Water management as a future necessity in sheep feedlots

Abstract

Improving water management in rural towns such as Wagin, Western Australia will decrease infrastructure damage caused by water and salinity, and produce a 'new water' resource. The aim of this paper is to predict feedlot water demand using a bio-economic model, H₂OSheep to determine if using such a 'new water' resource could be a viable option for this production system. Wagin (Latitude:-33.3075 S and Longitude: 117.3403 E), a township south-east of Perth, was chosen as the specific location for a sheep feedlot producing prime lambs. In this paper, the model was used to show how the price of water, in different feeding regimens and climate change influence feedlot returns by integrating feed and water intake of lambs, general feedlot water use and waste disposal. To show relative sensitivity of changing other model parameters that are not directly connected with water, changes in the purchase and sale price of lambs were also investigated. As might be expected H₂OSheep shows that returns from a sheep feedlot enterprise can be extremely sensitive to changes in lamb purchase (just over 7 per cent increase will result in negative returns) and sale prices (a four percent decrease will generate a negative outcome). With respect to water, the findings indicate that while increases in water use in the feedlot and price have to increase more than the relative price of sheep, monitoring the biological parameters associated with water as well as water prices is still important both from a management and an economic perspective. Hence if towns involved in the Rural Towns Liquid Assets project, such as Wagin, decide to sell their water, the relevant policy makers should ensure that the sale price enables an effective water management system for the town and is also attractive to end-users such as feedlots.

Keywords: sheep; water; cost benefit analysis

Introduction

Taking the issue of salinity and water management in rural Western Australia to the public, as has been recently undertaken by Sexton (2003) and others, has raised the question of how best to use any water that may be recovered as a consequence of managing salinity. A response to this question has been the development of the Rural Towns-Liquid Assets (RTLA) project to investigate issues of water management in rural towns as a complete system (Pluske *et al.* 2004). Should this system involve treating saline water, then an economically viable use for

this 'new water' is required to recover water processing and distribution costs. One option being considered by the RTLA project is to sell the water to sheep feedlots, a production method that, for several reasons expanded on by Dowling and Crossley (2004), is increasing in popularity. However, a feedlot would only buy the water if it is in the best interest of the feedlot to do so. Furthermore, for the water management system to work, demand for water must be reliable otherwise the viability of the system will be in jeopardy.

Regarding saline water as a resource is perhaps not only important in the context of the RTLA project but also in certain circumstances for farmers who might be considering treating ground water from their own properties, a possible option alluded to recently by Ridley and Pannell (2005). Having a tool available to predict water demand for a sheep feedlot, and the subsequent effects on net benefits generated would provide additional information to these decision makers.

The aim of this paper is to predict feedlot water demand using a bio-economic model, H₂OSheep. By integrating feed and water intake of sheep, general feedlot water use and waste disposal, the model also provides an indication as to how water price, different feeding regimens and climate change influence feedlot returns. To show relative sensitivity of changing other model parameters that are not directly connected with water, changes in the purchase and sale price of lambs were also investigated.

As geographical specific data such as temperature and rainfall is required in H₂OSheep, for the purpose of this paper, Wagin (Latitude:-33.3075 S and Longitude: 117.3403 E) was chosen as the specific location for the sheep feedlot. The town is south-east of Perth in a region dominated by grazing with winter production of grain. Demand for water by a feedlot will be contingent on the size of the feedlot, feed intake, and possibly changing climatic conditions. It is possible that temperature may increase by 2°C and rainfall decrease by 20% in south-western Australia over the next 30 years (Ash 2001). Should such a phenomenon occur then the demand to meet the water requirements of sheep, in terms of drinking water, water for dust control and cooling, is expected to increase.

In the following section the key parameters and equations that allow water demand in H₂OSheep to be calculated are described. The water sources for the feedlot and water balance

are also outlined before a description of the economic analysis. The last section details the results and the subsequent discussion and conclusion.

