Low Energy Precision Application (LEPA) and Low Elevation Spray Application (LESA) Trials in the Pacific Northwest

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Background

Irrigation accounts for 80-90% of the consumptive use of water in the arid areas of the Pacific Northwest where water shortages are felt the keenest. Center pivots and linear move irrigation systems account for well over half of the total irrigated acres in the Pacific Northwest, or 3.9 million irrigated acres (NASS Farm and Ranch Irrigation Survey, 2013). Even small changes in the efficiency of these systems will have a *huge* impact on the total water conservation.

Figures 1-3 show the progression over time of sprinklers on center pivots from high pressure impacts on the top of pivots to Low Elevation Spray Application (LESA).

Figure 1. When center pivots were first introduced, they used high pressure impact sprinklers on top of the pipe. These sprinklers needed 45-80 psi at the pivot point to operate properly, were spaced 20-30 ft apart, and the irrigation application efficiency was about 60% as measured by catch can tests without canopy. However due to the large wetted radius, there is more time for the water to infiltrate into the soil as the pivot rolls past.

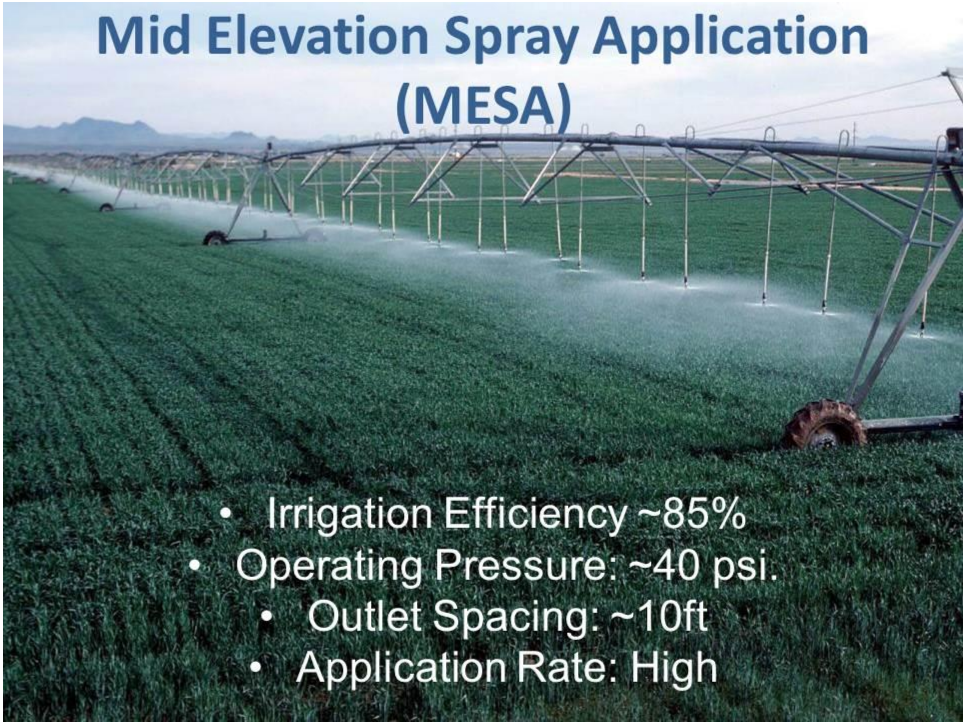

Figure 2. Currently most center pivots use mid elevation spray application (MESA). These sprinklers typically use 15-20 psi pressure regulators and thus need about 35-40 psi at the pivot point to operate properly. They are spaced about 10 ft apart, and the irrigation application efficiency is typically about 85% as measured with catch can tests without canopy. The smaller wetted radius doesn't allow as much time for the water to infiltrate into the soil as the pivot passes.

