9-1-2002

TB183: Investment, Ownership and Operating Costs of Supplemental Irrigation Systems for Maine Wild Blueberries

Timothy J. Dalton

Andrew Files

David Yarborough

Recommended Citation

Dalton, T.J., A. Files, and D. Yarborough. 2002. Investment, ownership and operating costs of supplemental irrigation systems for Maine wild blueberries. Maine Agricultural and Forest Experiment Station Technical Bulletin 183.

ISSN 1070–1524

Investment, Ownership and Operating Costs of Supplemental Irrigation Systems for Maine Wild Blueberries

Timothy J. Dalton

Andrew Files

David Yarborough

Technical Bulletin 183 **September 2002**

MAINE AGRICULTURAL AND FOREST EXPERIMENT STATION
The University of Maine

Investment, Ownership and Operating Costs of Supplemental Irrigation Systems for Maine Wild Blueberries

Timothy J. Dalton
Assistant Professor
Department of Resource Economics and Policy
5782 Winslow Hall
University of Maine
Orono, ME 04469-5782

Andrew Files
Research Associate
Department of Resource Economics and Policy
5782 Winslow Hall
University of Maine
Orono, ME 04469-5782

David Yarborough
Associate Professor of Horticulture
414 Deering Hall
University of Maine
Orono, ME 04469-5782

ACKNOWLEDGMENTS

This research was supported by a grant from the Maine Agricultural Center. The authors would like to thank the irrigation engineers and equipment dealers who assisted in the design and costing of these systems.

The authors also thank the three reviewers who provided constructive criticism on this manuscript.

CONTENTS

FIGURES

TABLES

INTRODUCTION

Interest in irrigation of agricultural crops has increased in the recent past due to seemingly inadequate and highly erratic distribution of rainfall. Although irrigation is generally supplemental in humid areas and less essential to farm profitability than for the management of production risk, intermittent dry spells at critical times can cause significant economic damage to the crop. A critical component of assessing the farm-level impact of irrigation investment is the variability in weather patterns over the life of the investment and timing of the investment decision. Rainfall patterns for the seasons following the irrigation investment decision can have a dramatic effect on repayment ability and farmer satisfaction with the decision.

This study will investigate the investment and annual cost of supplemental irrigation equipment used on lowbush blueberries and will calculate breakeven yields required to pay for annual costs and the earliest possible payoff period to recover investment costs. On one hand, supplemental irrigation investment is often thought of as a production risk-reducing strategy. On the other hand, it can be viewed as one that increases exposure to financial risk through investment repayment. Using an economic-engineering approach to simulating investment and operating costs, this project will assess breakeven requirements on irrigation investment.

A grower will need to evaluate three primary factors when choosing an irrigation system: technical requirements, economic returns or risk reduction, and financial impacts. This study will review several of the technical factors contributing to the irrigation decision, calculate economic costs and are breakeven measures, but only introduce some of the financial factors for a grower to consider. It must be emphasized that irrigation decisions are highly site specific. Engineering requirements, economic and financial impacts will differ from farm to farm and therefore, results will differ between growers. This publication provides some background information, but more detailed information from irrigation suppliers, engineers and bankers will be required for the final decision.

LITERATURE REVIEW

The use of irrigation for agricultural crops has different implications depending on the amount of rainfall needed by the crop and the average annual rainfall of the area being studied. In arid areas, where irrigation is required without question, the issue is a straightforward comparison of yields with, and without, irrigation. In more humid temperate regions, where in some years there is enough rainfall to meet crop needs, the question is more complicated. In these regions, irrigation is not used in a continual fashion as in arid regions, but is used in a supplemental fashion to meet the needs of crops when rainfall is insufficient. In these regions, the range of use for supplemental irrigation can be from "not at all" in wet years, to "frequently" in dry years. And obviously, there is no way to know beforehand whether this growing season will be a wet one or a dry one, let alone to know what the weather will be over the life of the equipment. Thus, the economic returns of an irrigation system are continually received in arid regions, while they are only sporadically received in temperate regions. This distinction will play a key role for producers in temperate regions who are deciding whether to irrigate.

Cost of Implementation/Use

The decision to irrigate or not in areas where rainfall can be sufficient in certain years is not an easy one. In addition to the requirement for increased management skills, there is also the obvious need for financial capital outlay to purchase, install, and operate the irrigation equipment. While purchase and operation are a significant portion of the overall costs of an irrigation system, one should not overlook the costs of installation. Accessing a sufficient water supply, whether drilling a well, creating a farm pond, or pumping from a stream or river with adequate flow, can also require significant cash outlays. Scherer and Weigel (1993) estimate well costs to range from $12,000 to $18,000 with per foot costs ranging from $125 to $175 (values are in 1993 dollars). With regards to an entire irrigation system, Marra and Woods (1990) estimated an initial investment for irrigating potatoes to range from $66,000 for a single-gun configuration on 70 irrigated acres to $335,000 for a center-pivot arrangement on 300 irrigated acres (values are in 1990 dollars). Leiby and Marra (1993) found that past research estimated irrigation costs to range from $145 per acre for rabbiteye blueberries with drip irrigation to $672 per acre for lowbush blueberries using a sprinkler and riser setup (values are in 1992 dollars).

Risk and Returns

While yield variability and equipment costs are significant aspects to consider with irrigation systems, a risk-reduction effect may also play a role in the decision-making process. As risk aversion increases, the greater the value of information on production or price risk. As Bosch and Eidman (1987: 659) point out, "additional information has diminishing marginal returns for a given level of risk aversion and the value of information increases with the level of risk aversion." And to assist in providing producers with appropriate information, Martin et al. (1996) use the Irrigation Cost Analysis Program (ICAP) to assist farmers to determine if supplemental irrigation is cost effective. This program helps farmers understand the finances of irrigation by determining the increase in yield necessary to pay the increased capital and operating costs. In another analysis, Boggess et al. (1983) use a time-dynamic soybean-yield simulation model to generate production estimates while other simulators generate the cost estimates. Historical weather and price information are the data that "drive" the simulators. Boggess and Amerling (1983) study a related topic by focusing their analysis on the impact of weather pattern variations on the profitability of irrigation investments in humid regions. Boggess and Ritchie (1988) use crop models to link information about the response of crops to irrigation with economic analysis and risk assessment in order to provide an integrated information base for making irrigation management decisions. But as Hatch et al. (1991:443) indicate, "irrigation may not be advisable or feasible depending on the farmer's debt load or debt limit. There is a clear tradeoff between production and financial risk that must be judged by the individual producer." Thus, these sources of risk are factors that each producer must evaluate on his or her own when considering the investment decision.

Type of Equipment to Use

The literature provides limited evaluations of specific irrigation equipment, but there are some major factors to take into account. First, the degree of rockiness and levelness of the land should be considered when determining what type of equipment to use. For large, level, rock-free fields it makes sense to use a traveling gun set-up, where the irrigation gun is actually moved across the field. However, these types of fields are few and far between in Maine, so an alternative selection would be a center-pivot style of irrigation. These systems are also rare in lowbush blueberry production and are not considered in the economic analysis. A third system involves manual movement of large sprinkler guns or a series of small sprinkler heads. A final alternative is to cover the field with immobile small sprinkler nozzles supplied by a system of buried piping. In this analysis four systems are considered: the hand-moved big gun, the hose-reel traveling gun, the hand-moved small sprinkler system, and a buried small sprinkler system. Second, the cost to operate irrigation equipment varies from system to system, and management time, labor, fuel and maintenance charges for each system are additional expenses that are incurred on the farm budget with irrigation adoption. And third, the cost of equipment and the development of the water source is another key factor in the decision-making process. Water development costs are highly variable from field to field and can dramatically affect investment cost.

Technical Factors Influencing Irrigation Decisions

Irrigation systems are designed to site-specific farming conditions or the owner's specific production objectives. Once alternative systems have been designed, the systems need to be compared on an economic basis to determine the least-cost method of meeting the production objective. In this section, several technical production factors are discussed briefly. Most of these factors vary from site to site and each decisionmaker will need to consider these components in greater detail.

Climate

The microclimate surrounding the farm and rainfall are two of the most important factors to consider when making the irrigation investment decision. As a general planning rule, lowbush blueberries need about one inch of water a week from April to October, but irrigation is commonly applied during the months of June, July, and August for proper plant and fruit development under Maine growing conditions.

The following graphs summarize rainfall histories along an east to west transect of the blueberry-growing region. Forty years of weather data (1959–1998) from the National Climatic Data Center from three sites were selected for illustration (National Climatic Data Center). These site are Jonesboro, Ellsworth, and Belfast. In the case of Ellsworth, data collection ceased in 1994, so the weather series is reduced to 35 years. Daily weather events were aggregated into weeks and presented over the period from the beginning of May until the end of September.

Two graphs for each site are presented: the first graph presents the probability that rainfall in a particular week (starting on May 1) will exceed the threshold level of 1", ¾" and ½". These graphs can be used to derive an estimate of rainfall risk and the probability of receiving ½", ¾", and 1" of rainfall per week (Figures 1, 3, and 5).

For nearly all of the growing season, the probability of receiving 1" of rainfall per week is less than 50%. The graphs also indicate a distinct decrease in the probability of rainfall during the critical period from mid-July (week 11) through August (week 17). This valley is more apparent in Figure 1 (Jonesboro) and Figure 3

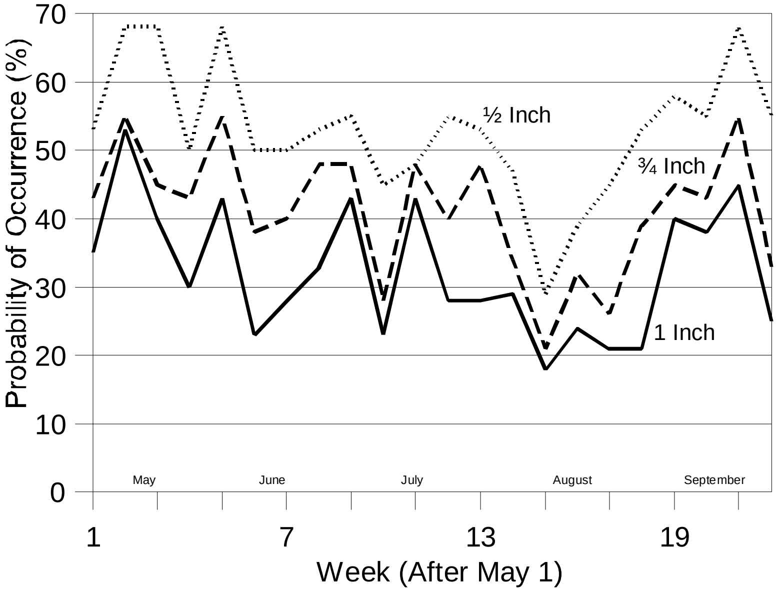

Figure 1. Weekly probabilities of rainfall exceeding limit, Jonesboro, ME, 1959–1998.

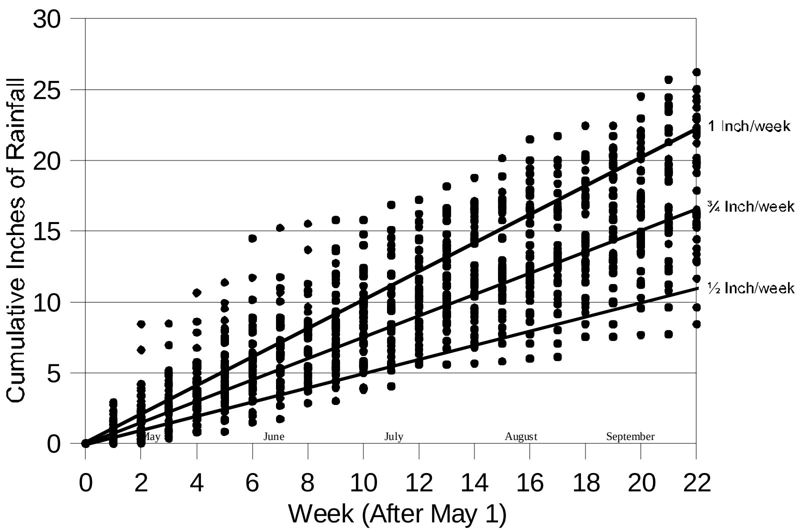

Figure 2. Cumulative rainfall over growing season, Jonesboro, ME, 1959–1998

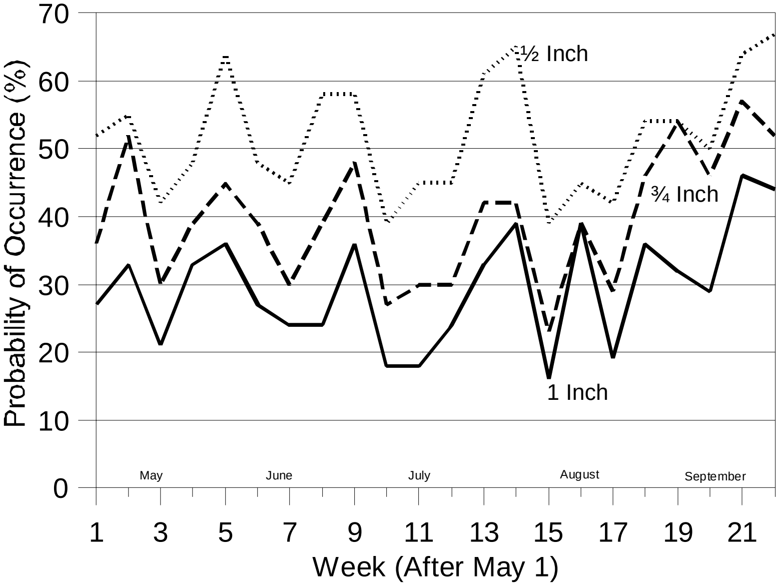

Figure 3. Weekly probabilities of rainfall exceeding limit, Ellsworth, ME, 1959–1994.

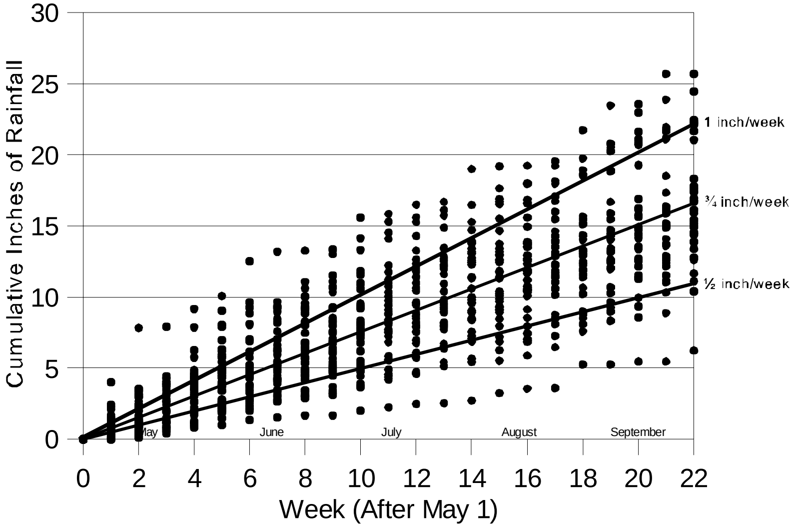

Figure 4. Cumulative rainfall over growing season, Ellsworth, ME, 1959–1994.