Materials and methods

H₂OSheep is a simulation model integrating economic and biological components. Annual costs and benefits forecast for a 20-year period are included in the costs benefit analysis. While the biological parameters of the model are translated into annual costs and benefits, the actual sheep input can be varied and so the length of time sheep are in the system depends on management plans that are selected by the user. The model structure is similar to that described in Pluske and Schlink (2006) for cattle with modifications made to the equations to predict sheep production in a feedlot. Estimates of growth and production are based on a combination of equations from AFRC (1993) and SCA (1990) to enable the effects of wool growth to be included into the AFRC (1993) equations. The model is implemented in the spreadsheet program, Microsoft Excel[®].

Water demand

Rainfall and temperature data specific for the feedlot location is required to calculate the quantity of water needed for dust control and water intake for sheep.

While it is readily acknowledged in Davis (2003), that a feedlot should be free from dust, little information seems to exist on the best management practices that ensure a feedlot does not generate excessive dust levels. As a consequence Dowling and Crossley (2004) call for more research to be done on the moisture levels that are needed to prevent dust, flies and odour becoming a problem in a feedlot. In this paper, to control dust when daily rainfall is less than three millimeters per day, it is assumed that water will be applied to the feedlot surface at a rate equivalent to three millimeters of water per day. That is, three litres of water per square meter per day. This assumption is based on Watts and Tucker (1994) who suggested that the manure surface moisture content in a cattle feedlot should be maintained at 25 to 35%. Miller and Berry (2005) suggest a surface moisture content of 20 to 41% (on a total mass basis) for beef feedlots. Extrapolating upon this knowledge, the litres of water required for dust control for sheep in the feedlot in any one month ($\dot{W}$) is dependant on the area of the feedlot in

hectares (A), the number of sheep in the feedlot (N), the millimeters of water required for dust control on a daily basis (w) and on average, the number of days per month where the rainfall is less than three millimeters (d).

$$\dot{W} = A N w d \quad (1)$$

Forbes (1968), NRC (1985) and Wilson (1966) have each developed separate models to calculate daily water intake for sheep and each generate different daily requirements using limited temperature ranges. To extend the temperature range to cover the environmental conditions of the regions, data from Forbes (1968) and ARC (1980) were used in a prediction equation for estimating the sheep's daily requirements for water in litres ($\hat{W}$) based on average daily temperature in degree Celsius (T), and kilograms of dry matter intake per head per day (D) (Option 1) can be depicted as:

$$\hat{W} = (1.74 + 0.0632T)D \quad (2)$$

NRC (1985) developed a different equation to calculate water intake ($\tilde{W}$) although using the same parameters as used by Forbes (1968) and ARC (1980) (Option 2) where:

$$\tilde{W} = (0.18T + 1.25)D \quad (3)$$

Data from Wilson (1966) was used to develop equations for predicting water intake in sheep that included salt intake in food and water. With respect to including feed consumption in the equation, the resulting estimation for water intake ($\bar{W}$) provides an additional check (Equation 4) in predicting the minimum litres of water required by the sheep (Option 3).

$$\bar{W} = 2.84 + 0.0322 * S \quad (4)$$

where S is the gNaCl in the feed/day

Results from the three possible combinations are presented in Table 1.

Table 1 about here

Temperature and dry matter intake are components of the H₂O Sheep model and Equation 2 (Option 1) also makes use of these parameters to produce water intakes similar to that

recommended by Seymour (2000) for the Western Australian environment. Therefore, this equation has been selected as the default water intake prediction equation in H₂O Sheep.

Water required in each month is therefore the daily water intake for sheep multiplied by the number of sheep in the feedlot at that time and the number of days in that month.