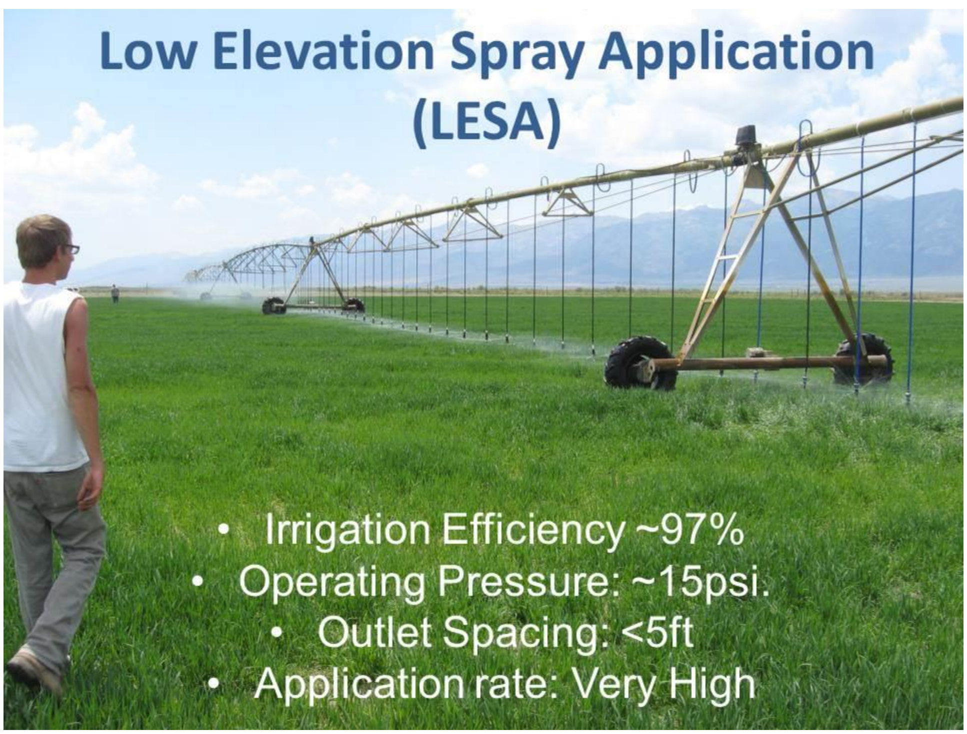

Figure 3. Low Elevation Spray Application (LESA) and Low Energy Precision Application (LEPA) need much less pressure to operate properly and use 6-10 psi pressure regulators. The drops are spaced 5 ft or

less apart, and the irrigation application efficiency is typically about 97% as measured by catch can tests without crop canopy. Because of the small wetted radius, ponding and runoff can be an issue on certain soils, slopes, and soil surface conditions.

What is LEPA? Low Energy Precision Application (LEPA) is a modification to the typical sprinkler configuration on center pivots or linear-move machines that minimizes evaporation and wind drift losses by running the water directly onto the soil surface at very low pressure (Figure 4 & 5). Because much less water is lost to wind drift and evaporation, it is more efficient (Lyle and Bordovsky, 1983). It operates at much lower pressures and consequently it also saves significant pumping energy. However, because an equivalent amount of water is applied in much less time, ponding and runoff can become a greater issue unless the field is tilled and the irrigation system is operated in such a way to limit this runoff. This may include using furrow diking and using drag socks to limit the erosion of these dikes (Figure 4), using a dammer/diker to increase the soil surface water storage (Jones and Baumhardt, 2003), or speeding up the irrigation system to apply smaller application depths in each pass.

What is LESA? Low Elevation Spray Application (LESA) is a similar modification to the typical sprinkler head configuration on center pivots or linear-move machines that places the water application very close to the soil surface, but uses a suspended sprinkler or spray head (Figures 3, 6, and 8-11). It also reduces water losses to wind drift and evaporation *and* is uses less energy since it runs at much lower pressures. However, because the water is spread out in a limited way by the sprinkler head, it applies water more uniformly than LEPA and gives the water more time to infiltrate into the soil. Because of this it has fewer problems with non-uniformity, crop germination, or with ponding and runoff than LEPA on fields without furrow dikes and therefore can be more flexible with a wide variety of crops, row orientations, and tillage systems than LEPA.

Figure 4. LEPA on a row crop using drag socks to minimize erosion to the furrow dikes that limit water movement in the furrows.

Figure 5. LEPA on mint. This setup allows conversion back to MESA for better crop germination if desired.

Figure 6. LESA operating in wheat with the sprinkler heads below the top of the canopy.

