# Field dimensions ratio and alignments of sprinklers and lateral effect on pump power for sprinkler solid-set system

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**Abstract:** This paper presents an effective variable in sprinkler irrigation design, the objective from the study is getting the most suitable ratio for a rectangle field (L/B) related by lateral and sprinkler spacing in order to achieve minimum Horse Power ($H_p$) required by the pump to irrigate the field using a solid-set alignment. A computer model was developed to simulate pressure and flow rate distribution along pipes of pressurized irrigation systems in operation. The software made by VISUAL BASIC and runs in a Windows environment and is capable of simulating irrigation systems having pump station, sprinkler irrigation whether solid-set, move stop and center pivot laterals with pressure regulators, as well as trickle irrigation. The input data of the model are: soil type, climate condition, water salinity, land dimensions and slopes. The model according to soil type and water salinity gives the available types of crops can be cultivated, and according to climate conditions gives the amount of water needed. The model gives complete analysis of the system including hydraulic design of main pipe and laterals and selecting suitable sprinkler and finally get pump head, discharge and power

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**Key words**: $H_p$; rectangle field; dimension ratio; sprinkler; solid-set.

## 1. Introduction:

Prescreening process is one of matching the capabilities of the potential irrigation systems to physical site conditions and the goals and impacts of the project. The necessary field factors to design an irrigation system are the soil characteristics, climate conditions, water supply characteristics, field shape, topography, obstructions, and crop characteristics (Awadallah, 2002).

Soils have been classified for agricultural purposes by the U.S. department of Agriculture. For the common arable soils, suitable crops (Doorenbos and Kassam, 1979) and the basic intake rates (Pair, C. H,1983). Basic intake rate of soil and characteristics of the grown crop affect the irrigation method selection. Field crops may be irrigated by drip and/or sprinkle methods. Solid-set is expensive and must avoid for low value crops [Doorenbos and Kassam, 1979].

Climate conditions and soil texture and land slope determine the recommended minimum water application rate (USDA, 1964) and maximum water application rate (Keller and Bliesner, 1990) for sprinkle to overcome evaporation and run-off losses, respectively. Sprinkle irrigation should be avoided if the recommended minimum application rate due to climate is greater than the recommended maximum application rate due to soil and land slope.

Farm size, shape, and topography must consider in the selection process. For small and irregular farms, there is no need for automated systems. For large and regular farms, the use of a mechanized system is the right choice especially on coarse soils when high frequency irrigation gifts are required. For sloping fields, some systems require a degree of leveling to produce the desired application uniformity. Center-pivot system should be avoided for irregular farms or that contain obstruction.

**Model description:**

1. Selecting type of soil, climate zone, water salinity and wind speed affects the suitable crops, water needs and sprinkler specifications.
2. The selected crops guide to select the suitable irrigation system whether sprinkler or trickle.
3. The model try the selected system using all variables needed in the design such as.

   application rate range, sprinkler spacing and lateral spacing, sprinkler operating head.
4. And by every change in any of the above data the model gives complete analysis and results for the irrigation system according to the inputs.
5. The output results in excel sheet showing all details for the system such as application rate used, sprinkler and lateral spacing, sprinkler operating head and nozzle size, riser height, uphill and downhill lateral lengths, diameters, head loss and inlet pressure, maim pipe reaches and length, diameter, head loss and inlet pressure on each reach, pump head, discharge of system, and pump power.