Cost of the water

As discussed by Masters *et al.* (2006) excess salt in the diet depresses growth in sheep. For the purpose of the following analyses it was assumed that water was sourced from saline groundwater that has been treated so that the maximum level of salt in the water, as suggested as by Seymour (2000) is below 5,000 parts per million. Prime lamb producers will therefore not incur a weight loss due to water quality issues in the scenarios developed in this paper. The total cost of desalinated water per month (C) (Australian dollars) is the quantity of desalinated water used in the feedlot in a particular month multiplied by the price of water per kilolitre (p). It is also assumed that the water will be produced in a treatment plant some distance from the feedlot and so there will be an additional cost for water transport ($\bar{p}$) in dollars per litre.

$$C = Wp + W\bar{p}$$

The economic model

H₂O Sheep has several components that are essential for running the model but will not be discussed in detail in this paper¹. Such components include the feedlot structure, feed intake and liveweight change, waste management and non-market benefits and costs. In addition important elements of the water management system, such as the abstraction and treatment of saline water, and subsequent environmental and infrastructural changes are described in Pluske *et al.* (2004) and are not discussed further in this paper.

Cost benefit analysis, the economic methodology that supports H₂O Sheep, uses a discounting approach. Present values of all costs and benefits for each year of the project are added to calculate the net present value (NPV) (Robison and Barry 1996). The preferred strategy has the

¹ For further detail, the model is available from the authors

highest NPV or highest internal rate of return (IRR) (that is the discount rate when the NPV equals zero).

Usually differing inflationary effects associated with inputs and/or outputs, revenue earned from interest on profit or tax implications are not included in public cost benefit analyses. However, as recommended by Pannell (2006), H₂OSheep can accommodate these extra parameters but they are not included in this general analysis. The net present value, in Australian dollars, is the sum of the net benefits (B) for each year (t), discounted using a discount rate (r).

$$NPV = \sum_{t=1}^n \frac{B_t}{(1+r)^t}$$

Assumptions and application

Inputs required for H₂OSheep include number and type of sheep entering the feedlot, store or feedlot entry weight, death rate, and time in the feedlot. Using this information, the model calculates the number of sheep in the feedlot for each month of the year and sale weight. For the purpose of this paper it is assumed that the feedlot has an annual output of 5,000 first cross lambs with a store starting weight of 35 kilograms and a length of confinement of 35 days as recommendations by Seymour (2000). Natural death rate is set at one per cent per year with loss due to shy feeders (sheep who for behavioral reasons are reluctant to consume allocated rations in a feedlot) fixed at five per cent.

There are over 50 different feed components specified in the model although there is capacity for additional feed components to be included if they are not already listed in the feed options. Using this diet list, a combination of components including the percentage quantity of each can be selected to specify the ration. The actual weight in kilograms of feed supplied per head per day is also a required input so that the model is able to calculate daily dry matter intake and live weight gain for each animal. In the base case analysis, feed is rationed at 1.8 kilograms per head and is composed mainly of grains and hay to produce a predicted daily live weight gain of 0.302 kilograms.

In practice the sheep meat industry currently uses a wide variety of grain feeding systems that fit the definition of feedlotting but due to varying degrees of control over diet, these may result in different growth rates and performance (Kirby and Beretta 2004; Wiese *et al.* 2003). Kirby and Beretta (2004) note that there are several comprehensive guides published by

various Australian State Departments of Agriculture (e.g., Bell *et al.* 2003) that cover the practicalities of setting up and running a feedlot. Bell *et al.* (2003) provide a clearly set out a plan for producing a 45kg lamb from a 35kg store lamb and hence it was followed in this paper. The ration used in this particular example was based on their suggestions and consisted of: 25 per cent wheat grain; 15 per cent barley grain; 15 per cent lupins; 20 per cent oat grain; 5 per cent silage; 15 per cent hay (50per cent DMD) 4.5 per cent lucerne hay and 0.5 per cent minerals and vitamins. The mineral and vitamin mix is unspecified but is designed to balance the diet including 130 grams of sodium per kilogram of mineral mix. While Kirby and Beretta (2004) acknowledge that there is a range of growth rates reported in the scientific literature, generally the literature supports growth rates of 140 to 350 grams per day and hence these figures are expected performance recommendations given in extension material.