Testing and Trials in the Pacific Northwest

Starting in the 2013 growing season, but continuing into the 2014 and 2015 growing season, adjacent spans of LESA and conventional MESA sprinkler mounting were tested on six center pivots in Idaho, four in Nevada, four in Washington, and one in Oregon. Many of these comparison trials have been operating for multiple years. Typically the last span of the pivot was converted to LESA or LEPA for comparison purposes with the rest of the pivot. These were primarily located in fairly flat fields without runoff issues. The crops grown included: timothy hay, alfalfa, grass seed, beans, mint, silage corn, barley, potatoes, and wheat.

Soil moisture sensors were installed in both the LESA/LEPA sections of the pivot as well as the MESA sections of the pivot and the differences were monitored over time (Figure 7).

Figure 7. Soil moisture sensors installed in an alfalfa field near Mud Lake Idaho. The foreground sensors are under MESA and the background sensors are under LESA. There are stark differences in crop health due to deficit irrigation on both showing the efficiency improvements under LESA.

In addition, a paired pivot study using one full pivot of the LESA system and one full pivot of MESA (drop nozzles on about 10-foot spacing) was also conducted near Eureka Nevada beginning in the summer of 2014. Two sets of adjacent pivots, one LESA and one conventional, were established in alfalfa. A third LESA / conventional comparison was performed on timothy hay. Irrigation scheduling was managed by the grower using their own traditional practices and experiences.

The LESA systems in this study had the following characteristics:

- All equipment used is currently available “off the shelf” from most agricultural irrigation equipment retailers.
- Sprinkler heads were set to be about 12 inches above the soil surface when the pipe is full of water (Figure 9).
- Sprinkler drop spacing was about 4-5 feet apart. This was typically double the number of drops used for MESA. This is often done by replacing single gooseneck fittings on outlets spaced 9 feet apart with double goosenecks in each outlet, running the hose drops over the outside of the pivot truss rods, and using truss-rod hose clamps to position the sprinkler properly. (Figures 10 and 11).
- Spray nozzles with grooved plates were used that apply water in about a 15-foot wetted diameter.
- 6 to 10 psi pressure regulators were used with the regulator located near the sprinkler head (Figure 8).

Figure 8. Weight, pressure regulator and spray head assembly for a LESA drop.

Figure 9. Growers examining LESA on a pivot at a field day near Arco, ID.

Figure 10. Double goosenecks and truss-rod hose clamps to position the hose correctly are used to increase the number of sprinkler drops (decrease the drop spacing) without requiring additional outlets in the pivot pipe.

Figure 11. Double Goosenecks and truss-rod hose slings to position the hoses help spread the water out to help offset shorter infiltration times.

Figure 12. Traditional MESA sprinkler head arrangement (left), and a LESA sprinkler placement about 1 foot above the ground (right).

Observations from the Trials

It is acknowledged that additional research needs to be done to replicate, validate, and quantify many of the observations noted below since there is a high degree of variability inherent in agriculture, soils, crops grown, weather conditions, possible sprinkler head configurations, and irrigation water management practices. However, we would like to share our preliminary observations from these trials as we believe they are of benefit.

- LESA provided many benefits over LEPA including the ability to more uniformly irrigate a broad area which benefits crop emergence and gives more flexibility for a wider variety of crops grown in rotation in the field, including a variety of crops, row spacings, and row orientations.
- Aside from removing old galvanized steel plugs in the top of pivot pipes, conversion from MESA to LESA was simple and didn't take very long.
- The stationary grooved plate sprinklers used in LESA were inexpensive at less than $2 while the rotators or wobblers typically used in MESA retail for about $15-$20/each.
- There were fewer runoff problems than anticipated.
- Almost all of the growers participating in this study expressed interest in expanding its use on their farms and many have already converted multiple pivots to LESA without prompting or cost share.
- No observable damage was done to the crops by dragging the sprinkler heads through the crop (Figures 19-20), even in corn.
- A 4 to 5 foot nozzle spacing with LESA heads mounted at about 1 foot above the ground adequately distributed water on almost all of the crops tested.