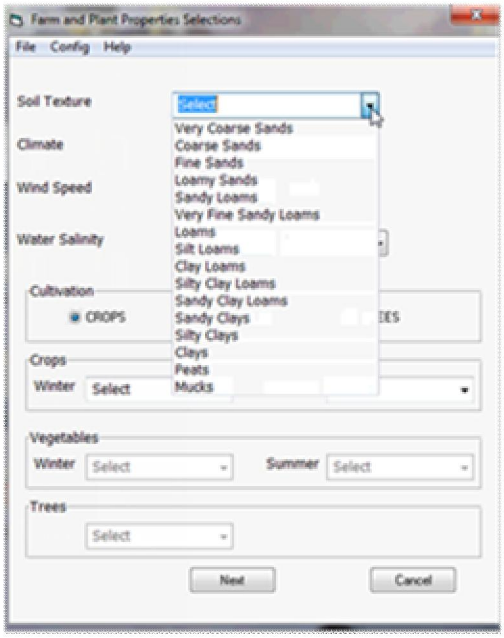


**Fig (1):** selecting soil type

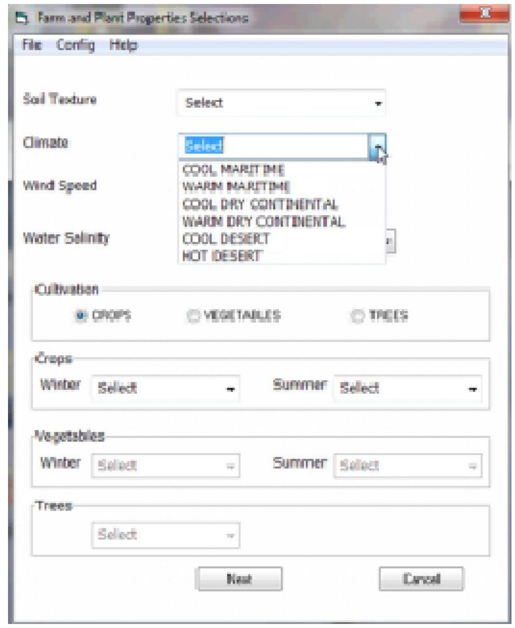


**Fig (2):** selecting climate zone

Selecting soil type and water salinity will give the suitable cultivation according to them.

And the wind speed will affect the sprinkler and lateral spacing which preferred less than 2.1 m/s (4.7 mph) to achieve better CU value (Dechmiet al,2003).

Minimum application rate is varies according to climate condition.

Maximum application rate is known according to soil type and land slopes.

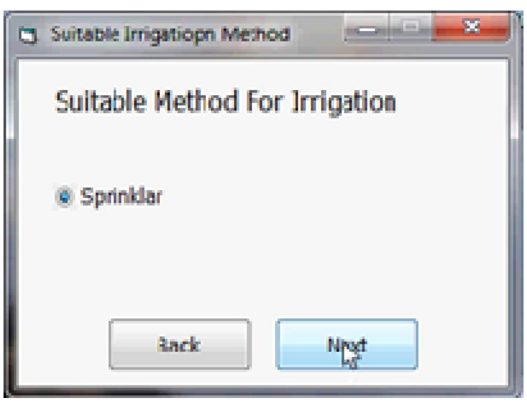


**Fig (3):** selecting suitable irrigation method

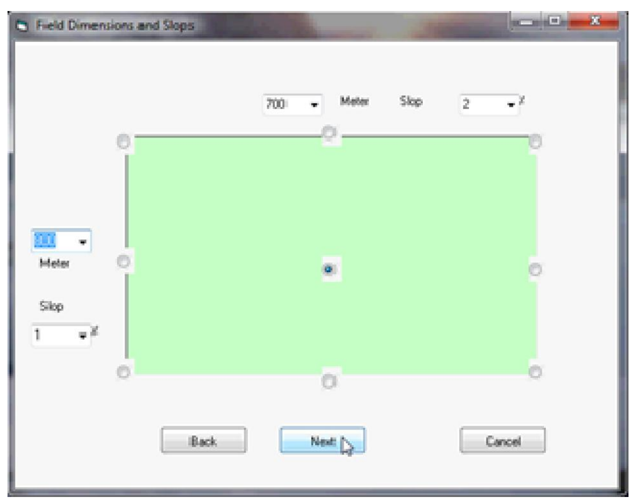


**Fig (4):** selecting farm dimensions and slopes

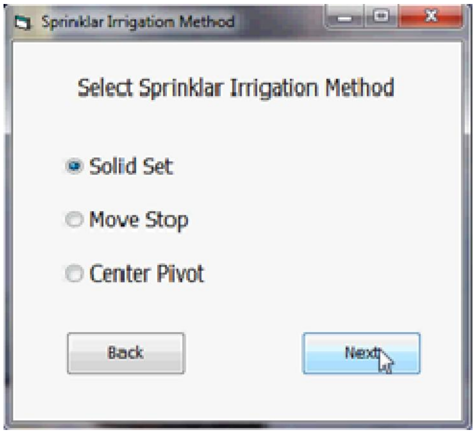


**Fig (5):** selecting sprinkler irrigation method

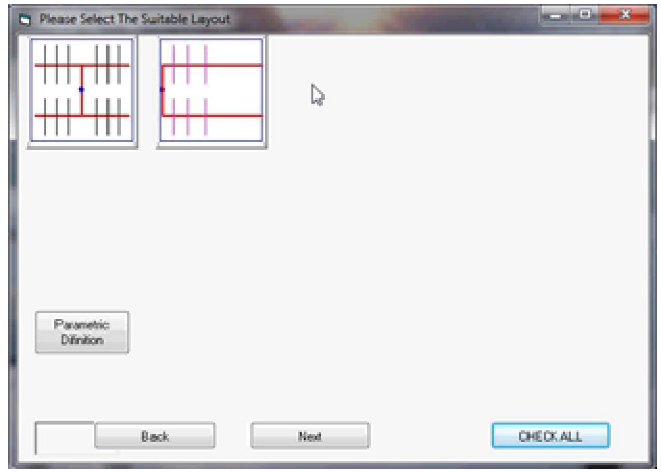


**Fig (6):** selecting main system shape

In the runs the program is trying many application rates starting from $Ar_{min}$ up to $AR_{max}$ then select the sprinkler and lateral spacing (Keller and Bliesner, 1990) to achieve the suitable uniformity coefficient (table 1), then select the suitable sprinkler specifications discharge, nozzle diameters and operating head (Keller and Bliesner, 1990) (table 4), the sprinkler discharge is calculated as qs=AR * SS * SL.