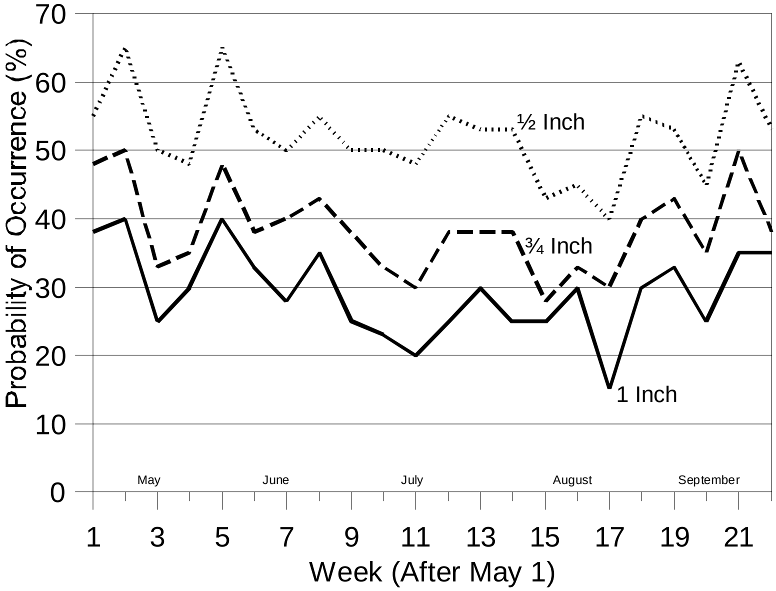

Figure 5. Weekly probabilities of rainfall exceeding limit, Belfast, ME, 1959–1998.

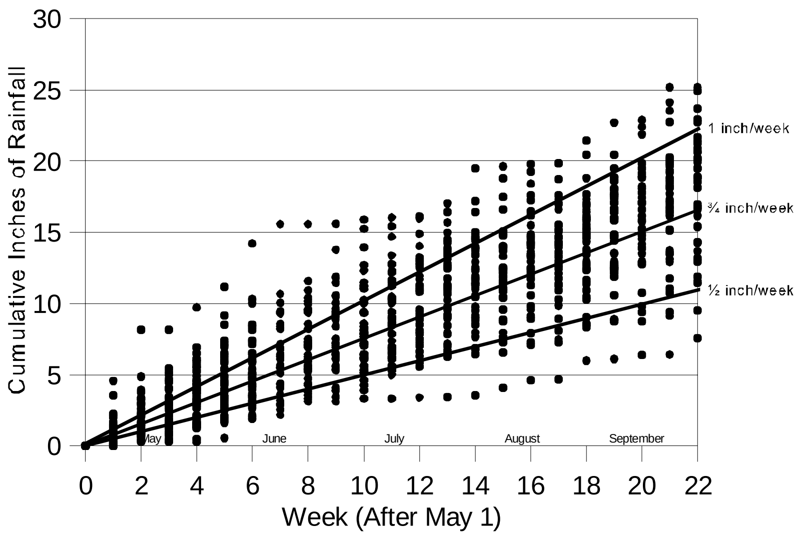

Figure 6. Cumulative rainfall over growing season, Belfast, ME, 1959–1998.

(Ellsworth). During this period, the probability of receiving any rainfall reaches its lowest in the season. There is less than a 20% chance of 1" of rainfall during this period.

While the first series of graphs concentrate on receiving a particular amount of rainfall every week, Figures 2, 4, and 6 illustrate cumulative rainfall over the growing season. These graphs thus allow for "catching up" from week to week. These three graphs plot the cumulative rainfall during the growing season from all 40 years for Jonesboro and Belfast or 35 years for Ellsworth.[1] Three straight lines are superimposed upon the yearly cumulative totals to indicate thresholds for receiving ½", ¾", and 1" of rainfall per week. Points that lie above each of these threshold lines exceed rainfall requirements.

Overall, by mid-July, less than 33% of all years exceeded one cumulative inch per week in Jonesboro, only 21% in Ellsworth, and 25% in Belfast indicating that early rainfall deficits were not made up during mid-season. During the same period, Jonesboro and Belfast received ¾" of rainfall nearly two-thirds of the 40 years, while Ellsworth received the same amount approximately 50% of the time. Jonesboro and Belfast are both virtually assured of at least ½" (approximately nine out of every 10 years) while Ellsworth is likely to receive at least ½" of rainfall eight out of every 10 years.

The figures indicate several trends. First, there are distinct intra-seasonal patterns of decreased rainfall beginning in mid-July and continuing through August. Across the blueberry-growing region, this translates to high probability of not receiving 1" per week of rainfall during the critical fruiting stage, a 50–50 chance of receiving at least ¾" per week during this stage, and a high chance of receiving at least ½" of rainfall per week. While absolute levels of rainfall are higher in Jonesboro and Ellsworth, Figures 1 and 3 indicate extreme volatility from week to week. Weekly rainfall variability is less in Belfast, but the probability of achieving higher levels of rainfall are lower. Highly variable weather patterns contribute to blueberry yield risk.

Topography and field shape

Irrigation systems vary in their ability to effectively cover the landscape with a consistent amount of water and work most effectively on fields with limited slope. Slope influences system choice by controlling runoff from application and in the system's ability to move about the field. To facilitate comparisons between irrigation

[1]Data were missing for some years. Cumulative totals were calculated up until the missing rainfall observations. Several missing observations occurred in July and August thereby limiting calculation of seasonal totals.

systems, this analysis will assume rectangular-shaped fields with limited slope.

Area coverage with center pivot systems is dependent upon boom length and whether the end of the boom is fitted with a corner extension system or an end gun. According to Patterson et al. (1996a), center-pivot systems in a 40-acre square field[2] can reach a land-coverage efficiency[3] (irrigated acres ÷ field acres) of up to 90% with the use of a corner system attachment, but only about 85% land-use efficiency using an end gun attachment. On a rectangular 80-acre field[4], a center pivot system could be designed to travel in a half-circle. Under this configuration, the corner system attachment could reach about 76 acres of the 80-acre field (about 96% efficient), but only 66 acres could be covered with the end gun (83% efficient). Center-pivot systems for a 160-acre square field can be configured to cover between 83% to 95% of the field, 133 and 152 acres, by end gun and corner system attachments, respectively.

Other systems have greater flexibility in coverage. Permanent set and moveable systems can be tailored through differing nozzle attachments, gun capacities, and placement to virtually cover the entire field. Using the three field sizes as examples, and restricting equipment to operate within field boundaries, it is common to achieve 96% coverage with these systems.

Soil and water characteristics

Soil and water characteristics will affect the productivity of irrigation investment. Soil characteristics such as texture, topsoil depth, and organic matter content will affect water-holding capacity. This study assumes that the irrigation system is set upon a typical Colton gravelly loamy sand soil. Soils with a greater water-holding capacity will require less irrigation than those with less water-holding capacity, with everything else constant. Slope also interacts with soil characteristics and will increase erosion unless measures are put in place to control the effect of water runoff.

Water resources must also be considered when planning the irrigation decision. Careful consideration of the quantity of water available for pumping throughout the growing season must be assessed. In addition, if water scarcity is an issue, then tradeoffs between water application efficiencies (effective soil moisture ÷ water applied) of the alternative systems should be considered. Water application efficiency is affected by wind and other weather conditions but on the average, center-pivot systems apply water more efficiently than handline or permanent set systems. Center-

---

[2]1,320 feet by 1,320 feet

[3]Also referred to as land-use efficiency.

[4]A field with a length two times the width (2,640 feet by 1,320 feet).

pivot systems apply water at an 80% efficiency rate, meaning that 1.25" of water must be applied for every 1" of desired moisture. Handline and permanent set systems are only 65% efficient, due to spray drift and nonuniformity, indicating that slightly more than 1.5" of water must be applied to produce 1" of soil moisture (Patterson et al. 1996a, 1996b).

Labor requirements

Labor requirements for the different irrigation options vary dramatically. Center-pivot systems require the least amount of time to operate. Labor requirements can increase if the mainline delivery system is used for multiple systems and requires setup for each irrigation and take down for other usages. Permanent set systems are buried subsurface and do not require substantial labor during the season as long as those lines remain undisturbed by tractor activities. They may, however, require substantial amounts of labor if sprinklers are removed at the end of the season and replaced at the beginning. On the average, studies have estimated that about two minutes per acre per irrigation can be budgeted for labor with center-pivot systems with slightly more if a corner system is employed. Permanent set systems require slightly more time, about three minute per acre per irrigation (Patterson et al. 1996a, 1996b).

On the other hand, gun and handline systems require considerable amounts of labor for setup, movement, and take-down for each irrigation. Patterson et al. (1996a, 1996b) have estimated that each irrigation can require up to 45 minutes per acre for set up and take down labor combined. Thus the flexibility of this system is offset by the variable labor requirement per irrigation. Total annual costs of labor, under this system, can vary dramatically from year to year depending upon system use. In addition, the variable labor requirement may constrain adoption if the farm is located in an area where part-time labor is expensive or difficult to hire.

General investment considerations

System components will vary according to farm-specific conditions. But in general, a decision to invest in irrigation machinery must consider four components: (1) water source development, (2) pumping system, (3) mainline water delivery system, and (4) water application system. The water application system (either gun, center-pivot, or small sprinkler system) will affect the sizing of the first three components.

Pumping systems can be elaborate, as in the form of a new diesel motor and pump, or nearly costless, if there is a second-hand tractor available with an available power take-off (PTO). If a PTO is available, the pumping investment will be reduced to selecting the proper delivery pump.

Mainline systems consist of buried PVC or aluminum pipe laid over ground with a diameter matched to water delivery requirements. Mainline systems will require additional fittings to connect with lateral lines in the case of permanent set, handline, and traveler systems, irrespective if they are buried or laid on top of the field surface.

Water application systems are variable in their capacity to deliver water over time, required operating pressure, and total system capacity. Handline and permanent set systems require investment in lateral lines, risers, and sprinklers spaced according to delivery design. The cost of each of these systems is broken into detail in the following section.

IRRIGATION SYSTEM DESCRIPTION AND COSTS

Four different irrigation systems are considered in this analysis: a handline moveable large gun system, a large gun attached to a hose-reel system, a handline moveable small sprinkler system, and a permanent set small sprinkler system. The last system is capable of watering the entire field at one time while the first three can only water a portion of the field at one time. These systems were selected to represent the range of tradeoffs in terms of investment capital, ability to protect against frost damage, management requirement, seasonal labor needs, and expansion ability. The descriptive differences of the systems are presented in Table 1.

In this analysis, each field is assumed to be equally divided between fruit-bearing and non-bearing plants. All systems were

Table 1. Irrigation system characteristics.

Irrigation System	Investment Capital Requirement	Frost Protection	Management Input	Labor Requirements	Expandable
Handline Moveable Large Gun	Low	No	Moderate to High	High	Yes[1]
Hose Reel Large Gun	Low	No	Low	Low	Yes[1]
Handline Small Sprinkler	Medium	Limited	Moderate to High	High	Yes[1]
Permanent Set Small Sprinkler	High	Yes	Low	Low	NA[2]

[1]Limited by pump capacity.

[2]The systems are designed to cover the entire field so expansion is not considered.

designed to minimize rainfall risk on both the fruiting and non-fruiting sides of the field. Due to limited water-holding capacity of many soils in the blueberry- growing region, systems were designed to apply $^2/_3$" of water, twice a week to ensure that the field would receive 1" of water per week net of application losses. In a worst case scenario, this is equivalent to having the capacity to water the entire field to ensure bud formation on the vegetative half and berry filling on the fruiting half during one week. The base models assume that 12 of these applications will occur on fruit-bearing land (effectively 6" of water per season) and four on non-bearing land (2" of water per season).

Only the permanent set small sprinkler system can provide complete field protection against frost. The handline small sprinkler system can provide limited protection depending upon how much area can be covered by the equipment. If frost damage is the primary concern of the operator, then only these systems can effectively reduce yield loss due to frost damage.

All irrigation systems were assumed to be located on level, on rectangular fields. The 25-acre field measures approximately 1200' (length) by 900' (width), the 50-acre, 2400 by 900, and the 100-acre, 2400 by 1800. Water is pumped from a farm pond located 100' from the irrigated field and all systems are assumed to have the same cost to develop the water source: $15,000. The power unit, sized to meet system peak capacity, and pump are located at the site of the pond.[5] Water is pumped by a diesel power unit from the pond through the mainline to the lateral delivery lines and subsequently to the delivery systems.

Table 2 presents a technical description of the systems broken down by the three acreage sizes. Design capacity of the system indicates the quantity of water applied per acre during operation while total system capacity reflects the pumping capacity of the water pump and the total number of acres that can be irrigated at one time. Based upon these two components, pumping units are selected with capacity to supply these needs at the required operating pressure, and then slightly oversized to provide limited expansion capacity, with the exception of the permanent set small sprinkler system. The system horsepower is presented in the third column of Table 2. The final column of the table calculates the approximate length of time that is required to supply $^2/_3$" of water on one acre. A brief description of each system is provided below and tables with all equipment requirements are presented in Appendix A, Tables A1 to A12.

---

[5]Any fixed structures required to house the motor and pump system are not included in this analysis.

Table 2. Design parameters of sample irrigation systems.

Irrigation Systems	Design Capacity (gpm/acre)	Total System Capacity (gpm)	System Horsepower (hp)	Time to Apply $^{2}/_{3}$ inch of water (min/acre)
Handline Moveable Large Gun				
25 acres	350	420	75	52
50 acres	350	840	100	52
100 acres	350	1680	200	52
Hose Reel Large Gun				
25 acres	125	125	40	145
50 acres	250	250	100	72
100 acres	350	350	100	52
Handline Small Sprinkler				
25 acres	102	420	75	177
50 acres	102	840	100	177
100 acres	102	1680	200	177
Permanent Set Small Sprinkler				
25 acres	65	1600	100	279
50 acres	65	3200	150	279
100 acres	65	6400	300	279

Handline Moveable Large Gun

The handline moveable large gun system is connected to the pumping unit by an aluminum mainline system. The mainline runs the length of the field and connects to aluminum lateral delivery line (or lines in the 50-acre and 100-acre scenarios). Approximately one gun station per acre is sufficient to ensure consistent coverage assuming that the sample gun delivers water over a 150' radius and a 35% overlap in spray patterns.