- Crop production observations of a similar nozzle arrangement on an alfalfa field in northern Nevada in 2013 indicated no crop production uniformity advantage by reducing nozzle spacing from 5 feet to about 30 inches.
- There appeared to be *better* irrigation uniformity in corn with LESA compared to MESA since corn can inhibit of the sprinkler application pattern of MESA, while with LESA there is an additional sprinkler in that space.
- The sprinkler spacing is close enough that sprinkler distribution uniformity issues have much less impact due to the soil's natural ability to move water laterally, and the root's ability to grow towards water.
- In a few instances bands of under-irrigated seedlings were observed on newly seeded barley with LESA on sandy soils. These crops eventually "grew out of it" and the uniformity problems didn't persist throughout the season as the root zones expanded. These problems are likely due to the very limited rooting zones of newly planted small grains, and the limited ability of sands to move water laterally. In instances such as these it might be best to raise the sprinkler heads up a little higher off the ground and/or use a type of sprinkler or spray plate that increases the wetted radius and overlap of the LESA sprinklers.
- Some uniformity issues were also observed in deep furrowed crops such as potatoes when the row orientation was parallel or nearly parallel to the direction of the sprinkler movement through the field, when the sprinkler spacing was not evenly divisible by the row spacing, and when the crop canopy obstructed the sprinkler's water trajectory. For example, potatoes on a 2.5 foot row spacing had uniformity issues with sprinklers on a 4 foot spacing when the sprinklers were in the canopy. Under this scenario some rows got more water than others. These issues were less of a problem when the rows were perpendicular to the sprinkler travel direction (parallel to the pivot orientation.)
- Because of the increased application efficiency of LESA and less sprinkler distortion by the wind, there were fewer issues with dry field edges and fewer differences in applied water depths due to weather and climate changes including day/night, and windy vs. non-windy differences. This resulted in more consistent irrigation application efficiency and consequently an improved uniformity on a larger field scale (Figure 21).
- Because of the limited wetted radius of LESA sprinklers, there appears to be more control over keeping wheel tracks drier to reduce pivot wheel track rutting (Figures 22-23).
- Later in the season, the top of the canopy stayed dry. This will likely result in greater differences in application efficiency than was measured using the catch can method on a bare soil surface (Figure 18).
- Some growers observed less lodging in their LESA fields (crop laying over which makes it difficult to harvest) due to the drier canopy. The dry canopy may also decrease disease pressure (Figure 24).
- Sprinkler inspection and maintenance can be performed by walking among the sprinklers with just irrigation boots and without ladders. (Figure 25)
- The sprinkler heads bumping along the soil surface due to terrain undulation also appeared to be a non-issue due to the closer sprinkler spacing (Figure 26).
- There will likely be less losses of nitrogen to volatilization during fertigation due to the increased application efficiency.

- When the pipe fills with water, the pipe span deflects down slightly, especially in the middle of the span between the towers, due to the additional weight of the water. This can lower the sprinkler head height up to 6 inches and should be accounted for during installation when setting the LESA head height.

Figure 19. Sprinklers operating within the canopy. The wheat heads stay dry. This may decrease lodging, and increase irrigation application efficiency due to less water lost to evaporation from wet canopy.

Figure 20. LESA worked well in corn. The narrow spacing eliminates typical uniformity issues with MESA on wider spacings due to the canopy disrupting the application pattern. Although the heads periodically were held up by the canopy, they made it through fine with few resultant uniformity issues. The growers did not plant in a circle and had no observable uniformity problems.

Figure 21. The wind drift losses are fairly visible under the MESA section and practically non-existent in the LESA section where the spray heads are below the top of the wheat canopy. The majority of water losses from sprinklers is to evaporation and of course water vapor of course is *not* visible.

Figure 22. Dry wheel track ahead of the LESA section.

Figure 23. Wheel track ahead of the MESA section with water running ahead of the pivot.

Figure 24. The sprinkler head can irrigate below the top of the canopy without problems. This may reduce disease problems and lodging. However, it may limit the ability to uniformly chemigate unless the nozzles are switched to chemigation nozzles that spray upwards.

Figure 25. Sprinkler maintenance is much easier and can be done while the system is running while simply wearing irrigation boots without getting overly wet.

Figure 26. Sprinkler head bumping along the ground in rare instances when pivot tracks get deep or the terrain undulates. This did not appear to damage the equipment or crops.

