that contained double environmental attributes. The coefficient, HiAirGrndSurWat, represents a dummy variable vector for the product with all three high-level environmental attributes

[7] Wealth effects are when participants change their bids because they won an earlier trial (Fox et al., 1995). See Davis and Holt for a further discussion of wealth effects in experimental markets (1993).

incorporated in the product. The vector of errors is represented by e and is assumed to have the standard properties that make ordinary least squares appropriate for analysis.

The estimated coefficient α_1 can be interpreted as the change in value of the physical attributes once the environmental information has been released. This value represents how much an ex ante dollar worth of physical attributes is valued once there are products with environmental attributes on the market. If the environmental information has no effect on the value of the physical attributes, then α_1 should be equal to one. A coefficient of less than one for this value implies that the physical attributes in the product are being negatively affected by the environmental information, while a value of greater than one implies that the environmental attributes have a positive effect on the physical attributes. The coefficients for α_2 through α_{10} can be interpreted as the willingness-to-pay for the respective attribute(s) embedded in the product. It is expected that the coefficients for the low-level products should be less than the high value products. Products with multiple attributes are expected to be higher than products that have only a single environmental attribute. If the consumer values the environmental attribute(s) embedded in the product, these coefficients should be positive.

Results and Implications

Before explaining the results from the regression, it is important to examine the 3290 bids from round three to round four. In round three the average bid for the ten packages of pork chops is $4.12 with a standard deviation of 2.21, while in round four when the environmental information is released about the packages the average bid increases to $4.16 with a standard deviation of 2.30. Examining the null hypothesis that the bids

between these two rounds are equal, it is found using a paired-sample t-test that the null hypothesis cannot be rejected at the ninety-five percent confidence level ($t = 1.57$). Hence, the environmental information did not significantly affect the overall average bid. This implies that the participants did not spend significantly more when they discovered that most of the products had environmental attributes. This is a significant result because it implies that the market as a whole may not gain by producing products with environmental attributes, i.e., the pork producers will not capture more of the consumer food dollar by producing products with environmental attributes.

Table 2 presents results of estimating Equation 1 with ordinary least squares. The coefficient for Bidsr3 is estimated at eighty-seven cents which demonstrates that releasing environmental information does have an effect on the physical attributes of the pork products. For every dollar that was bid in round three when the only information the participants possessed about the products was regarding the physical attributes, eighty-seven cents of that value carried over to round four when the environmental attributes became known. This result implies that releasing environmental information about the product can have a detrimental effect to those products that only maintain physical attributes without incorporating any environmental attributes. Testing the null hypothesis that this value is equal to one using a standard t-test, it is found that this hypothesis can be rejected at the ninety-nine percent confidence interval with a p-value less than 0.01.

Examining the coefficients related to the dummy variables in Table 2 shows that all values are significantly greater than zero at the ninety-nine percent level except for the

constant and the coefficient for low-level air quality improvement. This implies that the participants in the study valued environmental attributes embedded in the products. Comparing the single attribute products to the multiple attribute products shows that the multiple attribute products received higher premiums than the products with only a single-level attribute. In general, the magnitude of the willingness-to-pay for the attributes increased when a higher level of a single attribute was present.

The only exception to the premium not having the expected magnitude for ranking purposes was for the single low and high-level attribute for ground water where the low-level attribute was valued at forty-three cents and the high-level of the attribute was valued less at forty-one cents. Upon a closer examination of the bid data for the low-level product, it was found that the average bid for the low-level product was less than any other product in round three by at least thirteen cents. Hence, the magnitude of this premium may represent two affects—an attribute effect and a parity effect. The attribute effect would be the amount of money that the participant is willing-to-pay for the environmental attribute. The parity effect is the part of the premium that is paid to bring the physical attributes of the product up to parity with others.