This system is configured with shut-off valves on the mainline so that the pump does not need to be shut down and recharged on each movement of the gun. Nonetheless, considerable labor is required for each irrigation as pipe addition or removal is required when the gun moves from station to station. In these scenarios, one-half hour is allocated per irrigation per acre for this labor. Organizing and orchestrating the sequence of irrigations is management intensive as well.

As acreage increases, additional mainline and lateral piping is required and the diameter of the piping increases in order to handle greater flow requirements from the additional guns. In the 25-acre scenario, one gun is operated at a time with a second available to facilitate switching for subsequent sets. In the 50-acre scenario, two guns are operating simultaneously and a third available for switch-out. In the 100-acre case, four guns operate at one time with one available for switch-out.

Hose-Reel Gun Systems

Hose-reel systems are more appropriate for flat or slightly rolling fields and are considered because they require significantly less management time and labor than moveable pipe systems. The 25-acre system consists of a mainline that runs 600' to the middle of the field and then a 90 degree turn for 300'. The hose-reel system is set up at the end of the pipe and is unreeled for the remaining length of the field. A 125-GPM gun is attached to the end of the hose and slowly reeled in providing a uniform application of water over the tow path. When the application is complete, the reel is moved down the mainline to another station and the process repeated. Under this system, approximately three acres can be watered with one set of the hose reel system.

The 50- and the 100-acre scenarios use a larger reel system and 250-GPM and 350-GPM guns respectively. Both systems use the same hose reel system, but it is used twice as frequently, and with a slightly larger gun, in the 100-acre case. Under this system, approximately seven acres can be irrigated per pull, and two to three pulls per day can be achieved. Slightly higher investment costs are incurred for the 100-acre system due to a longer mainline.

Handline Moveable Small Sprinkler

The handline moveable small sprinkler is set up similarly to the handline moveable large gun. A mainline system runs on center the length of the field with laterals branching outwards. Laterals are connected to the mainline every 60'. Instead of mounting a large gun onto the end of the lateral line, small sprinklers (7.0 GPM) are set on risers every 50' along the laterals. Under this set-up, four acres can be irrigated at one time in the 25-acre case, eight and 16 in the 50- and 100-acre scenarios, respectively, using multiple lateral lines. Lateral valves are installed on the mainline to allow the pumping system to remain running while laterals are manually moved.

This system requires the most labor per irrigation, but it also allows for frost protection on those acres covered by a single irrigation set. Large amounts of management time are required to organize and orchestrate lateral pipe movement.

Permanent Set Small Sprinkler

Permanent set small sprinkler systems are the most capital-intensive irrigation systems. The system consists of small 7.0 GPM sprinklers set on risers spaced on a 50" x 60" grid. The water delivery system, composed of large diameter PVC pipe on the mainline and smaller diameter polyethylene pipe on the laterals, is buried underground. The pumping system is sized so that it can provide water to the entire field at one time in order to provide full frost protection coverage.

Permanent systems average between $2000 and $2500 per acre to construct, including materials and installation. At the beginning of the irrigation season, sprinkler heads and risers must be set-up and checked for leaks and performance. During the season, however, very little labor is required for operation.

ECONOMIC ANALYSIS OF IRRIGATION COSTS

This study focuses on calculating the ownership and operating costs of these four systems at three different acreage sizes. Ownership costs consist of depreciation and interest charges for the irrigation system plus taxes and insurance charges. Depreciation and interest charges are calculated on an annual cost basis using the Capital Recovery Method described in Appendix A. This is the approach approved by the National Task Force on Commodity Costs and Return Measurement Methods. Appendix A provides a detailed description of the investment costs for the different systems.

Ownership Expenses

Total investment costs are presented in Table 3. These figures represent the approximate cost to establish the four different systems described earlier including water source development, diesel engine, pump, mainline, and lateral delivery lines, sprinkler system, and installation labor. These costs were derived from interviews with irrigation equipment dealers conducted during 2001. Sales tax is not added to the total cost under the assumption that the grower holds a commercial agricultural production sales tax exemption certificate.

To derive the annual cost of these systems, each piece of equipment is depreciated over its estimated lifespan. Interest charges are added to the depreciation calculation and any salvage value at the end of the lifespan deducted from the annual charge. Long-term interest rates on irrigation equipment range between 7.5% to 10% depending upon the loan amount and buyer qualifica-

Table 3. Total investment costs for irrigation system establishment ($/field).

Irrigation System	25 Acres	50 Acres	100 Acres
Handline Moveable Large Gun	$41,000	$56,780	$80,760
Hose Reel Large Gun	$39,900	$53,759	$54,630
Handline Small Sprinkler	$45,038	$61,615	$93,315
Permanent Set Small Sprinkler	$63,564	$103,329	$185,750

Source: Authors' calculation from model results

tions (FCS). A fixed nominal investment interest rate of 9%, representative of "average" credit for loans written over a five- to ten-year period, is inflation adjusted to a real rate of 5.6%.[6] Lifespan and salvage coefficients used for calculating annual costs are presented in Table 4. Ownership costs are calculated by totaling depreciation, interest, taxes, and insurance charges.

This method of calculating the depreciation and interest cost of the investment differs from a financial analysis. A financial analysis would calculate principal and interest payments and then add an accounting measure of depreciation, which would differ from a depreciation measure based upon the useful economic lifespan of the implement. At the end of the loan repayment period, the equipment would be held free and clear of any encumbrance, but still have a remaining operational life. This remaining lifespan would be costless, in the financial sense, since the asset would be fully depreciated and interest charges paid. Financial returns during this period would be elevated since the equipment was "costless." An economic analysis, on the other hand, considers depreciation and interest as a "use" cost, similar to a lease payment or what one would need to set aside in a bank account to establish a system in the future.

In addition to depreciation and interest, ownership costs include insurance charges and property tax adjustments. Insurance rates range from $0.0056 to $0.0075 per $100 dollars of coverage for irrigation equipment (Diversified Agrisurance). The baseline analysis assumes a rate of $0.0068 per $100 dollars of coverage, calculated over the replacement value of the piece of equipment. Three of the four systems are aboveground systems that should not be considered as a land improvement and hence should not affect land valuation and taxable base. The permanent set system may be considered as a land improvement that could increase land value.

[6]Inflation averaged 3.2% annually for the 15-year period between 1987 and 2001.

Table 4. Lifespan, salvage value, and maintenance coefficients for irrigation components.

Components	Lifespan (years)	Salvage Value[1](%)	Maintenance[1] (%)
Water Source	33	0	2.0
Pumping System	15	15	4.0
PVC Tubing	20	0	1.0
Aluminum Tubing	20	33	1.0
Polyethylene Tubing	10	0	0.5
Sprinkler Guns	10	15	2.0
Hose Reel	10	15	4.0
Fittings	10	15	0.0

[1]As a percentage of total investment cost.

Ponds and impoundments may also increase land values as well. Evidence of tax reassessment after irrigation development is highly variable and specific to municipalities. In the baseline models, no new tax liability is assumed.

Operating Expenses

Operating costs to run and maintain the irrigation systems are calculated in a partial budget format; that is only costs associated with the operation of the irrigation system are captured. Each of these models assumes that there will be 12 irrigations per season on the land producing fruit and four upon non-bearing acreage. There are four primary components of the operating cost budgets: labor, power, maintenance, and interest charges.

Labor costs accumulate from two different sources: initial set up and end-of-season take-down of the system and variable labor usage per irrigation. The figures used to calculate labor charges are presented in Table 5. Managerial time is not included in the labor cost calculation. These per acre coefficients are applied uniformly across the three different acreage examples. A $9.40 hourly wage rate is applied in the calculations. This wage rate is based upon the 2001 Adverse Effect Wage Rate of $8.17 and inflated by 15% to account for meals and other benefits entitled to immigrant workers (USDA 2001a, USDA, 2001b). Alternatively, it can be seen as the benefits premium (Social Security, Unemployment Compensation, Workers Compensation Insurance) attached to attract local workers from non-agricultural employment alternatives. Since managerial labor is not included in the calculation, a constant cost-per-acre labor charge is calculated for the four different systems.

Table 5. Set-up/take-down and per irrigation labor requirements (hrs/acre).

Irrigation System	Set Up and Take Down[1]	Per Irrigation[2]
	----------- (Hours of labor/per acre)	-----------
Handline Moveable Large Gun	1	0.5
Hose Reel Large Gun	0.25	0.16
Handline Small Sprinkler	1	0.8
Permanent Set Small Sprinkler	2.4	0.083

[1]This figure represents the amount of time required at the beginning of the irrigation season to set up and end of the season to store the system.
[2]This figure represents the amount of time required to set up for an irrigation application, including moving pipe, moving guns, towing reel lines, and operating the pumping unit and valves.

Power costs are calculated by determining the number of hours that the pumping unit will operate in order to apply 8" of water on bearing land and $2\,^2/_3$" on non-bearing growth. Total pumping time is inflated by 10% to account for flushing, system testing, and mistakes. Total pumping time is then multiplied by hourly fuel-consumption rates of the different diesel motors and then by the per gallon price of diesel fuel ($1.25). This diesel price is based upon sales-tax-free prices from summer 2001. Average fuel costs decline as acreage increases reflecting economies of size in motor pumping.

Maintenance and upkeep charges are calculated for these systems as a fixed coefficient of initial purchase price. Maintenance and upkeep coefficients are derived from Paterson et al. (1996b) and are presented in the fourth column of Table 4. These coefficients represent an average charge that should be incurred over the life of the irrigation component, not one representing a new piece of equipment with little or no maintenance nor an old one with high upkeep costs. Pieces of equipment with moving parts require higher maintenance costs than fittings for example. Maintenance and upkeep on tubing represents limited unforseen breakage.

The final component of the operating budget is an interest charge on working capital used during the production season. The interest charge represents the financial cost of a short-term operating loan or the opportunity cost of producer capital used to pay for these expenses before blueberry receipts are received. A short-run nominal interest rate of 8%, inflation adjusted to 4.7%, is applied over a seven-month period of time, i.e., April through October on the balance of labor, fuel, and maintenance charges. This rate is a representative rate provided to producers by the Farm Credit Service for short-term operating loans.

RESULTS

The results presented in this section calculate the total annual cost for the different irrigation systems and the three field sizes. The total investment cost presented in Table 3 is annualized into depreciation and interest charges to derive the basis for annual ownership expense. Annual operating costs are added to the ownership costs to produce an estimate of the total annual cost of the irrigation system. This is a partial budget of the blueberry system because it only captures the costs associated with the irrigation system, not a full enterprise budget which would include all variable and fixed costs of production.[7] A summary of important price and cost assumptions used to calculate the partial budgets, breakeven yield, and payback period is summarized in Table 6.

From the annual cost budgets, breakeven yield impacts due to field irrigation are calculated. The breakeven yield is the minimum *additional* blueberry yield per acre every other year to pay off the total annual cost of the system. This additional (or incremental) yield is above the baseline yield of the field without irrigation. The third performance measure is an estimate of the earliest possible payoff period for the investment.

Since the price of blueberries has fluctuated dramatically over the past ten years, both the breakeven and repayment period calculations are evaluated over prices ranging from $0.30/lb to $0.65/lb. In addition, the yield response of blueberries to supplemental irrigation is also not known. As a result, the yield impact from irrigation is also varied from between 400 additional pounds per acre every other year to 4000 additional pounds per acre every other year.

Table 6. Price and cost assumptions applied to all models in the baseline scenarios.

Water source development cost ($/pond or $/well)	$15,000
Labor ($/hr)	$9.40
Diesel ($/gallon)	$1.25
Annual nominal capital investment interest rate (%/year)	9.0%
Annual nominal operating loan interest rate (%/year)	8.0%
Inflation rate (%/year)	3.2%
Insurance rate for irrigation equipment	0.7%

[7]These budgets can also be referred to as the incremental, or additional, cost of irrigation that should be added to production cost budget to produce the total enterprise budget.

Partial Cost Budgets

Incremental cost budgets are calculated on a total field basis and on a per acre account. The cost budget of the irrigation system is composed of two elements: ownership costs tied to depreciation, interest, tax, and insurance costs and operating charges distinctly attributable to the irrigation process. These budgets are presented in Tables 7, 8, 9, and 10 for the large gun, hose-reel traveler, handline small sprinkler, and permanent set small sprinkler systems, respectively. Overall, the hose-reel systems are the least expensive to own and operate, followed by the handline big gun system, and the handline sprinkler system. The permanent set system is the most costly. These illustrative budgets can be used to examine the tradeoffs between capital investment and annual operating charges, in particular tradeoffs between equipment and labor. The largest cost component lies with depreciation and interest of the irrigation equipment. Depreciation and interest accounts for 50% to 63% of total cost in the handline systems, 40% to 62% in the traveler systems, and 75% for the permanent set sprinkler arrangement. The importance of this cost category decreases as field size increases, illustrating economies of field size.

Labor is the second most important cost component. Both handline systems require considerable seasonal labor to move and operate the irrigation systems. Total labor cost is the highest on the handline sprinkler system, followed by the handline big gun system.

Table 7. Cost estimates for moveable big gun sprinkler systems ($/field or $/acre).

	----- 25 Acre ----		----- 50 Acre -----		--- 100 Acre ----	
Costs	Total	Per Acre	Total	Per Acre	Total	Per Acre
	------------------------------------ $ ------------------------------------					
Annual Operating Costs						
Labor	1,410	56.40	2,820	56.40	5,640	56.40
Fuel	830	33.19	1,060	21.20	2,040	20.40
Maintenance & Upkeep	921	36.82	1,179	23.59	1,569	15.69
Interest	86	3.44	138	2.75	252	2.52
Total Operating Costs	3,246	129.85	5,197	103.94	9,501	95.01
Annual Ownership Costs						
Depreciation & Interest	4,279	171.16	5,788	115.76	8,088	80.88
Tax and Insurance	279	11.15	386	7.72	549	5.49
Total Ownership Costs	4,558	182.31	6,174	123.48	8,637	86.37
Total Annual Cost	7,804	312.16	11,371	227.42	18,137	181.37

Source: Authors' calculation.

Table 8. Cost estimates for hose-reel systems ($/field or $/acre).