Potential Drawbacks

- Applying the same amount of water in less time due to the decreased wetted radius can increase ponding and runoff (Figure 27). If a grower is already experiencing problems with ponding and runoff due to tight (high clay content) soils or steep field slopes, then converting to LEPA or LESA is not recommended without using tillage practices that increase the soil surface water storage or improve infiltration.
- There is an increased installation costs, mostly associated with increased amounts of hose, more pressure regulators and additional sprinkler weights (Tables 2-4 below).
- Slightly smaller nozzle sizes are used due to less water required per sprinkler drop. This can lead to an increased propensity for sprinkler nozzle plugging with dirty surface water sources. To compensate and prevent plugging, finer filter screens may be required. However, nozzle sizes are larger than many would expect due to the lower operating pressures.
- If the sprinkler spacing is decreased on the inside two spans of most pivots they would require impractically small nozzle sizes to avoid overwatering. It may be best for these two spans to continue to operate on a larger spacing as MESA.
- LESA may cause issues with chemigation uniformity when the sprinklers are below the top of the canopy. Chemigation plates are available that spray water upwards (Figure 28), but studies have not yet been done on how effective these are for pest and disease control when the sprinklers are below the tops of the canopy.

Figure 27. Due to its smaller wetted diameter, LESA allows less time for water to infiltrate into the soil. Therefore LEPA or LESA may not be suitable to tight soils or steep slopes where infiltration and runoff can be an issue.

Figure 28. Chemigation plates can be used to spray water upwards to improve canopy wetting for chemigation.

Measured Water Savings.

Catch can tests were performed using large cans (5-gallon buckets) to measure differences in irrigation application efficiency (water applied per unit time / water caught in the buckets) between LESA and

MESA. The cans were dug into the soil so that their openings were at or near the soil surface. There was no crop planted during the tests. There were 24 cans in each section. This test was done on ten different dates and times to attempt to capture a variety of weather events. The materials, methods, and detailed results of this study are included in a manuscript titled “Evaluation of different types of Center Pivot Irrigation system under different weather conditions, WA, USA” (Mehanna and Peters, 2016).

In these experiments an average of **96%** of the water that left the LESA nozzles was collected in the catch cans. In comparison, an average of **81%** of the water that left the MESA nozzles was collected in the catch cans. This translates to ***18% more water reaching the ground with LESA when compared with MESA*** (Figure 29). These differences were statistically significant ($p <= 0.05$). These differences are likely higher when the LESA sprinklers operate below the top of a crop canopy. The efficiency measurements for LESA is comparable with those found by other researchers (Lyle and Bordovsky, 1983; Fipps and New, 1990; Rajan et al., 2015)

This improved irrigation application efficiency can result in large yield and crop quality increases to growers *especially* when there are water shortages and the marginal value of getting additional water into the soil is high. In other words, when there isn’t enough water there are very strong economic benefits (additional yield due to more water in the soil) to converting from MESA to LESA. When there is access to an adequate amount of water and the costs of additional water is negligible, then the primary economic benefits of LEPA and LESA are derived from pumping energy savings because the pump requires less power and operating time to deliver an equivalent amount of water to the soil. However, even if there is adequate water available and the only return to the growing operation is pumping power savings, it can still be cost effective to convert to LESA (see the cost estimate section below).