While it is recognized that the ration for lambs is likely to differ over the confinement period, the effect on water intake was assumed to be negligible. Therefore for simplicity in this paper, just one ration was assumed for the total time lambs were in the feedlot.

Based on Elders (2006a) the price of heavy cross bred lambs ranged from \$70 to \$88 with the price of stores from \$35 to \$55 per head. It is assumed in the following analyses that a store price of \$1.05 per kilogram (or \$36.75 per head) and sale price of \$1.65/kg or (\$75.22 per head) are reasonable base case values. Other details regarding assets, revenue and most costs are derived from cost, revenue or biological data obtained from research and/or industry sources. The discount rate is assumed to be 7 per cent.

The use of desalinated water produced as a result of the RTLA project is still being investigated and as it is not currently traded in the market, the price for this source of ‘new water’ is yet to be determined (Pluske *et al.* 2006). Hence in this paper, the price of desalinated water in the initial analysis is assumed to be \$1.20 per kilolitre. This is also the average price of water (first 300kL) provided for country commercial purposes by the Integrated Water Supply System (Water Corporation, 2005). The distance between treatment plant and feedlot is assumed to be five kilometers with transport costs assumed to be \$0.25 per kilolitre per kilometer.

An initial or base case analysis (Analysis 1) is produced using H₂OSheep with the aforementioned set of assumptions and data. Additional analyses are completed to determine the sensitivity of the model to these parameter values.

To demonstrate how water price affects the model output of the base case option, Analysis 2a uses the same parameter values as for the initial analysis but the price of water is doubled to \$2.40 per kilolitre in line with an estimated price of water (over 300kL) provided for country commercial purposes (see Water Corporation, 2005). In Analysis 2b, the price is increase to such a level that the NPV becomes zero.

If the amount of feed offered is altered, water requirements will change as water intake is primarily determined in this model by dry matter intake. In Analysis 3, feed allocation is increased to 2 kilograms per head per day (Analysis 3a) and decreased to 1.5 kilograms per head per day (Analysis 3b) with the water price at \$1.20 per kilolitre. These values provide a daily weight gain at either end of the expected range outlined by Seymour (2000) for lambs in a feedlot. In addition, for each of these analyses, water price is increased to a level where the NPV falls below zero (Analysis 3c and 3d respectively).

To estimate the effect of potential climatic impact of Greenhouse Effects on the feedlot, a fourth analysis involves changing temperature and rainfall parameters, and water required for dust control and cooling based on the Greenhouse Effects predicted by Ash (2001). In Analysis 4, the value of all model parameters are the same as those in Analysis 1 except temperature is increased by 2°C, rainfall decreased by 20 percent and the amount of water sprayed for dust control and cooling is increased by 20 percent (Analysis 4a). To determine the effect of water price on this option, it is again increased to a level so that the NPV equals zero (Analysis 4b).

Analysis 5 explores the use of water for dust control. In Analysis 5a, the quantity of water used for controlling dust is reduced from three litres per square meter to two, and it is increased to four litres per square meter in Analysis 5b. As it is possible that water for dust control may not need to be treated, in Analysis 5c, the cost of water for this purpose is reduced to \$0.60 per kilolitre while the cost of water for sheep consumption is maintained at \$1.20 per kilolitre.

The final analysis provides a relative comparison with these ‘water related’ parameters by showing how a change in lamb purchase or sale price affects the model outcome. Using the same parameter values as for Analysis 1, Analysis 6 is set to show how much the lamb purchase or sale price would have to increase to see a negative net return. To achieve this

result the purchase price is increased in Analysis 6a and the sale price decreased in Analysis 6b. In Analysis 6c, the water price is increased to \$2.40 per kilolitre and the lamb sale price is reduced until the Net Present Value is zero.