Costs	25 Acre Total	25 Acre Per Acre	50 Acre Total	50 Acre Per Acre	100 Acre Total	100 Acre Per Acre
	$					
Annual Operating Costs						
Labor	418	16.73	837	16.73	1,673	16.73
Fuel	1,394	55.76	3,518	70.36	7,036	70.36
Maintenance & Upkeep	1,144	45.77	1,538	30.76	1,546	15.46
Interest	80	3.22	160	3.20	279	2.79
Total Operating Costs	3,037	121.47	6,053	121.05	10,534	105.34
Annual Ownership Costs						
Depreciation & Interest	4,386	175.43	5,754	115.09	5,822	58.22
Tax & Insurance	271	10.85	366	7.31	371	3.71
Total Ownership Costs	4,657	186.28	6,120	122.40	6,193	61.93
Total Annual Cost	7,694	307.75	12,173	243.45	16,727	167.27

Source: Authors' calculation.

Table 9. Cost estimates for handline small sprinkler systems ($/field or $/acre).

Costs	25 Acre Total	25 Acre Per Acre	50 Acre Total	50 Acre Per Acre	100 Acre Total	100 Acre Per Acre
	$					
Annual Operating Costs						
Labor	2,444	97.76	4,888	97.76	9,776	97.76
Fuel	830	33.19	1,047	20.94	2,064	20.64
Maintenance & Upkeep	851	34.04	1,036	20.72	1,364	13.64
Interest	112	4.49	190	3.79	359	3.59
Total Operating Costs	4,237	169.48	7,161	143.21	13,563	135.63
Annual Ownership Costs						
Depreciation & Interest	6,751	270.06	9,133	182.66	12,661	126.61
Tax & Insurance	306	12.25	419	8.38	635	6.35
Total Ownership Costs	7,058	282.31	9,552	191.04	13,296	132.96
Total Annual Cost	11,295	451.78	16,712	334.25	26,859	268.59

Source: Authors' calculation.

Permanent set systems have the third highest labor cost due to initial set-up and take-down requirements. Hose-reel traveler systems have the lowest labor cost. Labor cost accounts for 16% to 33% of total cost in the handline systems, but only 5% to 12% in the traveler and permanent set systems.

Table 10. Cost estimates for permanent set small sprinkler systems ($/field or $/acre)

Costs	----- 25 Acre ----		----- 50 Acre -----		--- 100 Acre ----	
	Total	Per Acre	Total	Per Acre	Total	Per Acre
	---------------------------------- $ ----------------------------------					
Annual Operating Costs						
Labor	1,284	51.36	2,568	51.36	5,136	51.36
Fuel	271	10.82	439	8.78	878	8.78
Maintenance & Upkeep	1,009	40.36	1,292	25.84	2,307	23.07
Interest	70	2.79	117	2.34	226	2.26
Total Operating Costs	2,633	105.33	4,416	88.32	8,548	85.48
Annual Ownership Costs						
Depreciation & Interest	7,996	319.84	14,601	292.02	27,156	271.56
Tax & Insurance	432	17.29	703	14.05	1,263	12.63
Total Ownership Costs	8,428	337.13	15,304	306.08	28,419	284.19
Total Annual Cost	11,062	442.46	19,720	394.39	36,967	369.67

Source: Authors' calculation.

The third most important cost category is linked to fuel costs. Although the permanent set systems require the largest diesel engines for pumping, they run the fewest hours to deliver the required water. As a result, fuel costs are only 2% of the budget. Fuel costs are 6% to 10% of the handline budgets. Hose-reel traveler systems require the longest operation for water application, creating fuel costs of between 16% and 38% of the total budget. Combined, these three cost components account for about 90% of total irrigation costs.

Modified Breakeven Analysis

Using the cost estimates in the previous section, a modified breakeven analysis was conducted. A typical breakeven analysis would derive the minimum yield impact attributable to irrigation to pay off the total annual cost, if price were known, or it could derive the minimum price if yield response curves were available.

This study calculates the breakeven point by using a modified approach. The approach calculates the net return to irrigation investment by varying both components of net revenue: price and yield response. Price varies between $0.30/lb and $0.65/lb. Yield response varies from a low of 400 lbs/acre to a high of 4000 lbs/acre.[8] Returns calculated using this approach represent the incremental gain or loss to irrigation, not a measure of an entire enterprise profit or loss. Total enterprise profit and loss could be calculated by combining the partial budget on the irrigation decision with an enterprise budget without irrigation. The result is a calculation that represents the return to management time and water. Complete tables presenting the modified breakeven approach are presented in Appendix Table B1 to B12

Tables B1 to B12 derive the yield advantage and price combinations that will pay for the total annual costs of the systems. Across the top of each table, yield advantage varies from 400 lbs/acre to 4000 lbs/acre. Along the first column, price varies from $0.30/lb to $0.65/lb. In each table, the approximate breakeven yield and price combination is shaded. The breakeven line descends from the upper right corner of the table (where prices are low and yields high) to the bottom left (where prices are high and yield low). These tables are presented in this manner to illustrate the yield-price combinations that generate profits or losses for the blueberry producer.

A more precise presentation of breakeven yield impact is presented in Table 11. Table 11 examines just the $0.40/lb price scenario and derives the minimum yield to recover total annual costs in order to compare this case against the state average yield. In Maine, the statewide average yield is about 2200 lbs/acre. In two cases out of the 12, yields will need to more than double for a grower to recover the total annual cost of the irrigation investment. On the other hand, yields need to increase by less than 50% above the statewide average in the handline and hose-reel large gun systems on 100 acres.

Consistent with the previous table showing decreasing cost with size, Table 11 indicates that the breakeven yield to pay for the annual ownership and operating expenses is the lowest for the 100-acre field. This effect is more dramatic for the over-ground systems where the 25-acre cases are between 70% to 91% more expensive than their 100-acre counterparts. Per acre breakeven yield is the highest for the permanent set system, but the difference between the 25-acre and the 100-acre systems is less than 22%.

Payoff Period

The final measure of economic performance is calculation of the number of years required to pay for the investment. This measure is calculated differently from the cost budgets or the breakeven

---

[8]Yield response research is currently under investigation at The University of Maine's Blueberry Hill Farm in Jonesboro, Maine. As an alternative to subjective yield response estimates, compare yields from years when water was abundant to yields when water was limiting.

Table 11. Breakeven yield impact to pay off total annual cost at a blueberry price of $0.40/lb.

Irrigation System	25 Acre Yield*	25 Acre % above state average yield	50 Acre Yield*	50 Acre % above state average yield	100 Acre Yield*	100 Acre % above state average yield
Handline Moveable Large Gun	1,561	71	1,137	52	907	41
Hose Reel Large Gun	1,539	70	1,217	55	836	38
Handline Small Sprinkler	2,259	103	1,671	76	1,343	61
Permanent Set Small Sprinkler	2,212	101	2,972	90	1,848	84

*lbs/acre every other year.
Source: Authors' calculation.

calculation in that it assumes that all investment costs are paid at installation. Operating costs from the budget calculations are subtracted from revenue in order to calculate returns over incremental operating cost (ROIOC). Ownership costs are not included in the calculation since payment for the equipment occurred before the first year. However, the opportunity cost of the investment capital is included as a cost. The opportunity cost of the investment is calculated as the investment amount multiplied by the real investment interest rate. The ROIOC amount (including the opportunity cost of the investment) is used to payoff the investment. Each year, the static ROIOC calculation is discounted by 5.6% in the same manner as one would conduct a net present value analysis. The payoff year is the first season when the whole investment is paid off.

Calculating the earliest possible payoff of the investment is also dependent upon whether the equipment is fully used from year to year. As Figures 1 to 6 indicate, there are years when irrigation would not be necessary and the equipment would stand idle. In a very good rainfall year, nonirrigated yield would be comparable to irrigated yield thereby eliminating any incremental yield effect. At the same time, some operating costs plus the opportunity cost of the investment would accumulate.

The payoff period calculation does not control for this type of uncertainty. It assumes very strong conditions: (1) the equipment is used as described above, for the same number of hours and irrigations from year to year; (2) it is used consistently from purchase until the payoff period; and (3) price and yield effects are constant over time. These calculations thus assume a string of poor rainfall years and well-managed agronomic treatment of the crop. This calculation therefore represents the *earliest* possible payoff period for the investment. The earliest possible payoff year is presented for two yield impact scenarios—1600 lbs/acre and 3200 lbs/acre—at $0.40/lb in Table 12. Appendix C presents repayment tables for all systems with prices ranging from $0.35/lb to $0.55/lb and yield effects from 400 lb/acre to 4000 lb/acre. Calculation of the breakeven payoff year is not carried beyond 15 years.

Table 12 indicates a wide range of repayment periods that decrease as field size increases. Repayment periods also decrease as yield impact increases, as expected.[9] The opportunity cost of the investment is a large additional charge that must be factored into the investment decision since it represents a forgone alterative use for the investment funds. The table also illustrates the importance of having a well-managed field that can take advantage of additional moisture. When the yield impact doubles, repayment period declines by more than a proportional factor. Limited yield effects and small field size make it difficult to payoff large capital investment.

Table 12. Earliest possible repayment period at a blueberry price of $0.40 per lb (years).

Irrigation System	1600 lb/acre yield impact 25 Acres	50 Acres	100 Acres	3200 lb/acre yield impact 25 Acres	50 Acres	100 Acres
Handline Moveable Large Gun	>15	10	6	5	3	2
Hose Reel Large Gun	>15	11	4	5	3	2
Handline Small Sprinkler	>15	>15	10	6	4	3
Permanent Set Small Sprinkler	>15	>15	>15	9	6	5

Source: Authors' calculation.

[9]Interpretation of this table, and Appendix C, should be done cautiously since it is constructed upon very strong assumptions. A yield effect from an "average" or "good" year should be assumed as a representative yield effect rather than a "poor" rainfall year, which would artificially speed forward the repayment calculation.

Sensitivity of Results

The three most important cost components were identified as depreciation and interest, labor, and fuel. Depreciation and interest are calculated on the cost of developing the water source, the prices of the equipment, their economic lifespan, and the interest rate used for capitalization. Labor costs are determined largely by the prevailing wage rate and fuel through the diesel price.

This study has concentrated on deriving cost estimates for irrigation systems. While the cost of these system did not vary much from dealer to dealer, the cost of developing the water source is highly variable. The current assessments assume that $15,000 is required to construct a water source. This is a low estimate if a well is drilled and an impoundment constructed but likely on the high end if a pond is scraped with the hope of locating an artesian spring. Labor cost was calculated based upon an hourly wage rate of $9.40 and fuel costs using a $1.25 diesel price.

The impact of doubling water source development costs to $30,000 is presented in Table 13. Agricultural well-drilling costs in Washington County ranged from $10,000 to $25,000 in 2001 (Pennell). This would put the baseline figure of $15,000 within the range of observed costs, but on the lower end. The cost to develop a well is dependent upon numerous factors including underlying geology and location within the field and the regional watershed. Since this expense is one of the largest in the budgets, the results were recalculated using a $30,000 water development cost in order to derive its impact upon cost. The impact of increasing the cost to $30,000 is presented in Table 13, and it is also presented in percentage terms as a change in total cost, from the original base of $15,000, in Table 14.

Doubling the cost of the water source can be used to simulate more expensive drilling or pond development expenses or it can also be attributed to the addition of permitting costs.[10] Overall, doubling the amount spent on developing the water source has a greater impact upon the results of the 25-acre field than the 50- or 100-acre fields. This is due to the fact that the water source is a larger proportion of the ownership cost in the small fields than in the larger fields where equipment costs dominate ownership costs.

Under the scenario of an every-other-year yield increase of 1600 lb/acre, doubling the water development cost alters the repayment period analysis. All systems on the 25- and 50-acre fields are repaid

---

[10]The additional cost could also represent a system consisting of a well with an adjacent impoundment, plus the purchase of a high-volume low-pressure feeder pump. The operating cost budget, however, would need to be adjusted to account for the additional fuel or electricity required to operate this pump.

Table 13. Cost, breakeven and repayment impacts of increasing water development cost to $30,000.

Irrigation System	Investment cost ($)	Ownership cost/acre ($)	Total annual cost/acre ($)	Breakeven Yield at 0.40/lb	Earliest repayment at $0.40/lb and 1600/lbs every other year	and 3200/lbs every other year
Handline Moveable Large Gun						
25 Acres	56,000	226.80	368.98	1,845	>15	8
50 Acres	77,505	145.73	255.83	1,279	>15	4
100 Acres	103,524	97.49	195.58	978	8	3
Hose-Reel Large Gun						
25 Acres	54,900	230.77	364.57	1,823	>15	8
50 Acres	68,759	144.65	271.86	1,359	>15	4
100 Acres	69,630	73.05	181.48	907	5	2
Handline Small Sprinkler						
25 Acres	60,038	326.80	508.60	2,543	>15	10
50 Acres	76,615	213.28	362.66	1,813	>15	5
100 Acres	108,315	144.08	282.79	1,414	13	3
Permanent Set Small Sprinkler						
25 Acres	78,564	381.63	499.28	2,496	>15	14
50 Acres	118,329	328.32	422.80	2,114	>15	8
100 Acres	200,750	295.32	383.88	1,919	>15	6

Source: Authors' calculation.

Table 14. The percentage change of total cost to a 10% change in the price of three key inputs (percentage change).

	Water Development ($/pond or $/well)			Labor Wage ($/hr)			Diesel Price ($/gallon)		
	Acres								
Irrigation System	25	50	100	25	50	100	25	50	100
Handline Moveable Large Gun	1.8	1.2	0.8	1.9	2.5	3.2	1.1	1.0	1.2
Hose Reel Large Gun	1.8	1.2	0.8	0.6	0.7	1.0	1.9	3.0	4.3
Handline Small Sprinkler	1.3	0.9	0.5	2.2	3.0	3.7	0.8	0.6	0.8
Permanent Set Small Sprinkler	1.3	0.7	0.4	1.2	1.3	1.4	0.3	0.2	0.2

Source: Authors' calculation.

in more than 15 years. The additional investment cost adds one to three years on the 100-acre fields. Under the high yield scenario (3200 lb/acre yield impact every other year), the higher water development costs add three to five years on the 25-acre fields and a maximum of only three years on the 50-acre fields, and one year to the 100-acre fields. In two cases– the hose-reel traveler and the handline small sprinkler– doubling the cost of the water source did not alter the repayment period on the 100-acre fields.

The sensitivity of the total annual cost estimates to a 10% change in the price of these three inputs is presented in Table 14. If an increase in one of these prices is a primary concern in the decision process, then identifying the impact upon output and determining whether cost is highly sensitive to increases in these input prices can shed light on the implications of unforseen or unpredictable changes. Each entry represents the percentage change in total cost when water development, the hourly wage rate, or the per gallon cost of diesel increases by 10%. For example, total annual cost of the permanent set small sprinkler systems increase by about 1/5 of 1% when diesel prices increase by 10% (Table 14 columns seven, eight, and nine of the bottom row of the results). On the other hand, total annual cost increases by 3.7% for the 100-acre handline small sprinkler scenario when the wage rate increase by 10% (Table 14 column six, row three).