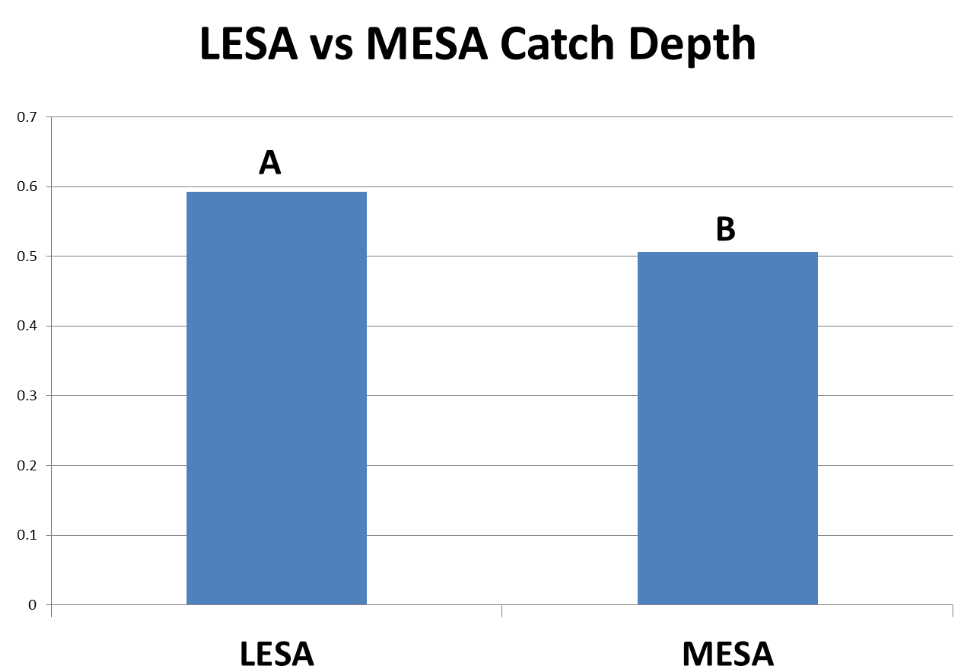

Figure 29. Catch can efficiency comparisons (10 replications) measured an average of 18% more water to the ground with LESA compared to MESA. Differences were statistically significant at the 0.05 level.

Anecdotal Corroboration of Water Savings Estimates

- In our trials during 2014 in Idaho, a grower managed a pair of pivots, one totally converted to LESA, and the other to MESA. The grower stated that the LESA-irrigated alfalfa pivots were able to be shut off for 1-2 days per week while the conventional MESA alfalfa pivots required continuous operation during the majority of the season to achieve similar yields.
- In 2015, the LESA pivot on one alfalfa field had water supply reduced by about 20% due to well problems, but still yielded nearly the same as the MESA field with full water application.
- Similar results were obtained from another pair of pivots under alfalfa. The grower plans to reduce capacity on the LESA pivot from 900 gpm to 750 gpm.
- On one trial the grower was deficit irrigating due to issues with his pump. The differences between MESA and LESA were highly visual (Figure 30).

With observed improvement in application efficiency pivots that may have been under-designed are now able to meet peak crop water use rates (the pivot keeps up on very hot days). However they may require more careful irrigation scheduling since they may need to be stopped periodically to avoid over-watering.

Figure 30. MESA (on the left) compared with LESA (on the right) on an alfalfa field near Mud Lake, ID. The stark differences in crop health are partially due to deficit irrigation on both showing the irrigation application efficiency differences.

Power Savings Analysis

Real power savings will depend on many aspects of the grower's particular situation including pump configuration, pump efficiency, depth to water source, and elevation differences. However, we made some estimates for a typical ¼ mile long center pivot (120 acres) designed at 7.5 gpm/acre for a total of 900 gpm as shown below (Table 1). A modest 10 psi pressure reduction was assumed from 35 psi required at the pump to 25 psi. A 15% decrease in the total run time of the LESA compared with the

MESA was also assumed because LESA can get more water into the soil per hour of run time. This results in an estimated 172 kW-hr savings per acre per irrigation season.

Table 1. Pumping power cost savings estimates for a typical center pivot with very little lift (surface water source).

Pumping Costs Estimates.

LESA	LESA	MESA	Units
Power Requirements *	25	35	hp
Power Requirements	18.6	26.1	kw
Hours/season **	1700	2000	hrs
Energy Use/Season	31620	52200	kwh
Cost/kwh	0.073	0.073	$
Demand Charge/month	10	10	$
Months/year	5	5	
Pumping Cost/Season	**$ 3,238**	**$ 5,116**	**$/year**

* LESA assumes 35 psi & 900 gpm. MESA assumes 50 psi & 900 gpm @ pump.
** Better efficiency results in fewer required operating hours for LESA
Assumes a 120 acre field designed at about 7.5 gpm/acre.

Power savings in kwh/acre…………………………………… **172** kW-hr/acre
Pumping Costs Saved with LEPA/Season………………… $ 1,877

One of the large benefits from a power generation and supply perspective is that the power savings from LESA can be realized during the hot part of the summer when both water *and* power supplies are most limited, so it could help directly reduce power generation capacity requirements.

How Much Does it Cost? Is It Worth It?

Assuming that it is time to replace the pressure regulators and sprinklers of a typical ¼ mile long pivot, a comparison was done of the costs the hardware of converting to LESA vs. replacing the existing MESA sprinklers and regulators on the pivot. The costs to replace MESA drops on a typical 9-10 ft spacing are shown in Table 2, and the parts for a LESA retrofit are shown in Table 4. The costs were annualized at a 4.0% interest rate for the number of years shown for each item. The approximate cost for a MESA replacement components for a ¼ mile machine (115 drops) is $3,939 and for the LESA configuration (250 drops) is about $6,400.