**Table (1):** Recommended Nozzle Sizes and Pressures With Expected Average CU for Different AR and $S_s$ x $S_l$ Under Wind (0 to 5 mph), [Keller and Bliesner 1990]

| Sprinkler | | Water application rates, in./hr ± 0.02 in./hr | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Spacing ft x ft | Operation | 0.10 | 0.15 | 0.20 | 0.25 | 0.30 | 0.35 | 0.40 |
| 30 x 40 | Nozzle, inch | 3/32 | 3/32 | 7/64 | 1/8 | 9/64 | 5/32 | 9/64 x 3/32 |
| | Pressure, psi | 30 | 50 | 45 | 45 | 45 | 40 | 40 |
| | CU, % | 82 | 83 | 82 | 83 | 83 | 85 | 88 |
| 30 x 50 | Nozzle, inch | 3/32 | 7/64 | 1/8 | 9/64 | 5/32 | 11/64 | 11/64 |
| | Pressure, psi | 40 | 40 | 45 | 50 | 45 | 40 | 50 |
| | CU, % | 83 | 88 | 86 | 86 | 84 | 85 | 86 |
| 30 x 60 | Nozzle, inch | | 1/8 | 9/64 | 5/32 | 11/64 | 3/16 | 3/16 |
| | Pressure, psi | | 40 | 45 | 45 | 45 | 45 | 50 |
| | CU, % | | 88 | 88 | 89 | 88 | 85 | 87 |
| 40x 40 | Nozzle, inch | 7/64 | 1/8 | 9/64 | 1/8 x 3/32 | 5/32 x 3/32 | 5/32 x 3/32 | 5/32 x 1/8 |
| | Pressure, psi | 30 | 35 | 35 | 40 | 35 | 40 | 35 |
| | CU, % | 78 | 82 | 86 | 87 | 88 | 89 | 90 |
| 40 x 50 | Nozzle, inch | | | 5/32 | 5/32 x 3/32 | 5/32 x 3/32 | 11/64 x 3/32 | 3/16 x 3/32 |
| | Pressure, psi | | | 35 | 35 | 45 | 40 | 40 |
| | CU, % | | | 78 | 83 | 84 | | 89 |
| 40 x 60 | Nozzle, inch | | | 5/32 | 11/64 | 3/16 | 13/64 | 7/32 |
| | Pressure, psi | | | 50 | 50 | 50 | 50 | 50 |
| | CU, % | | | 83 | 85 | 85 | 84 | 86 |
| 60 x 60 | Nozzle, inch | | | 3/16 | 13/64 | 7/32 | 1/4 | 1/4 |
| | Pressure, psi | | | 60 | 65 | 65 | 50 | 65 |
| | CU, % | | | 88 | 88 | 88 | 88 | 88 |

$S_s \times S_l$ = Sprinklers and lateral spacings. AR = Water application rate. CU = Expected uniformity coefficient.

**Table (2):** Pressure Range for Common Sprinkler Sizes, [Keller and Bliesner, 1990]

| Nozzle Sizes, NZ, (in.) | Pressure ranges, P, |
|---|---|
| 5/64 to 3/32 | 20 to 45 |
| 7/64 to 9/64 | 25 to 50 |
| 5/32 to 11/64 | 30 to 55 |
| 3/16 to 7/32 | 35 to 60 |

Then, the lateral can be sized due to its flow rate, length, material, allowable head loss, number of outlets, and first outlet position by using one of the common formulas. The widespread for various pipe materials is the Hazen-Williams formula.

$$h_f = 1.212\times10^{10}\times\left(\frac{Q}{C}\right)^{1.852}\times D^{-4.8704}\times L \qquad (1)$$

Where,

$h_f$, Q = head loss due to pipe friction, m, and flow rate in the pipe, L/s, respectively.

D, L = inside diameter, mm, and length of the pipe, m, respectively.

C = friction coefficient, which is function of pipe material (table 3).

For small diameter pipes (< 3.0 in.) the studies show that the Darcy-Weisbach equation represents the friction losses better than does the Hazen-Williams formula Churchill (1977).

$$hf = \frac{8\ f\ L\ Q^2}{g\ \pi^2\ D^5}$$

Sometimes, designers want to use two lateral sizes to reduce initial costs, especially in permanently buried laterals. Design steps of lateral have two sizes are usually give minimized friction losses (Bazaraa, 1982).