The current budgets estimate that the cost of developing the water source is $15,000. While no system is highly sensitive to changes in this cost, a 10% increase only represents $1,500 of additional cost. On the other hand, both the moveable gun system and the moveable sprinkler systems are moderately sensitive to increases in the wage rate due to their high reliance upon seasonal labor for pipe movement and operation. Hose-reel systems are the most sensitive to an increase in diesel prices due to the time that the power unit must operate to distribute irrigation water.

Financial Risk

This study has presented analysis based upon an economic methodology used to calculate commodity costs and returns. A financial analysis would differ from this method in several areas; however, the most important would be in the treatment of the capital investment, repayment, depreciation, and income tax burden (Robinson and Barry 1996: 201). If the irrigation investment is financed through loans, the producer would assume additional debt burden and repayment responsibility. Loans for irrigation equipment are usually written for five- to ten-year terms. As a result, financial calculations, as compared to economic calculations, would increase ownership costs by up to 50%. Breakeven yield impact would increase by a proportional amount.

The financial risk that accompanies investment in supplemental irrigation occurs when the equipment is not used or when there is no yield advantage to irrigation. In such a situation, there is no additional revenue for irrigation debt repayment. Careful consideration of capital debt recovery capacity is required to ensure that default on loan payments will not occur in years when irrigation does not provide additional revenue. The economic analysis presented in the preceding section should be used as a first step in the decision question. The economic analysis measures whether irrigation is a good use of production resources. A subsequent step is to calculate whether the financial risk can be supported by examining budget and cash flow statements.

CONCLUSIONS

Rainfall in Maine's blueberry growing region is highly variable. There is 1" or more of rainfall per week during the critical period from mid-July to late August in fewer than one in every five years. There is a 50% chance or receiving at least ¾" during the same period.

This study has estimated the investment, annual operating, and ownership costs of four types of supplemental irrigation systems for three different acreage sizes. Using these cost estimates, the breakeven yield impact was calculated over a range of prices ranging from $0.30/lb to $0.65/lb. Based upon the cost estimates, the earliest possible year to pay off the investment was calculated under the assumption of constant and consistent usage and prices.

Overall, the investment cost for irrigation systems ranges from a low of $39,900 for a 25-acre field fitted with a traveling gun system to a permanent set small sprinkler system on a 100-acre field for $185,750. Ownership costs, calculated by summing depreciation, interest, and insurance costs for the equipment varied from $62/acre to $337/acre. All investment scenarios assume that it will cost $15,000 to develop the water source to supply the irrigation system. This is on the low end for a drilled well and impoundment system, but on the high side for a pond. Total costs for the systems increase from 0.4% to 1.8% when the cost of the water source increases by 10%. While the sensitivity of the results to ponds cost does not seem strong in relative terms, this cost can be dramatically different depending on geography and underlying geology and whether the pond is located in an unorganized township requiring permitting.

Operating costs varied significantly between the systems. Operating costs are composed of labor, fuel, maintenance, and interest charges attributable to the irrigation system. Operating cost ranged from $85/acre to $169/acre. Labor and fuel costs were the largest expenses. Both handline moveable systems were moderately sensitive to changes in the prevailing wage rate due to their large reliance on labor for moving, setting, and operating the systems. Given that the Adverse Agricultural Wage Rate increased 6.3% from 2000 to 2001, labor costs may continue to increase faster than the rate of inflation. The hose-reel traveler systems were the most sensitive to fuel price variability since their pumping systems are operated the longest. Overall, traveler systems were the least expensive systems, followed by moveable big gun, moveable small sprinkler, and permanent set small sprinkler systems.

Based upon these cost estimates, the breakeven yield impact on fruit-bearing acreage was calculated over prices from $0.30/lb to $0.65/lb. The breakeven yield is defined as the minimum additional yield, attributed to irrigation, to pay for total per acre irrigation costs. Breakeven yield is calculated based upon an average acre composed of half fruit-bearing and half vegetative growth. The breakeven requirements ranged from 918 lbs/acre every other year to 2,542 lbs/acre every other year.

The minimum length of time to pay off the investment was calculated using a net-present-value approach and ranged over several price and yield response scenarios. This calculation was based upon the assumption that irrigation would be used consistently and at a constant rate from year to year. Under the assumption of a price of $0.40/lb, irrigation investment was difficult to repay with only a 1600-lb/acre yield response every other year, especially on the 25-acre fields. Under the assumption of an increase of 1600-lb/acre every other year, the repayment period was greater than 15 years for all acreages under the permanent set system. When the yield response doubled to 3200 lb/acre every other year, the repayment period decreased to between two to six years in the aboveground systems to between five and nine years for the permanent set system.

Under conservative price assumptions and a yield response of 2300 lbs/acre every other year, supplemental irrigation systems are repayable and can add income per acre to a farm, as long as production without irrigation is profitable. This study has highlighted the key differences in system design, cost, and variable input requirement in order to improve farmer decisionmaking when considering irrigation investment. Irrigation investment requires considerable personal investigation in order to decide which system is the most appropriate given the constraints and opportunities facing individual growers. Given the highly variable and largely insufficient rainfall patterns of the past 40 years, irrigation has the potential to dramatically reduce production risk, but at the same time increase the exposure of farmers to financial risk.

LITERATURE CITED

Bernardo, D.J. 1988. The effect of spatial variability of irrigation applications on risk-efficient irrigation strategies. *Southern Journal of Agricultural Economics* 20(1): 77–86.

Boggess, W.G., and C.B. Amerling. 1983. A bioeconomic simulation analysis of irrigation investments. *Southern Journal of Agricultural Economics* 15(1): 85–91.

Boggess, W.G., and J.T. Ritchie. 1988. Economic and risk analysis of irrigation decisions in humid regions. *Journal of Production Agriculture* 1(2): 116–122.

Boggess, W.G., G.D Lynne, J.W. Jones, and D.P. Swaney. 1983. Risk-return assessment of irrigation decisions in humid regions. *Southern Journal of Agricultural Economics* 15(2): 135–143.

Bosch, D.J. and V.R. Eidman 1987. Valuing information when risk preferences are nonneutral: An application to irrigation scheduling. *American Journal of Agricultural Economics* 69(3): 658–668.

Diversified Agrisurance. 2001. <http://www.dfsfin.com/directory/default.asp>.

Hatch, L.U., W.E. Hardy Jr., E.W. Rochester, and R.L. Pickren. 1991. A farm management analysis of supplemental center-pivot irrigation in humid regions. *Journal of Production Agriculture* 4(3): 442–447.

Leiby, J.D., and M.C. Marra. 1993. The profitability of irrigating lowbush blueberries in Maine: Preliminary analysis of secondary data. Department of Agricultural and Resource Economics Staff Paper #445, University of Maine, Orono, Maine.

Marra, M.C., and T.A. Woods. 1990. The profitability of supplemental irrigation for Maine potatoes. Maine Agricultural Experiment Station Bulletin #832.

Martin, E.C., J.T. Ritchie, and B.D. Baer. 1996. Computer programs: Assessing investment risk of irrigation in humid climates. *Journal of Production Agriculture* 9(2): 228–233.

National Climatic Data Center (NCDC). 2001. <http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwDI~SelectStation~USA~ME>.

Patterson, P.E., King, B.R., and R.L. Smathers. 1996a. Economics low-pressure sprinkler irrigation systems: Center pivot and linear move. University of Idaho Cooperative Extension Service Bulletin No. 787.

Patterson, P.E., B.R. King, and R.L. Smathers. 1996b. Economics of sprinkler irrigation systems: Handline, solid set, and wheeline University of Idaho Cooperative Extension Service Bulletin No. 788.

Pennell, N. 2001. Personal interview. 26 September.

Robinson, L.J., and P.J. Berry. 1996. *Present Value Models and Investment Analysis.* Northport, AL: The Academic Page.

Scherer, T., and J. Weigel. 1993. Planning to irrigate…a checklist. North Dakota State University Extension Service, Fargo, ND.

USDA. 2001a. 1 October 2001. <http://www.usda.gov/oce/oce/labor-affairs/aewr01.htm>.

USDA. 2001b. 1 October 2001. <http://www.usda.gov/oce/oce/labor-affairs/aewr2001.htm>.

APPENDIX A–ESTIMATING OWNERSHIP COSTS

Ownership costs differ from investment cost in that they represent the value of service provided by a long-term asset over time rather than a one-time outlay. The primary component of ownership cost is the depreciation and interest charge tied to the investment itself. Secondary costs include maintenance and upkeep and taxes and insurance.

Depreciation and Interest

The investment costs of the irrigation decision should be allocated over the useful life of the asset in order to derive an estimate of the annual ownership costs. Ownership costs are composed of the annual charge for depreciation of the equipment, based upon wear-and-tear and obsolescence, and the opportunity cost of financial capital tied to the investment. The opportunity cost of the investment is the real interest rate.

Intuitively, this amount can be thought of as the amount of money that should be budgeted for the equipment in order to pay it off during its useful life. In many situations, the useful life of an asset can exceed the repayment period thereby providing the impression that the equipment is costless. This method is also similar to the idea of saving for the purchase of a new implement in the future based upon a current price and an expected rate of inflation.

Depreciation and interest were calculated using the capital recovery method which is recommended over the straight-line depreciation plus average rate of return on investment. The annualized cost of the asset is calculated as

where

$$A = P \times \frac{i(1+i)^n}{(1+i)^n - 1} - SV \times \frac{i}{(1+i)^n - 1} \quad \textbf{(1)}$$

A = the annual cost of the implement;
P = the purchase price;
i = the real interest rate;
SV = the salvage value of the implement at the end of its useful life; and
n = the economic life of capital good.

Annual costs are divided into two parts. The first part of the formula calculates the depreciation and interest charge on the purchase amount. The second part of the equation calculates the annualized value of the salvage receipt. This receipt occurs at the end of the implements life as a lump sum pay-out. Analogous to the amortization of a purchase amount, this component of depreciation and interest must be accounted for in order to establish the annualized net cost—net of salvage income at the end of the lifespan—of an implement.

Maintenance and Upkeep

In addition to the depreciation of the equipment, annual maintenance and upkeep charges are included. These costs are often computed as a percentage of the purchase price of the piece of equipment. Engines, pumps and other mechanical items usually require more annual maintenance than non-moving parts. This charge is calculated as

$$M = P \times AM \qquad \textbf{(2)}$$

where
M = Annual maintenance charge; and
AM = Estimate average percentage of original cost required for upkeep.

Taxes and Insurance

Irrigation investment requires insurance coverage, especially if bank financed. The cost of insurance is calculated over the average level of the investment using a rate of 0.68%. In addition, irrigation investment can raise the value of your property and thereby increase property tax charges. This charge is calculated as

$$IN = r \times P \qquad \textbf{(3)}$$

where
IN = Annual insurance and tax charge; and
r = Combined insurance and tax mill rate.

Total ownership costs can be calculated as the sum of depreciation plus interest and insurance plus taxes or

$$OC = A + IN \qquad \textbf{(4)}$$

This calculation can be used to estimate the economic cost of any investment that has a lifespan greater than one year. The purpose of annualizing the investment cost is to derive the annual cost associated with purchase and to compare it with expected benefits. This cost can also be used to calculate a breakeven yield increase to pay for the investment decision. The list of equipment used for the calculations is presented in Tables A1 through A12. Maintenance costs are included in the operating cost budgets.

Table A1. Investment and ownership cost for a handline moveable gun system on a 25-acre field ($/field).

Item	Qty (No.)	Unit	Price per unit ($)	Total Purchase Price ($)	Salvage Value ($)	Useful Life (Years)	Depreciation and Interest ($)	Tax and Insurance (rate/$)	Tax and Insurance Charge ($)	Annual Ownership Cost($)
Water Source										
Well/Pond	1	well	15,000	15,000	0	33	1,010	0.007	102	1,112
Permitting	1	lump charge	0	0	0	33	0	-	-	-
Irrigation System Pump										
Engine (75 HP)	1	engine	7,000	7,000	1,050	15	657	0.007	48	705
Pump (420 GPM)	1	pump	3,500	3,500	525	15	329	0.007	24	352
Base and housing	1	base/housing	1,000	1,000	50	15	98	0.007	7	105
Suction, discharge, primer, check valve assembly	1	suction unit	800	800	40	15	79	0.007	5	84
(expansion)	-		0	0	0	1	0	0.007	-	-
Mainline										
Mainline to field*	100	feet	5	450	150	20	34	0.007	3	37
Mainline within field*	1,400	feet	5	6,300	2,100	20	474	0.007	43	516
(expansion)	-		0	0	0	1	0	0.007	-	-
(expansion)	-		0	0	0	1	0	0.007	-	-
Application System										
Valve T	6	valve T	200	1,200	180	10	146	0.007	8	154
Guns (350 GPM) (includes stand and valve opener)	2	sprinkler gun	2,100	4,200	630	10	512	0.007	29	541
End Plugs	2	plug	30	60	9	10	7	0.007	0	8
90 degree elbow fittings	2	elbow	120	240	36	10	29	0.007	2	31
(expansion)	-		0	0	0	10	0	0.007	-	-
Miscellaneous										
Installation/set up charges	1	installation	0%	0	0	20	0	0.007	-	-
Pipe trailer	1	trailer	1,250	1,250	417	1	904	0.007	9	912
(expansion)	-		0	0	0	1	0	0.007	-	-
Total Charges				**41,000**	**5,187**		**4,279**		**279**	**4,558**

* = (6" Aluminum)

Table A2. Investment and ownership cost for a handline moveable gun system on a 50-acre field ($/field).