The installation labor cost estimates are given in Table 3 for MESA, and Table 5 for LESA.

Table 2. Equipment costs for a ¼ mile MESA system. The annualized costs ($/year) are at a 4% interest rate for the estimated years of life shown. Prices are for 2015.

MESA Drop	Cost	Years	$/Year	Notes
Gooseneck	$ 5.00	30	$0.29	

pinch Clamp	$ 0.21	10	$0.03	0.21/each
Drop Hose	$ 2.34	10	$0.29	0.39/ft x 6 ft.
Hose Barb	$ 0.92	10	$0.11	Nelson
pinch Clamp	$ 0.21	10	$0.03	(seems high)
Pressure Regulator	$ 6.92	5	$1.55	Nelson
Weight	$ 5.54	30	$0.32	
nozzle	$ 1.05	5	$0.24	Nelson
Nelson Rotator R3000	$ 17.06	5	$3.83	Body, plate, and cap
Total/Drop	$ 34.25		$6.69	
Drops per ¼ mile pivot	115		115	
Total Equipment Costs	**$ 3,939**		**$768.85**	per ¼ mile pivot

Table 3. Estimated Installation Labor Costs

MESA Drop	**Cost**	**Years**	**$/Year**
Labor Costs/Drop	$ 11.00		
Total Labor Costs	$ 1,265	5	**$284.15**

Table 3. Equipment cost estimates for a ¼ mile LESA system. The costs are annualized ($/year) at a 4% interest rate for the estimated years of life shown. Prices are for 2015.

LESA Drop	Cost	Years	$/Year	Notes
Double Gooseneck	$ 2.10	10	$0.26	4.20/each / 2
pinch Clamp	$ 0.21	10	$0.03	0.21/each
Drop Hose	$ 3.90	10	$0.48	0.39/ft x 10 ft.
Truss Rod Hose Clamp	$ 2.99	10	$0.37	Cost independent of size
Hose Barb	$ 0.92	10	$0.11	Nelson
pinch Clamp	$ 0.21	10	$0.03	(seems high)
Pressure Regulator	$ 6.92	5	$1.55	Nelson
Weight	$ 5.54	30	$0.32	
nozzle	$ 1.05	5	$0.24	Nelson
Nelson D3000 Spray	$ 1.82	10	$0.22	Body, plate, and cap
Total/Drop	**$ 25.66**		$3.61	
Drops per ½ mile pivot	250			
Total Equipment Costs	**$ 6,415**		**$ 902**	$/year per ¼ mile pivot

Table 5. Estimated LESA Installation Labor Costs

LESA Drop	Cost	Years	$/Year
Labor Costs/Drop	$ 11.00		
Total Labor Costs	$ 2,750	5	**$617.72**

In order to achieve the maximum power savings from converting to LESA a pump will often have to be reworked (the impeller trimmed) so that it will be most efficient at the decreased pressure requirement. These annualized costs at 4% interest rate over a 10 year life span are shown in Table 6 along with the costs of replacing the filter screen to filter out smaller particulates to avoid plugging the smaller nozzles.

Table 6. Annualized pump rework and replacement filter screen cost estimates.

Pump Rework Costs	Cost/hp	Yrs	$/Year
VFD&Filter or Rework	$ 150		
	$ 3,750	10	**462.341**
Water Filter (Fine Screen)	$ 400	10	**$49.32**
Total			**$ 462.34**

The total annualized cost estimates of deciding to convert to LESA vs. refit with MESA are shown in Table 7. This shows that although the upfront equipment costs of LESA is higher, over time this is repaid by power cost savings to create an estimated total cost *savings* of about $850 per year to convert to LESA. This results in about a 4 year simple payback and does *not* account for the large potential increases in overall income due to improved crop yields and quality.

Table 7. Total annualized cost difference estimates.

	LESA	MESA
Equipment	$ 902.16	$ 768.85
Labor/Maintenance	$ 617.72	$ 284.15
Annual Pumping Costs	$ 3,333.31	$ 5,115.60
Pump Rework	$ 462.34	$ -
Total/year	$ 5,315.53	$ 6,168.60
Difference/year	**$ 853.07**	

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