Results

The data and assumptions used for Analysis 1 resulted in the total amount of water used in the feedlot per year being 3,099 kilolitres with a cost of \$3,719 for the water, and \$3,874 for water transport. Thus water costs amounted to 2.5 percent of total feedlot costs. The cost of feed per sheep per day was calculated to be \$0.29 and the live weight gain per head per day was calculated to be 0.302 kg. The NPV for the 20 year period was positive at \$154,934 with an IRR of 11.6 per cent.

When compared with Analysis 1, doubling the price of water to \$2.40 per kilolitre in Analysis 2a, resulted in a slight decrease in net returns (Table 2). For Analysis 2b, increasing the water price to \$5.50 per kilolitre more than doubled the percentage of water costs to total costs, when compared with Analysis 1 and generated a NPV below zero and an IRR below the 7 per cent discount rate (Table 2).

Table 2 about here

Increasing the feed ration to 2 kilograms per sheep per day in Analysis 3a, increased daily feed costs and water consumption to 4.59 litres per head and hence water costs when compared to Analysis 1, although water as a percentage of total costs did not change. However, lamb liveweight gain increased to 0.351 kilograms resulting in an increase in net returns (Table 3). Alternatively in Analysis 3b when the daily feed ration was decreased to 1.5 kilograms per sheep, water intake decreased to 3.45 litres per head per day and although the water costs as a percent of total costs did not change, the net returns decreased (Table 3). In Analysis 3c, with the same scenario as Analysis 3a but with water costs increased to \$8.20 per kilolitre, the net returns fell below (Table 3). In Analysis 3d (given the same assumptions as Analysis 3b but with water priced at \$2.30 per kilolitre, a relatively small increase in water price was required before the net returns fell below zero (Table 3).

Table 3 about here

Altering the value of parameters to account for predicted Greenhouse climate changes in Analysis 4a resulted in an increase in water demand by the feedlot of approximately five per cent, thus increasing the cost of water and slightly decreasing the NPV and IRR in comparison with Analysis 1 (Table 4). Further increasing the water price to \$4.90 per kilolitre in Analysis 4b provided an expected increase in the percentage of water costs to total costs but saw the NPV fall to around zero and the IRR decrease to 7 per cent (Table 4).

Table 4 about here

Decreasing the water used in dust control by one litre per square meter resulted in a 13 per cent increase in returns while increasing it by the same amount saw an equivalent drop in returns (Table 5). With the price of treated water for sheep consumption at \$1.20 per kilolitre and that for dust control at half the price, net returns increased by just under ten percent (Table 5).

Table 5 about here

Increasing the purchase price of store sheep to \$1.13 per kilogram or by seven percent in Analysis 6a resulted in break even returns (Table 6). Likewise decreasing the sale price of lambs in Analysis 6b by just over four percent to \$1.58 per kilogram saw a similar result (Table 6). However, if the water price was increased to \$2.40 per kilolitre then the sale price only had to decrease by three per cent before the enterprise had a Net Present Value of around zero.

Table 6 about here

Discussion

While some of the results produced by H₂O Sheep might have been as expected there are also some findings that will be useful for decision makers involved in primary production and local water allocation. This might be especially so if there is a trade-off between allocating scarce water for production and human use. Based on WAGov (2003) data, in Western Australia each person uses 155 kilolitres per person annually. Hence the sheep feedlot outlined in this study would use the equivalent amount of water annually as 20 people.

The simulations showed that efficient management of water use in the feedlot is important for producing positive net returns, and that water price can have a significant impact on profitability. Assuming a discount rate of seven percent, the base case analysis indicated that a reasonable return can be expected from the feedlot even when the price of water is set at \$1.20 per kilolitre. Furthermore, at this point, doubling the water price should still provide a return on investment that is greater than an investment in bank bonds (assumed at 7 per cent for this study). However, if for example there is an increase in demand or a shortage in water supply that drive the price up to beyond the \$5.50 per kilolitre price, the sheep feedlot outlined in this paper will turn into a non-viable investment proposition.