Item	Qty (No.)	Unit	Price per unit ($)	Total Purchase Price ($)	Salvage Value ($)	Useful Life (Years)	Depreciation and Interest ($)	Tax and Insurance (rate/$)	Tax and Insurance Charge ($)	Annual Ownership Cost($)
Water Source										
Well	1	well	15,000	15,000	0	33	1,010	0.007	102	1,112
Permitting	1	lump charge	0	0	0	33	0	-	-	-
Irrigation System Pump										
Engine (100 HP)	1	engine	9,500	9,500	1,425	15	892	0.007	65	956
Pump (840 GPM)	1	pump	4,000	4,000	600	15	375	0.007	27	403
Base and housing	1	base/housing	1,000	1,000	50	15	98	0.007	7	105
Suction, discharge, primer, check valve assembly	1	suction unit	800	800	40	15	79	0.007	5	84
(expansion)	-		0	0	0	1	0	0.007	-	-
Mainline										
Mainline to field*	100	feet	5	450	150	20	34	0.007	3	37
Mainline within field*	1,200	feet	9	10,200	3,400	20	767	0.007	69	836
Mainline within field**	1,200	feet	5	5,400	1,800	20	406	0.007	37	443
(expansion)	-		0	0	0	1	0	0.007	-	-
Application System										
Valve T	8	valve T	225	1,800	270	10	219	0.007	12	232
Guns (350 GPM) (includes stand and valve opener)	3	sprinkler gun	2,100	6,300	945	10	768	0.007	43	811
End Plugs	3	plug	30	90	14	10	11	0.007	1	12
90 degree elbow fittings	3	elbow	120	360	54	10	44	0.007	2	46
8"-4" Reducers	3	reducer	65	195	29	10	24	0.007	1	25
8" T fitting	3	t fitting	145	435	65	10	53	0.007	3	56
Miscellaneous										
Installation/set up charges	1	installation	0%	0	0	20	0	0.007	-	-
Pipe trailer	1	trailer	1,250	1,250	313	1	1,008	0.007	9	1,016
(expansion)	-		0	0	0	1	0	0.007	-	-
Total Charges				**56,780**	**9,155**		**5,788**		**386**	**6,174**

*(8" Aluminum) **(6" Aluminum)

Table A3. Investment and ownership cost for a handline moveable gun system on a 100-acre field ($/field).

Item	Qty (No.)	Unit	Price per unit ($)	Total Purchase Price ($)	Salvage Value ($)	Useful Life (Years)	Depreciation and Interest ($)	Tax and Insurance (rate/$)	Tax and Insurance Charge ($)	Annual Ownership Cost($)
Water Source										
Well/Pond	1	well	15,000	15,000	0	33	1,010	0.007	102	1,112
Permitting	1	lump charge	0	0	0	33	0	-	-	-
Irrigation System Pump										
Engine (200 HP)	1	engine	12,000	12,000	1,800	15	1,126	0.007	82	1,208
Pump (1680 GPM)	1	pump	5,000	5,000	750	15	469	0.007	34	503
Base and housing	1	base/housing	1,100	1,100	55	15	108	0.007	7	116
Suction, discharge, primer, check valve assembly	1	suction unit	800	800	40	15	79	0.007	5	84
(expansion)	-		0	0	0	1	0	0.007	-	-
Mainline										
Mainline to field*	100	feet	9	850	283	20	64	0.007	6	70
Mainline within field**	2,400	feet	7	15,600	5,200	20	1,173	0.007	106	1,279
Mainline within field***	2,400	feet	5	10,800	3,600	20	812	0.007	73	885
(expansion)	-		0	0	0	1	0	0.007	-	-
Application System										
Valve T	16	valve T	225	3,600	540	10	439	0.007	24	463
Guns (350 GPM) (includes stand and valve opener)	6	sprinkler gun	2,100	12,600	1,890	10	1,536	0.007	86	1,622
End Plugs	6	plug	30	180	27	10	22	0.007	1	23
90 degree elbow fittings	6	elbow	120	720	108	10	88	0.007	5	93
8"-4" Reducers	6	reducer	65	390	59	10	48	0.007	3	50
8" T fitting	6	t fitting	145	870	131	10	106	0.007	6	112
Miscellaneous										
Installation/set up charges	1	installation	0%	0	0	20	0	0.007	-	-
Pipe trailer	1	trailer	1,250	1,250	313	1	1,008	0.007	9	1,016
(expansion)	-		0	0	0	1	0	0.007	-	-
Total Charges				**80,760**	**14,795**		**8,088**		**549**	**8,637**

*(10" Aluminum) ** (8" Aluminum) *** (6" Aluminum)

Table A4. Investment and ownership cost for a hose reel traveller gun system on a 25-acre field ($/field).

Item	Qty (No.)	Unit	Price per unit ($)	Total Purchase Price ($)	Salvage Value ($)	Useful Life (Years)	Depreciation and Interest ($)	Tax and Insurance (rate/$)	Tax and Insurance Charge ($)	Annual Ownership Cost($)
Water Source										
Well/Pond	1	well	15,000	15,000	0	33	1,010	0.007	102	1,112
Permitting	1	lump charge	0	0	0	33	0	-	-	-
Irrigation System Pump										
Engine (40 HP)	1	engine	7,000	7,000	1,050	15	657	0.007	48	705
Pump (125 GPM)	1	pump	2,500	2,500	375	15	235	0.007	17	252
Base and housing	1	base/housing	1,000	1,000	50	15	98	0.007	7	105
Suction, discharge, primer, check valve assembly	1	suction unit	800	800	40	15	79	0.007	5	84
(expansion)	-		0	0	0	1	0	0.007	-	-
Mainline										
Mainline to field*	100	feet	2	200	67	20	15	0.007	1	16
Mainline within field*	1,000	feet	2	2,000	667	20	150	0.007	14	164
(expansion)	-		0	0	0	1	0	0.007	-	-
(expansion)	-		0	0	0	1	0	0.007	-	-
Application System										
Hose reel system (gun included)	1	hose reel system	10,000	10,000	1,500	10	1,219	0.007	68	1,287
End Plugs	1	plug	30	30	5	10	4	0.007	0	4
90 degree elbow fittings	1	elbow	120	120	18	10	15	0.007	1	15
(expansion)	-		0	0	0	1	0	0.007	-	-
Miscellaneous										
Installation/set up charges	1	installation	0%	0	0	20	0	0.007	-	-
Pipe trailer	1	trailer	1,250	1,250	417	1	904	0.007	9	912
(expansion)	-		0	0	0	1	0	0.007	-	-
Total Charges				**39,900**	**4,188**		**4,386**		**271**	**4,657**

*(3" Aluminum)

Table A5. Investment and ownership cost for a hose reel traveller gun system on a 50-acre field ($/field).

Item	Qty (No.)	Unit	Price per unit ($)	Total Purchase Price ($)	Salvage Value ($)	Useful Life (Years)	Depreciation and Interest ($)	Tax and Insurance (rate/$)	Tax and Insurance Charge ($)	Annual Ownership Cost($)
Water Source										
Well/Pond	1	well	15,000	15,000	0	33	1,010	0.007	102	1,112
Permitting	1	lump charge	0	0	0	33	0	-	-	-
Irrigation System Pump										
Engine (100 HP)	1	engine	9,500	9,500	1,425	15	892	0.007	65	956
Pump (250 GPM)	1	pump	2,500	2,500	375	15	235	0.007	17	252
Base and housing	1	base/housing	1,000	1,000	50	15	98	0.007	7	105
Suction, discharge, primer, check valve assembly	1	suction unit	800	800	40	15	79	0.007	5	84
(expansion)	-		0	0	0	1	0	0.007	-	-
Mainline										
Mainline to field*	100	feet	3	275	92	20	21	0.007	2	23
Mainline within field	2,650	feet	3	7,288	2,429	20	548	0.007	50	597
(expansion)	-		0	0	0	1	0	0.007	-	-
(expansion)	-		0	0	0	1	0	0.007	-	-
Application System										
Hose reel system (gun included)	1	hose reel system	16,000	16,000	2,400	10	1,951	0.007	109	2,060
End Plugs	1	plug	30	30	5	10	4	0.007	0	4
90 degree elbow fittings	2	elbow	58	116	17	10	14	0.007	1	15
(expansion)	-		0	0	0	1	0	0.007	-	-
Miscellaneous										
Installation/set up charges	1	installation	0%	0	0	20	0	0.007	-	-
Pipe trailer	1	trailer	1,250	1,250	417	1	904	0.007	9	912
(expansion)	-		0	0	0	1	0	0.007	-	-
Total Charges				**53,759**	**7,249**		**5,754**		**366**	**6,120**

*(4" Aluminum)

Table A6. Investment and ownership cost for a hose reel traveller gun system on a 100-acre field ($/field).

Item	Qty (No.)	Unit	Price per unit ($)	Total Purchase Price ($)	Salvage Value ($)	Useful Life (Years)	Depreciation and Interest ($)	Tax and Insurance (rate/$)	Tax and Insurance Charge ($)	Annual Ownership Cost($)
Water Source										
Well/Pond	1	well	15,000	15,000	0	33	1,010	0.007	102	1,112
Permitting	1	lump charge	0	0	0	33	0	-	-	-
Irrigation System Pump										
Engine (100 HP)	1	engine	9,500	9,500	1,425	15	892	0.007	65	956
Pump (250 GPM)	1	pump	2,500	2,500	375	15	235	0.007	17	252
Base and housing	1	base/housing	1,000	1,000	50	15	98	0.007	7	105
Suction, discharge, primer, check valve assembly	1	suction unit	800	800	40	15	79	0.007	5	84
(expansion)	-		0	0	0	1	0	0.007	-	-
Mainline										
Mainline to field*	100	feet	4	400	133	20	30	0.007	3	33
Mainline within field*	2,000	feet	4	8,000	2,667	20	601	0.007	54	656
(expansion)	-		0	0	0	1	0	0.007	-	-
(expansion)	-		0	0	0	1	0	0.007	-	-
Application System										
Hose reel system (gun included)	1	hose reel system	16,000	16,000	2,400	10	1,951	0.007	109	2,060
End Plugs	1	plug	30	30	5	10	4	0.007	0	4
90 degree elbow fittings	2	elbow	75	150	23	10	18	0.007	1	19
(expansion)	-		0	0	0	1	0	0.007	-	-
Miscellaneous										
Installation/set up charges	1	installation	0%	0	0	20	0	0.007	-	-
Pipe trailer	1	trailer	1,250	1,250	417	1	904	0.007	9	912
(expansion)	-		0	0	0	1	0	0.007	-	-
Total Charges				**54,630**	**7,534**		**5,822**		**371**	**6,193**

*(5" Aluminum)

Table A7. Investment and ownership cost for a handline small sprinkler system on a 25-acre field ($/field).

Item	Qty (No.)	Unit	Price per unit ($)	Total Purchase Price ($)	Salvage Value ($)	Useful Life (Years)	Depreciation and Interest ($)	Tax and Insurance (rate/$)	Tax and Insurance Charge ($)	Annual Ownership Cost($)
Water Source										
Well/Pond	1	well	15,000	15,000	0	33	1,010	0.007	102	1,112
Permitting	1	lump charge	0	0	0	33	0	-	-	-
Irrigation System Pump										
Engine (75 HP)	1	engine	7,000	7,000	1,050	15	657	0.007	48	705
Pump (420 GPM)	1	pump	3,500	3,500	525	15	329	0.007	24	352
Base and housing	1	base/housing	1,000	1,000	50	15	98	0.007	7	105
Suction, discharge, primer, check valve assembly	1	suction unit	800	800	40	15	79	0.007	5	84
(expansion)	-		0	0	0	1	0	0.007	-	-
Mainline										
Mainline to field*	100	feet	5	450	150	20	34	0.007	3	37
Mainline within field	1,100	feet	5	4,950	1,650	20	372	0.007	34	406
Mainline within field	100	feet	3	275	92	20	21	0.007	2	23
6x4 valve-opening tees	22	valves	140	3,080	1,027	1	2,227	0.007	21	2,248
4x4 valve-opening tees	2	valves	90	180	60	1	130	0.007	1	131
Plugs	2	plugs	22	44	15	1	32	0.007	0	32
Application System										
Lateral Lines***	3,600	feet	1	5,040	756	10	614	0.007	34	649
Risers (12" x 3/4")	60	riser	3	180	27	10	22	0.007	1	23
Sprinklers (7 GPM)	60	sprinkler gun	12	690	104	10	84	0.007	5	89
Plugs	8	plugs	13	100	15	10	12	0.007	1	13
(expansion)	-		0	0	0	10	0	0.007	-	-
Miscellaneous										
Installation/set up charges	1	installation	10%	1,499	0	20	127	0.007	10	137
Pipe trailer	1	trailer	1,250	1,250	417	1	904	0.007	9	912
(expansion)	-		0	0	0	1	0	0.007	-	-
Total Charges				**45,038**	**5,976**		**6,751**		**306**	**7,058**

*6" Aluminum ** 4" aluminum *** 2" Aluminum

Table A8. Investment and ownership cost for a handline small sprinkler system on a 50-acre field ($/field).

Item	Qty (No.)	Unit	Price per unit ($)	Total Purchase Price ($)	Salvage Value ($)	Useful Life (Years)	Depreciation and Interest ($)	Tax and Insurance (rate/$)	Tax and Insurance Charge ($)	Annual Ownership Cost($)
Water Source										
Well/Pond	1	well	15,000	15,000	0	33	1,010	0.007	102	1,112
Permitting	1	lump charge	0	0	0	33	0	-	-	-
Irrigation System Pump										
Engine (100 HP)	1	engine	9,500	9,500	1,425	15	892	0.007	65	956
Pump (840 GPM)	1	pump	3,500	3,500	525	15	329	0.007	24	352
Base and housing	1	base/housing	1,000	1,000	50	15	98	0.007	7	105
Suction, discharge, primer, check valve assembly	1	suction unit	800	800	40	15	79	0.007	5	84
(expansion)	-		0	0	0	1	0	0.007	-	-
Mainline										
Mainline to field*	100	feet	5	450	150	20	34	0.007	3	37
Mainline within field*	2,200	feet	5	9,900	3,300	20	744	0.007	67	811
Mainline within field**	100	feet	3	275	92	20	21	0.007	2	23
Mainline within field***	100	feet	3	275	92	20	21	0.007	2	23
8x4 valve opening tees	22	valves	180	3,960	1,320	1	2,863	0.007	27	2,890
6x4 valve opening tees	2	valves	150	300	100	1	217	0.007	2	219
4x4 valve opening tees	2	valves	90	180	60	1	130	0.007	1	131
Plugs	3	plugs	22	66	22	1	48	0.007	0	48
Application System										
Lateral Lines****	7,200	feet	1	10,080	1,512	10	1,229	0.007	69	1,298
Risers (12"x3/4")	120	riser	3	360	54	10	44	0.007	2	46
Sprinklers (7 GPM)	120	sprinkler gun	12	1,380	207	10	168	0.007	9	178
Plugs	16	plugs	13	200	30	10	24	0.007	1	26
Reducers	8	reducers	45	360	54	10	44	0.007	2	46
Miscellaneous										
Installation/set up charges	1	installation	10%	2,779	0	20	235	0.007	19	254
Pipe trailer	1	trailer	1,250	1,250	417	1	904	0.007	9	912
(expansion)	-		0	0	0	1	0	0.007	-	-
Total Charges				**61,615**	**9,449**		**9,133**		**419**	**9,552**

*8" Aluminum ** 6" Aluminum *** 4" Aluminum ****2" Aluminum

Table A9. Investment and ownership cost for a handline small sprinkler system on a 100-acre field ($/field).