Table 3 presents the results of examining whether the value of the environmental attributes in multiple products is equal to the value of the premium given for a combination of attributes combined in one product. It appears at first glance that in all cases the multiple attributes from the purchase of a single product is greater than the value of the attributes when the participant had to purchase the equivalent attributes from multiple packages. For example, the premiums for the three single-level attribute

products add up to $1.33, whereas the product with the three equivalent attributes combined into one product had a premium of $1.46. Testing the restriction that the coefficient for the multiple attribute product is equal to the addition of the coefficients from the multiple package shows that at the ninety-five percent level of confidence that none of the null hypotheses can be rejected. Hence, the premiums for the attributes appear to be additively separable. This implies that from the consumer standpoint, there is nothing significantly gained by packaging multiple attributes into one product.

While the premiums above appear to be additively separable, does this mean that it does not matter whether a producer produces a product with single attributes or a product with multiple environmental attributes? Before information about environmental attributes was released to the participants, it was found that the average bid for the packages was $4.12. This leaves open the question of which producers would benefit from a market that had pork products with embedded environmental products. Using the results from Table 2 and Equation 1, each product can be examined in an ex post fashion to see what the expected price would be for each package containing embedded environmental attributes. This information is presented in Table 4. If the expected price is greater than the average bid from round three, i.e., $4.12, then the producer would be better off producing a package with that combination and/or level of environmental attributes.[8] On the other hand, if the value is less than $4.12, the producer would be

[8] This statement is only valid from the standpoint that the producer would be compensated for the loss of the environmental attributes. This is not considering whether the premium gained compensates for the cost of producing a product with the particular embedded environmental attributes.

better-off if there was a market with no pork products that have embedded environmental attributes.

From Table 4, it can be seen that the expected price the participants would be willing to pay for a product that has a single level attribute, in general, would not be more than if there were no products with environmental attributes. This implies that the producers of products with single-level attributes would be worse-off. The producers that would gain ex post in being in a market that has environmental attributes would be those that produced products with double or triple attributes embedded in the product. The product with a high-level impact reduction in surface water appears to be on the margin whether this product would be beneficial to the producer. These findings imply that if a pork producer is in a market where pork products with environmental attributes exist, then that producer should produce hogs that have multiple attributes.

Summary and Conclusions

This paper examines from the consumer's standpoint whether it would be better for producers to sell pork products with embedded environmental attributes separately or in combination. To accomplish this task, a consumer experiment utilizing a multi-product second-price auction with five bidding rounds was presented that would allow for collecting data to examine this issue. In the first three rounds of the auction, the participants bid on physical characteristics of the pork products. In round four of the bidding, consumers were made aware of the environmental attributes embedded in each of the ten products being auctioned. From this information, ordinary least squares was

used to estimate the value of each environmental attribute embedded in a single product, as well as, the value of multiple environmental attributes combined into one product.

There are three major findings of this paper. First, it was discovered that pork producers, in general, do not gain if a subset of producers produce products with environmental attributes. The average bid from round three when the environmental attributes were unknown to the participants was only four cents less than the average bid in round four when participants were made aware of the environmental attributes embedded in the products. This did not represent a significance difference in the bids. The second major finding was that when information about environmental attributes embedded in pork products are released, then the producer should expect that the consumer will value the physical attributes of the product less. For each dollar that was spent on the physical attributes in round three, only eighty-seven cents was estimated to be spent in round four for those same attributes. Finally, it appears that the premiums for single-level attributes can be additively combined to make-up the premium for the multiple attribute product. This implies that the consumer is not significantly gaining from a product that has multiple attributes combined.

Overall, it appears from this study that the pork industry will not gain as a whole if pork is sold with environmental attributes. If the industry moves towards selling products that explicitly purport to have environmental attributes, then it would be best for producers to sell a product with multiple attributes in order to be better off than they were

before environmental products were released.[9] This is because the physical attributes of the pork products get devalued by approximately thirteen percent.