Results from H₂OSheep also clearly showed that feed management within the feedlot is also important. It is expected that first cross lambs will grow at around 300 grams per day to reach an end weight of 46 kilograms which is in line with the range suggested by Seymour (2000). Not only does water intake change with different feed intakes but the net returns expected from the feedlot can also change quite markedly. Working through different simulations would be a worthwhile management activity especially if water prices are expected to increase in the future. This may be even more significant given findings by Bowen *et al.* (2006) that suggested that there can be a large variation between individual sheep in their growth rate during grain feeding. They concluded that relatively large numbers of animals growing slowly with poor feed conversion and failing to meet target carcass weight presented a hidden cost associated with sheep feedlotting.

The assumed effects of climate change used in the analysis for this paper indicate that, provided the relatively cheap price of water at \$1.20 is maintained, the net returns generated by the feedlot would not decrease dramatically. However, with higher temperatures and less rainfall, more water would need to be made available directly for livestock and, indirectly, for dust control. Should the price of water increase to a higher price of \$4.90 per kilolitre, this feedlot would no longer be considered a viable investment.

From a biological perspective, the level of moisture in feedlots is important (Dowling and Crossley 2004). However, results from this study indicated that there were relatively small economic consequences if the quantity of water sprayed for dust control was increased or decrease by a third or the price of water for dust control reduced by half (no additional capital costs were assumed for this dual system). It should be noted that if water used for dust control is not treated then there may be environmental issues associated with salt leaching into the

soil and possibly waterways in the vicinity of the feedlot resulting in increased costs. Furthermore, should the price of water increase significantly or the base qualities of water suggested for dust control in this paper be underestimated, then the additional water costs would impact negatively on feedlot returns.

To demonstrate the sensitivity of the model to parameters other than those related directly to water, lamb purchase and sale prices were examined in sensitivity analyses. The model outcome was very sensitive to a change in either lamb purchase price or sale price. This is in line with conclusions made by Bowen et al. (2006) who noted that the profitability of a feedlotting enterprise will be determined by the performance of sheep, the cost of feed, infrastructure and labour, and the market value of mutton and lamb. Only a seven percent increase in purchase price or a four per cent decrease in sale price of lambs was required before the net returns generated by the feedlot fell to below zero. For example, within the temporal price range provided by Elders (2006a) for April 2006, a decrease from the top of the sale price range to the bottom is a 20 per cent decrease. Likewise an increase from the bottom of the store price range to the top is a 57 per cent increase. Furthermore, the bottom of the store price range increased from \$35 for April 2006 to reach \$40 for June 2006 (Elders 2006b) (an increase of around 14 per cent). However, the bottom of the range for the sale price for June 2006 dropped to \$65 per head (Elders 2006b) from \$70 per head in April 2006 (a change of over 7 per cent). This means that for the same class of sheep within the same time period or at different sale times (at the same location: Midland, Elders (2006b)), the percentage change in price was in excess of what H₂OSheep predicts could be the difference between a relatively sound return and a negative one.

Conclusion

The results generated by H₂OSheep are dependant on the data and assumptions used in the model and should be interpreted accordingly. Furthermore, altering the values of parameters in other parts of the model, such as feedlot size and the components in the feed ration, can all significantly alter the economic outcome.

As might be expected H₂OSheep shows that returns from a sheep feedlot enterprise are extremely sensitive to changes in purchase and sale prices of sheep. However, physical and/or

economic changes to feedlot water management also influence the economic viability of a feedlot, although to a lesser extent than other feedlot parameters.

In conclusion, this paper provides an indication of how water use and price can alter the economic viability of a sheep feedlot. In addition it shows how sensitive returns are to a change in purchase and/or sale prices. However, with respect to water, the findings indicate that keeping a check on biological parameters associated with water, as well as water prices, is important both from a management and an economic perspective. Therefore if towns involved in the RTLA project, such as Wagin, are keen to sell their water the relevant policy makers will have to make sure that the sale price not only results in an effective water management system for the town but is also attractive to end-users such as feedlots.