Item	Qty (No.)	Unit	Price per unit ($)	Total Purchase Price ($)	Salvage Value ($)	Useful Life (Years)	Depreciation and Interest ($)	Tax and Insurance (rate/$)	Tax and Insurance Charge ($)	Annual Ownership Cost($)
Water Source										
Well/Pond	1	well	15,000	15,000	0	33	1,010	0.007	102	1,112
Permitting	1	lump charge	0	0	0	33	0	-	-	-
Irrigation System Pump										
Engine (200 HP)	1	engine	12,000	12,000	1,800	15	1,126	0.007	82	1,208
Pump (1680 GPM)	1	pump	5,000	5,000	750	15	469	0.007	34	503
Base and housing	1	base/housing	1,000	1,000	50	15	98	0.007	7	105
Suction, discharge, primer, check valve assembly	1	suction unit	800	800	40	15	79	0.007	5	84
(expansion)	-		0	0	0	1	0	0.007	-	-
Mainline										
Mainline to field*	100	feet	8	800	267	20	60	0.007	5	66
Mainline within field	2,100	feet	8	16,800	5,600	20	1,263	0.007	114	1,377
Mainline within field**	100	feet	5	450	150	20	34	0.007	3	37
Mainline within field***	100	feet	3	275	92	20	21	0.007	2	23
Mainline within field****	100	feet	3	275	92	20	21	0.007	2	23
10x4 valve-opening tees	22	valves	180	3,960	1,320	1	2,863	0.007	27	2,890
8x4 valve-opening tees	2	valves	180	360	120	1	260	0.007	2	263
6x4 valve-opening tees	2	valves	150	300	100	1	217	0.007	2	219
4x4 valve-opening tees	2	valves	90	180	60	1	130	0.007	1	131
Plugs	4	plugs	22	88	29	1	64	0.007	1	64
Application System										
Lateral Lines*****	7,200	feet	2	15,120	2,268	10	1,843	0.007	103	1,946
Lateral Lines******	7,200	feet	1	10,080	1,512	10	1,229	0.007	69	1,298
Risers (12" x 3/4")	240	riser	3	720	108	10	88	0.007	5	93
Sprinklers (7 GPM)	240	sprinkler gun	12	2,760	414	10	337	0.007	19	355
Plugs	32	plugs	13	400	60	10	49	0.007	3	51
Reducers	8	reducers	50	400	60	10	49	0.007	3	51
Miscellaneous										
Installation/set up charges	1	installation	10%	5,297	0	20	448	0.007	36	484
Pipe trailer	1	trailer	1,250	1,250	417	1	904	0.007	9	912
(expansion)	-		0	0	0	1	0	0.007	-	-
Total Charges				**93,315**	**15,308**		**12,661**		**635**	**13,296**

*10" Aluminum **8" Aluminum *** 6" Aluminum ****4" Aluminum *****3" Aluminum ******(2" Aluminum)

Table A10. Investment and ownership cost for a permanent set small sprinkler system on a 25-acre field ($/field).

Item	Qty (No.)	Unit	Price per unit ($)	Total Purchase Price ($)	Salvage Value ($)	Useful Life (Years)	Depreciation and Interest ($)	Tax and Insurance (rate/$)	Tax and Insurance Charge ($)	Annual Ownership Cost($)
Water Source										
Well/Pond	1	well	15,000	15,000	0	33	1,010	0.007	102	1,112
Permitting	1	lump charge	0	0	0	33	0	-	-	-
Irrigation System Pump										
Engine (100 HP)	1	engine	9,500	9,500	1,425	15	892	0.007	65	956
Pump (1625 GPM)	1	pump	3,500	3,500	525	15	329	0.007	24	352
Base and housing	1	base/housing	1,000	1,000	50	15	98	0.007	7	105
Suction, discharge, primer, check valve assembly	1	suction unit	800	800	40	15	79	0.007	5	84
(expansion)	-		0	0	0	1	0	0.007	-	-
Mainline										
Mainline to field*	100	feet	4	425	0	20	36	0.007	3	39
Mainline within field	1,200	feet	4	5,100	0	20	431	0.007	35	466
10x4 valve-opening tees	20	valves	90	1,800	0	1	1,901	0.007	12	1,914
Plugs	1	plugs	22	22	0	1	23	0.007	0	23
Application System										
Lateral Lines**	9,000	feet	1	6,210	0	10	829	0.007	42	871
Lateral Lines***	9,000	feet	0	3,150	0	10	421	0.007	21	442
Couplers	363	couplers	7	2,541	0	10	339	0.007	17	357
Risers (12" x 3/4")	363	riser	3	1,089	0	10	145	0.007	7	153
Sprinklers (4.5 GPM)	363	sprinkler gun	12	4,175	0	10	557	0.007	28	586
Plugs	40	plugs	13	500	0	10	67	0.007	3	70
Reducers	40	reducers	50	2,000	0	10	267	0.007	14	281
Miscellaneous										
Installation/set up charges	1	installation	25%	6,753	0	20	571	0.007	46	617
(expansion)	-		0	0	0	1	0	0.007	-	-
Total Charges				**63,564**	**2,040**		**7,996**		**432**	**8,428**

*10" PVC **2" polyethylene tubing ***1¼" polyethylene tubing

Table A11. Investment and ownership cost for a permanent set small sprinkler system on a 50-acre field ($/field).

Item	Qty (No.)	Unit	Price per unit ($)	Total Purchase Price ($)	Salvage Value ($)	Useful Life (Years)	Depreciation and Interest ($)	Tax and Insurance (rate/$)	Tax and Insurance Charge ($)	Annual Ownership Cost($)
Water Source										
Well/Pond	1	well	15,000	15,000	0	33	1,010	0.007	102	1,112
Permitting	1	lump charge	0	0	0	33	0	-	-	-
Irrigation System Pump										
Engine (150 HP)	1	engine	11,000	11,000	1,650	15	1,033	0.007	75	1,107
Pump (3250 GPM)	1	pump	4,500	4,500	675	15	422	0.007	31	453
Base and housing	1	base/housing	1,000	1,000	50	15	98	0.007	7	105
Suction, discharge, primer, check valve assembly	1	suction unit	800	800	40	15	79	0.007	5	84
(expansion)	-		0	0	0	1	0	0.007	-	-
Mainline										
Mainline to field*	100	feet	6	600	0	20	51	0.007	4	55
Mainline within field*	1,200	feet	6	7,200	0	20	609	0.007	49	658
Mainline within field**	600	feet	5	3,000	0	20	254	0.007	20	274
Mainline within field***	600	feet	4	2,550	0	20	216	0.007	17	233
14x4 valve-opening tee	20	valves	110	2,200	0	1	2,324	0.007	15	2,339
12x4 valve-opening tees	10	valves	100	1,000	0	1	1,056	0.007	7	1,063
10x4 valve-opening tees	10	valves	90	900	0	1	951	0.007	6	957
Plugs	2	plugs	22	44	0	1	46	0.007	0	47
Application System										
Lateral Lines****	18,000	feet	1	12,420	0	10	1,658	0.007	84	1,743
Lateral Lines*****	18,000	feet	0	6,300	0	10	841	0.007	43	884
Couplers	726	couplers	7	5,082	0	10	678	0.007	35	713
Risers (12" x 3/4")	726	riser	3	2,178	0	10	291	0.007	15	306
Sprinklers (4.5 GPM)	726	sprinkler gun	12	8,349	0	10	1,115	0.007	57	1,171
Plugs	80	plugs	13	1,000	0	10	134	0.007	7	140
Reducers	80	reducers	50	4,000	0	10	534	0.007	27	561
Miscellaneous										
Installation/set up charges	1	installation	25%	14,206	0	20	1,202	0.007	97	1,298
(expansion)	-		0	0	0	1	0	0.007	-	-
Total Charges				**103,329**	**2,415**		**14,601**		**703**	**15,304**

*14" PVC **12" PVC ***10" PVC ****2" Polyethylene tubing *****1¼" polyethylene tubing

Table A12. Investment and ownership cost for a permanent set small sprinkler system on a 100-acre field ($/field).

Item	Qty (No.)	Unit	Price per unit ($)	Total Purchase Price ($)	Salvage Value ($)	Useful Life (Years)	Depreciation and Interest ($)	Tax and Insurance (rate/$)	Tax and Insurance Charge ($)	Annual Ownership Cost($)
Water Source										
Well/Pond	1	well	15,000	15,000	0	33	1,010	0.007	102	1,112
Permitting	1	lump charge	2,000	0	0	33	0	-	-	-
Irrigation System Pump										
Engine (150 HP)	2	engine	11,000	22,000	3,300	15	2,065	0.007	150	2,215
Pump (3250 GPM)	2	pump	4,500	9,000	1,350	15	845	0.007	61	906
Base and housing	2	base/housing	1,000	2,000	100	15	197	0.007	14	210
Suction, discharge, primer, check valve assembly	2	suction unit	800	1,600	80	15	157	0.007	11	168
(expansion)	-		0	0	0	1	0	0.007	-	-
Mainline										
Mainline to field*	1,100	feet	6	6,600	0	20	558	0.007	45	603
Mainline within field*	2,400	feet	6	14,400	0	20	1,218	0.007	98	1,316
Mainline within field**	1,200	feet	5	6,000	0	20	508	0.007	41	548
Mainline within field***	1,200	feet	4	5,100	0	20	431	0.007	35	466
14x4 valve-opening tee	40	valves	110	4,400	0	1	4,648	0.007	30	4,678
12x4 valve-opening tees	20	valves	100	2,000	0	1	2,113	0.007	14	2,126
10x4 valve-opening tees	20	valves	90	1,800	0	1	1,901	0.007	12	1,914
Plugs	2	plugs	22	44	0	1	46	0.007	0	47
Application System										
Lateral Lines****	36,000	feet	1	24,840	0	10	3,316	0.007	169	3,485
Lateral Lines*****	36,000	feet	0	12,600	0	10	1,682	0.007	86	1,768
Couplers	726	couplers	7	5,082	0	10	678	0.007	35	713
Risers (12" x 3/4")	1,452	riser	3	4,356	0	10	582	0.007	30	611
Sprinklers (4.5 GPM)	1,452	sprinkler gun	12	16,698	0	10	2,229	0.007	114	2,343
Plugs	80	plugs	13	1,000	0	10	134	0.007	7	140
Reducers	80	reducers	50	4,000	0	10	534	0.007	27	561
Miscellaneous										
Installation/set up charges	1	installation	25%	27,230	0	20	2,303	0.007	185	2,489
(expansion)	-		0	0	0	1	0	0.007	-	-
Total Charges				**185,750**	**4,830**		**27,156**		**1,263**	**28,419**

*14" PVC **12" PVC ***10" PVC ****2" polyethylene tubing *****1¼" polyethylene tubing

APPENDIX B—MODIFIED BREAKEVEN CALCULATIONS

Modified breakeven calculations are presented in Table B1 to B12 of this appendix. Since the yield response of wild blueberries to supplemental irrigation is not known, a range of potential yield effects is presented along the top row of each table, ranging from 400 lbs/acre every other year to 4000 lbs/acre every other year. To capture the uncertainty in future blueberry prices, the per pound price is also varied along the first column. Prices range from $0.30/lb to $0.65/lb.

The amount listed in the intersection of a row and column represents the net return to the irrigation investment. The accounting convention of bracketing negative amounts is employed in the tables. Breakeven price and yield combinations can be derived by finding where the values switch from negative to positive. For example in Table B1, in the first row of $0.30/lb, the investment breaks even just below 2400 lbs/acre every other year. Any yield advantage level below this amount would produce a negative return to irrigation investment. Two lines down, at $0.40/lb, the breakeven point is just below 1600 lbs/acre every other year. Using the switching point between negative and positive values will produce a close approximation to the breakeven yield at the different price levels. In general, the breakeven line descends from the upper right of the table to the lower left.

Table B1. Breakeven calculations for a 25-acre moveable big gun system ($/acre).

Price ($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.30	(252)	(192)	(132)	(72)	(12)	48	108	168	228	288
$0.35	(242)	(172)	(102)	(32)	38	108	178	248	318	388
$0.40	(232)	(152)	(72)	8	88	168	248	328	408	488
$0.45	(222)	(132)	(42)	48	138	228	318	408	498	588
$0.50	(212)	(112)	(12)	88	188	288	388	488	588	688
$0.55	(202)	(92)	18	128	238	348	458	568	678	788
$0.60	(192)	(72)	48	168	288	408	528	648	768	888
$0.65	(182)	(52)	78	208	338	468	598	728	858	988

Column heading: Yield Advantage on bearing acre (lbs/acre)

Table B2. Breakeven calculations for a 50-acre moveable big gun system ($/acre).

Price ($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.30	(167)	(107)	(47)	13	73	133	193	253	313	373
$0.35	(157)	(87)	(17)	53	123	193	263	333	403	473
$0.40	(147)	(67)	13	93	173	253	333	413	493	573
$0.45	(137)	(47)	43	133	223	313	403	493	583	673
$0.50	(127)	(27)	73	173	273	373	473	573	673	773
$0.55	(117)	(7)	103	213	323	433	543	653	763	873
$0.60	(107)	13	133	253	373	493	613	733	853	973
$0.65	(97)	33	163	293	423	553	683	813	943	1,073

Column heading: Yield Advantage on bearing acre (lbs/acre)

Table B3. Breakeven calculations for a 100-acre moveable big gun system ($/acre).

Price ($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.30	(121)	(61)	(1)	59	119	179	239	299	359	419
$0.35	(111)	(41)	29	99	169	239	309	379	449	519
$0.40	(101)	(21)	59	139	219	299	379	459	539	619
$0.45	(91)	(1)	89	179	269	359	449	539	629	719
$0.50	(81)	19	119	219	319	419	519	619	719	819
$0.55	(71)	39	149	259	369	479	589	699	809	919
$0.60	(61)	59	179	299	419	539	659	779	899	1,019
$0.65	(51)	79	209	339	469	599	729	859	989	1,119

Column heading: Yield Advantage on bearing acre (lbs/acre)

Table B4. Breakeven calculations for a 25-acre hose-reel traveler system ($/acre).

Price ($/lb)	Yield Advantage on bearing acre (lbs/acre) 400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.30	(248)	(188)	(128)	(68)	(8)	52	112	172	232	292
$0.35	(238)	(168)	(98)	(28)	42	112	182	252	322	392
$0.40	(228)	(148)	(68)	12	92	172	252	332	412	492
$0.45	(218)	(128)	(38)	52	142	232	322	412	502	592
$0.50	(208)	(108)	(8)	92	192	292	392	492	592	692
$0.55	(198)	(88)	22	132	242	352	462	572	682	792
$0.60	(188)	(68)	52	172	292	412	532	652	772	892
$0.65	(178)	(48)	82	212	342	472	602	732	862	992

Table B5. Breakeven calculations for a 50-acre hose-reel traveler system ($/acre).