There are many avenues that can be followed for continuing research regarding embedding environmental attributes in products. Since this study used pork products as the basis of comparison for pork products with environmental attributes, it would be useful to know what would happen if a different product was used as a comparison, such as chicken or beef. It is conjectured that if a different product is used as the basis for environmental improvement, then the consumer would significantly shift part of her consumer dollar away from the industry of comparison to the industry purporting products with environmental attributes. A further extension to this is to examine what the premium structure would look like if you sold competing products from two different industries which both had products with and without embedded environmental attributes.

Another avenue of research would be to examine what would happen to bids if the participants were required to purchase a combination of single-level attribute products that would make them as well off as having products with multiple attributes. It is unknown whether the consumer would discount the value of the environmental attributes if she had to purchase multiple products. The experiments in this paper had the properties of a single unit auction. Hence, the consumer was not affected by having to purchase multiple units to obtain an equivalent amount of attributes contained in one product.

[9] This assumes that the additional cost of producing pork with the respective environmental attributes is less than the premium the consumer is willing to pay for those attributes.

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Table 1: Environmental Attributes for the Packages of Pork Loin Chops

Pork Chop Environmental Attributes (Level of Improvement over the Typical)	Package Labeling for Experiment
No Specific Attributes (Typical Product)	Package 1
Odor 30-40%	Package 2
Odor 80-90%	Package 3
Ground water 15-25%	Package 4
Ground water 40-50%	Package 5
Surface Water 15-25%	Package 6
Surface Water 40-50%	Package 7
Odor 80-90%/Ground Water 40-50%	Package 8
Odor 80-90%/Surface Water 40-50%	Package 9
Odor 80-90%/Ground Water 40-50%/Surface Water 40-50%	Package 10

Table 2: Explanatory Variables and Estimated Coefficients

Variable	Coefficient	Standard Error	T-Value
Intercept	0.04	0.08	0.46
BidRnd3	0.87	0.01	90.96*
LowAir	0.14	0.09	1.52
HiAir	0.37	0.09	4.00*
LowGrndWat	0.43	0.09	4.58*
HiGrndWat	0.41	0.09	4.44*
LowSurWat	0.36	0.09	3.79*
HiSurWat	0.55	0.09	5.81*
HiAirGrndWat	0.85	0.09	9.00*
HiAirSurWat	0.94	0.09	9.94*
HiAirGrndSurWat	1.46	0.09	15.55*
N = 3290	R^2=0.72	F-Value = 870.02	

*Indicates significance at the 99% level.

Table 3: Hypothesis Tests for Additively Separable Premiums

Null Hypothesis*	Summation of Single Package Premiums	Premium for Multiple Attribute Product	F-Value	Prob > F
HiAir + HiGrndWat + HiSurWat = HiAirGrndSurWat	$1.33	$1.46	0.42	0.52
HiGrndWat + HiAirSurWat = HiAirGrndSurWat	$1.35	$1.46	0.69	0.41
HiSurWat + HiAirGrndWat = HiAirGrndSurWat	$1.40	$1.46	0.27	0.60
HiAir + HiSurWat = HiAirSurWat	$0.92	$0.94	0.01	0.93
HiAir + HiGrndWat = HiAirGrndWat	$0.78	$0.85	0.16	0.69

*The null hypothesis is rejected if Prob > F is less than or equal to 0.05

Table 4: Bids Evaluated at the Average Bid of $4.16 for the Estimated Equation 1 with the Particular Environmental Attribute

Package Containing Given Environmental Attribute	Expected Value of Package in an Environment with Environmental Attributes
Odor 30-40%	$3.74
Odor 80-90%	$3.97
Ground water 15-25%	$4.03
Ground water 40-50%	$4.01
Surface Water 15-25%	$3.96
Surface Water 40-50%	$4.15
Odor 80-90%/Ground Water 40-50%	$4.45
Odor 80-90%/Surface Water 40-50%	$4.54
Odor 80-90%/Ground Water 40-50%/Surface Water 40-50%	$5.06