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Table 1. Predicted daily water consumption outcomes of sheep for the modeling options derived from various references and described for Analysis 1

Option	Water consumption (L/day/sheep)	Reference
1	4.13	Forbes (1968); ARC (1980)
2	6.24	NRC (1985)
3	2.96	Wilson (1966)

461 **Table 2.** The effect on the model outcome given the assumptions specified for Analysis 2
 462 and when water price is doubled (Analysis 2a) and increased until the NPV=0 (Analysis 2b)

Parameter	Analysis 1	Analysis 2a	Analysis 2b
Water costs (\$/kL)	1.2	2.4	5.5
Water costs as a percent of total costs	2.5	3.7	7.1
NPV (\$)	154,934	115,532	-2,676
IRR (%)	11.6	10.5	6.9

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Table 3. The effect on the model outcome given the assumptions specified for Analysis 3 and when feed intake is increased (Analysis 3a) and decreased (Analysis 3b) within a range suggested by Seymour (2000) and when the price of water is also increased for each of these scenarios until the NPV=0 (Analysis 3c and 3d)

Parameter	Analysis 1	Analysis 3a	Analysis 3b	Analysis 3c	Analysis 3d
Feed intake (kg/sheep.day)	1.8	2	1.5	2	1.5
Liveweight gain (kg/day)	0.302	0.351	0.230	0.351	0.230
Water intake (L/sheep.day)	4.13	4.59	3.45	4.59	3.45
Water costs (\$/kL)	1.20	1.20	1.20	8.20	2.30
Water costs as a percent of total costs	2.5	2.5	2.5	6.7	3.6
NPV (\$)	154,934	234,275	34,029	-1334	-732
IRR (%)	11.6	13.7	8.1	7.0	7.0

Table 4. The effect on the model outcome given the assumptions specified for Analysis 4 and when Greenhouse climate changes cause temperature to increase by 2°C, rainfall to decrease by 20 percent and the amount of water sprayed for dust control and cooling to increase by 20 percent (Analysis 4a) and when the price of water is also increased for this scenario until the NPV=0 (Analysis 4b)

Parameter	Analysis 1	Analysis 4a	Analysis 4b
Daily water intake (L/sheep)	4.13	4.32	4.32
Cost of water (\$/kL)	1.20	1.20	4.90
Water costs as a percent of total costs	2.5	2.9	7.0
NPV (\$)	154,934	141,666	137
IRR (%)	11.6	11.2	7.0

Table 5. The effect on the model outcome given the assumptions specified for Analysis 5 and when water for dust control is lowered to 2L/m² (Analysis 5a), increased to 4L/m² (Analysis 5b), at a water price of \$1.20/kL, and when the cost of water for animal consumption is set at \$1.20/kL and water for dust control is set at \$0.60/kL (Analysis 5c)

Parameter	Analysis 1	Analysis 5a	Analysis 5b	Analysis 5c
Water costs as a percent of total costs	2.5	1.9	3.2	2.1
Total water used annually (kL)	3,099	2,301	3,898	3,099
NPV (\$)	154,934	175,670	134,198	170,169
IRR (%)	11.6	12.2	11.0	12.0

484 **Table 6.** Based on the assumptions specified in Analysis 6, the effect of increasing the sheep
 485 purchase price or decreasing the sale price to levels that result in the NPV=0 (price of water is
 486 \$1.20/kL for all analyses except for Analysis 6c where it is \$2.40/kL).

Parameter	Analysis 1	Analysis 6a	Analysis 6b	Analysis 6c
Purchase price (\$/kg/sheep)	1.05	1.13	1.05	1.05
Total purchase price (\$/sheep)	36.75	39.41	36.75	36.75
Sale price (\$/kg/sheep)	1.65	1.65	1.58	1.60
Total sale price (\$/sheep)	75.22	75.22	72.07	72.94
NPV (\$)	154,934	755	192	821
IRR (%)	11.6	7.0	7.0	7.0

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