Price ($/lb)	Yield Advantage on bearing acre (lbs/acre) 400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.30	(183)	(123)	(63)	(3)	57	117	177	237	297	357
$0.35	(173)	(103)	(33)	37	107	177	247	317	387	457
$0.40	(163)	(83)	(3)	77	157	237	317	397	477	557
$0.45	(153)	(63)	27	117	207	297	387	477	567	657
$0.50	(143)	(43)	57	157	257	357	457	557	657	757
$0.55	(133)	(23)	87	197	307	417	527	637	747	857
$0.60	(123)	(3)	117	237	357	477	597	717	837	957
$0.65	(113)	17	147	277	407	537	667	797	927	1,057

Table B6. Breakeven calculations for a 100-acre hose-reel traveler system ($/acre).

Price ($/lb)	Yield Advantage on bearing acre (lbs/acre) 400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.30	(107)	(47)	13	73	133	193	253	313	373	433
$0.35	(97)	(27)	43	113	183	253	323	393	463	533
$0.40	(87)	(7)	73	153	233	313	393	473	553	633
$0.45	(77)	13	103	193	283	373	463	553	643	733
$0.50	(67)	33	133	233	333	433	533	633	733	833
$0.55	(57)	53	163	273	383	493	603	713	823	933
$0.60	(47)	73	193	313	433	553	673	793	913	1,033
$0.65	(37)	93	223	353	483	613	743	873	1,003	1,133

Table B7. Breakeven calculations for a 25-acre moveable small sprinkler big gun system ($/acre).

Price	Yield Advantage on bearing acre (lbs/acre)									
($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.30	(392)	(332)	(272)	(212)	(152)	(92)	(32)	28	88	148
$0.35	(382)	(312)	(242)	(172)	(102)	(32)	38	108	178	248
$0.40	(372)	(292)	(212)	(132)	(52)	28	108	188	268	348
$0.45	(362)	(272)	(182)	(92)	(2)	88	178	268	358	448
$0.50	(352)	(252)	(152)	(52)	48	148	248	348	448	548
$0.55	(342)	(232)	(122)	(12)	98	208	318	428	538	648
$0.60	(332)	(212)	(92)	28	148	268	388	508	628	748
$0.65	(322)	(192)	(62)	68	198	328	458	588	718	848

Table B8. Breakeven calculations for a 50-acre moveable small sprinkler big gun system ($/acre).

Price	Yield Advantage on bearing acre (lbs/acre)									
($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.30	(274)	(214)	(154)	(94)	(34)	26	86	146	206	266
$0.35	(264)	(194)	(124)	(54)	16	86	156	226	296	366
$0.40	(254)	(174)	(94)	(14)	66	146	226	306	386	466
$0.45	(244)	(154)	(64)	26	116	206	296	386	476	566
$0.50	(234)	(134)	(34)	66	166	266	366	466	566	666
$0.55	(224)	(114)	(4)	106	216	326	436	546	656	766
$0.60	(214)	(94)	26	146	266	386	506	626	746	866
$0.65	(204)	(74)	56	186	316	446	576	706	836	966

Table B9. Breakeven calculations for a 100-acre moveable small sprinkler big gun system ($/acre).

Price	Yield Advantage on bearing acre (lbs/acre)									
($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.30	(209)	(149)	(89)	(29)	31	91	151	211	271	331
$0.35	(199)	(129)	(59)	11	81	151	221	291	361	431
$0.40	(189)	(109)	(29)	51	131	211	291	371	451	531
$0.45	(179)	(89)	1	91	181	271	361	451	541	631
$0.50	(169)	(69)	31	131	231	331	431	531	631	731
$0.55	(159)	(49)	61	171	281	391	501	611	721	831
$0.60	(149)	(29)	91	211	331	451	571	691	811	931
$0.65	(139)	(9)	121	251	381	511	641	771	901	1,031

Table B10. Breakeven calculations for a 25-acre permanent set small sprinkler system ($/acre).

Price	Yield Advantage on bearing acre (lbs/acre)									
($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.30	(382)	(322)	(262)	(202)	(142)	(82)	(22)	38	98	158
$0.35	(372)	(302)	(232)	(162)	(92)	(22)	48	118	188	258
$0.40	(362)	(282)	(202)	(122)	(42)	38	118	198	278	358
$0.45	(352)	(262)	(172)	(82)	8	98	188	278	368	458
$0.50	(342)	(242)	(142)	(42)	58	158	258	358	458	558
$0.55	(332)	(222)	(112)	(2)	108	218	328	438	548	658
$0.60	(322)	(202)	(82)	38	158	278	398	518	638	758
$0.65	(312)	(182)	(52)	78	208	338	468	598	728	858

Table B11. Breakeven calculations for a 50-acre permanent set small sprinkler system ($/acre).

Price	Yield Advantage on bearing acre (lbs/acre)									
($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.30	(334)	(274)	(214)	(154)	(94)	(34)	26	86	146	206
$0.35	(324)	(254)	(184)	(114)	(44)	26	96	166	236	306
$0.40	(314)	(234)	(154)	(74)	6	86	166	246	326	406
$0.45	(304)	(214)	(124)	(34)	56	146	236	326	416	506
$0.50	(294)	(194)	(94)	6	106	206	306	406	506	606
$0.55	(284)	(174)	(64)	46	156	266	376	486	596	706
$0.60	(274)	(154)	(34)	86	206	326	446	566	686	806
$0.65	(264)	(134)	(4)	126	256	386	516	646	776	906

Table B12. Breakeven calculations for a 100-acre permanent set small sprinkler system ($/acre).

Price	Yield Advantage on bearing acre (lbs/acre)									
($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.30	(310)	(250)	(190)	(130)	(70)	(10)	50	110	170	230
$0.35	(300)	(230)	(160)	(90)	(20)	50	120	190	260	330
$0.40	(290)	(210)	(130)	(50)	30	110	190	270	350	430
$0.45	(280)	(190)	(100)	(10)	80	170	260	350	440	530
$0.50	(270)	(170)	(70)	30	130	230	330	430	530	630
$0.55	(260)	(150)	(40)	70	180	290	400	510	620	730
$0.60	(250)	(130)	(10)	110	230	350	470	590	710	830
$0.65	(240)	(110)	20	150	280	410	540	670	800	930

APPENDIX C—EARLIEST PAYOFF CALCULATIONS

Tables C1 through C12 present the earliest possible payoff periods given the assumptions detailed in the text. As discussed in Appendix B, the payoff period is calculated over a range of price and yield scenarios. Prices in this appendix vary from $0.35/lb to $0.55/lb. The yield levels remain the same.

In a number of the 25- and 50-acre cases, the returns over operating costs are negative. In such a situation, the investment would never pay itself off. In those situations, the payoff period is not indicated but replaced with ROIOC<0, which indicates that the return over incremental operating cost is negative. In situations where the returns of incremental operating costs were positive, but still low, repayment would take more than 15 years. This is a very long-term planning period and indicated by >15 years to pay off the investment.

Table C1. Earliest payoff of investment costs on a 25-acre moveable big gun system (years).

Price	-------------------- Yield Advantage on bearing acre (lbs/acre) ---------------------									
($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.35	ROIOC<0	ROIOC<0	ROIOC<0	>15	>15	12	8	6	5	4
$0.40	ROIOC<0	ROIOC<0	>15	>15	14	9	6	5	4	4
$0.45	ROIOC<0	ROIOC<0	>15	>15	10	7	5	4	4	3
$0.50	ROIOC<0	ROIOC<0	>15	14	8	6	4	4	3	3
$0.55	ROIOC<0	ROIOC<0	>15	11	7	5	4	3	3	3

Table C2. Earliest payoff of investment costs on a 50-acre moveable big gun system (years).

Price	-------------------- Yield Advantage on bearing acre (lbs/acre) ---------------------									
($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.35	ROIOC<0	ROIOC<0	>15	>15	8	6	5	4	3	3
$0.40	ROIOC<0	ROIOC<0	>15	10	6	5	4	3	3	2
$0.45	ROIOC<0	>15	>15	8	5	4	3	3	2	2
$0.50	ROIOC<0	>15	13	6	4	3	3	2	2	2
$0.55	ROIOC<0	>15	10	5	4	3	3	2	2	2

Table C3. Earliest payoff of investment costs on a 100-acre moveable big gun system (years).

Price	-------------------- Yield Advantage on bearing acre (lbs/acre) ---------------------									
($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.35	ROIOC<0	ROIOC<0	>15	8	5	4	3	3	2	2
$0.40	ROIOC<0	>15	12	6	4	3	3	2	2	2
$0.45	ROIOC<0	>15	8	5	3	3	2	2	2	2
$0.50	ROIOC<0	>15	7	4	3	2	2	2	2	1
$0.55	ROIOC<0	>15	6	4	3	2	2	2	2	1

Table C4. Earliest payoff of investment costs on a 25-acre hose-reel traveler system (years).

Price	-------------------- Yield Advantage on bearing acre (lbs/acre) ---------------------								
($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.35	ROIOC<0	ROIOC<0	ROIOC<0	>15	>15	11	8	6	5	4
$0.40	ROIOC<0	ROIOC<0	>15	>15	12	8	6	5	4	4
$0.45	ROIOC<0	ROIOC<0	>15	>15	9	6	5	4	3	3
$0.50	ROIOC<0	ROIOC<0	>15	12	7	5	4	4	3	3
$0.55	ROIOC<0	>15	>15	10	6	5	4	3	3	2

Table C5. Earliest payoff of investment costs on a 50-acre hose-reel traveler system (years).

Price	-------------------- Yield Advantage on bearing acre (lbs/acre) ---------------------								
($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.35	ROIOC<0	ROIOC<0	>15	>15	9	6	4	4	3	3
$0.40	ROIOC<0	ROIOC<0	>15	11	6	5	4	3	3	2
$0.45	ROIOC<0	ROIOC<0	>15	8	5	4	3	3	2	2
$0.50	ROIOC<0	>15	14	6	4	3	3	2	2	2
$0.55	ROIOC<0	>15	10	5	4	3	2	2	2	2

Table C6. Earliest payoff of investment costs on a 100-acre hose-reel traveler system (years).

Price	-------------------- Yield Advantage on bearing acre (lbs/acre) ---------------------								
($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.35	ROIOC<0	>15	10	5	3	3	2	2	2	2
$0.40	ROIOC<0	>15	7	4	3	2	2	2	1	1
$0.45	ROIOC<0	>15	5	3	2	2	2	1	1	1
$0.50	ROIOC<0	12	4	3	2	2	2	1	1	1
$0.55	ROIOC<0	9	4	2	2	2	1	1	1	1

Table C7. Earliest payoff of investment costs on a 25-acre moveable small sprinkler system (years).

Price	Yield Advantage on bearing acre (lbs/acre)									
($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.35	ROIOC<0	ROIOC<0	ROIOC<0	>15	>15	>15	12	8	7	5
$0.40	ROIOC<0	ROIOC<0	ROIOC<0	>15	>15	13	8	6	5	4
$0.45	ROIOC<0	ROIOC<0	ROIOC<0	>15	>15	9	7	5	4	4
$0.50	ROIOC<0	ROIOC<0	>15	>15	11	7	5	4	4	3
$0.55	ROIOC<0	ROIOC<0	>15	>15	9	6	5	4	3	3

Table C8. Earliest payoff of investment costs on a 50-acre moveable small sprinkler system (years).

Price	Yield Advantage on bearing acre (lbs/acre)									
($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.35	ROIOC<0	ROIOC<0	ROIOC<0	>15	13	8	6	5	4	3
$0.40	ROIOC<0	ROIOC<0	>15	>15	9	6	5	4	3	3
$0.45	ROIOC<0	ROIOC<0	>15	12	7	5	4	3	3	2
$0.50	ROIOC<0	ROIOC<0	>15	9	6	4	3	3	2	2
$0.55	ROIOC<0	>15	>15	7	5	4	3	3	2	2

Table C9. Earliest payoff of investment costs on a 100-acre moveable big gun system (years).

Price	Yield Advantage on bearing acre (lbs/acre)									
($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.35	ROIOC<0	ROIOC<0	>15	>15	8	5	4	3	3	2
$0.40	ROIOC<0	ROIOC<0	>15	10	6	4	3	3	2	2
$0.45	ROIOC<0	ROIOC<0	>15	7	5	3	3	2	2	2
$0.50	ROIOC<0	>15	12	6	4	3	2	2	2	2
$0.55	ROIOC<0	>15	9	5	3	3	2	2	2	2

Table C10. Earliest payoff of investment costs on a 25-acre permanent set small sprinkler system (years).

Price	-------------------- Yield Advantage on bearing acre (lbs/acre) ---------------------									
($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.35	ROIOC<0	ROIOC<0	ROIOC<0	>15	>15	>15	>15	12	9	7
$0.40	ROIOC<0	ROIOC<0	ROIOC<0	>15	>15	>15	12	9	7	6
$0.45	ROIOC<0	ROIOC<0	>15	>15	>15	13	9	7	6	5
$0.50	ROIOC<0	ROIOC<0	>15	>15	>15	10	7	6	5	4
$0.55	ROIOC<0	ROIOC<0	>15	>15	12	8	6	5	4	4

Table C11. Earliest payoff of investment costs on a 50-acre permanent set small sprinkler system (years).

Price	-------------------- Yield Advantage on bearing acre (lbs/acre) ---------------------									
($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.35	ROIOC<0	ROIOC<0	>15	>15	>15	>15	10	8	6	5
$0.40	ROIOC<0	ROIOC<0	>15	>15	>15	11	8	6	5	4
$0.45	ROIOC<0	ROIOC<0	>15	>15	12	8	6	5	4	4
$0.50	ROIOC<0	ROIOC<0	>15	>15	10	7	5	4	4	3
$0.55	ROIOC<0	>15	>15	13	8	6	5	4	3	3

Table C12. Earliest payoff of investment costs on a 100-acre permanent set small sprinkler system (years).

Price	-------------------- Yield Advantage on bearing acre (lbs/acre) ---------------------									
($/lb)	400	800	1,200	1,600	2,000	2,400	2,800	3,200	3,600	4,000
$0.35	ROIOC<0	ROIOC<0	>15	>15	>15	12	8	7	5	5
$0.40	ROIOC<0	ROIOC<0	>15	>15	13	9	7	5	5	4
$0.45	ROIOC<0	ROIOC<0	>15	>15	10	7	5	5	4	3
$0.50	ROIOC<0	>15	>15	13	8	6	5	4	3	3
$0.55	ROIOC<0	>15	>15	10	7	5	4	4	3	3