Then, the main pipe can be sized due to its flow rate, length, material using eqn (1) and eqn (2)

**Table (3):** Values of 'C' for Use in Hazen-Williams Equation

| Pipe Material | C |
|---|---|
| Plastic | 150 |
| Epoxy-coated steel | 145 |
| Cement asbestos | 140 |
| Galvanized steel | 135 |
| Aluminum (with couplers every 10- m) | 130 |
| Steel (new) | 130 |
| Steel (15 years old) or concrete | 100 |

**Application design example**

Given:

Soil is loams, Climate is cool dry continental, wind speed 4 mph, water salinity 2000 ppm, cultivated crops are Barley and Soybean, farm length (L) 1000 m, farm width (B) varies 500, 600, 700, 800, 900, 1000 m, bigger land slope (DZ = 2%) parallel to farm length and smaller land slope (Z = 1%) parallel to farm width and main pipe H shape with pump at center of field (fig: 7).

The model will make design according to the above data and according to sprinkler and lateral spacing the results are:

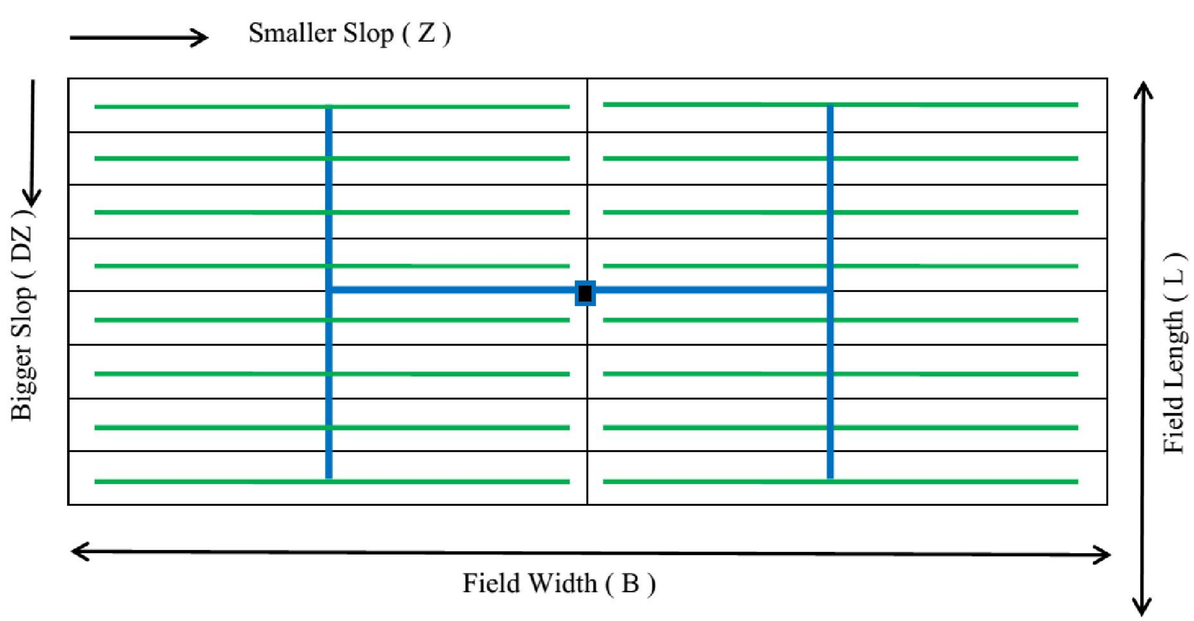


**Fig (7):** field data dimensions, slopes, main and sub main pipes (Blue lines), Laterals (Green lines), pump at center of field

**Table (4):** Minimum power of pump

| B (m) | L/B | Minimum pump head (kw-hr) SS X SL (ft) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 30x40 | 30x50 | 30x60 | 40x40 | 40x50 | 40x60 |
| 500 | 2.00 | 286.1 | 266.0 | 547.4 | 255.9 | 277.5 | 593.7 |
| 600 | 1.67 | 319.6 | 307.4 | 627.1 | 352.7 | 343.6 | 699.2 |
| 700 | 1.43 | 375.5 | 361.4 | 739.7 | 360.0 | 380.5 | 770.8 |
| 800 | 1.25 | 429.0 | 413.8 | 857.3 | 417.4 | 440.8 | 907.8 |
| 900 | 1.11 | 488.8 | 470.4 | 970.5 | 470.2 | 510.8 | 1063.3 |
| 1000 | 1.00 | 544.7 | 507.7 | 1082.5 | 530.6 | 570.4 | 1102.1 |

(soil texture sandy loams, climate zone cool dry continental, water salinity = 2000 ppm, field length = 1000m, DZ=2%, Z=1%, wind speed 4.0 mph, cultivated crops are Barely and Soybeans, Main pipe are H shape and pump on center of field)

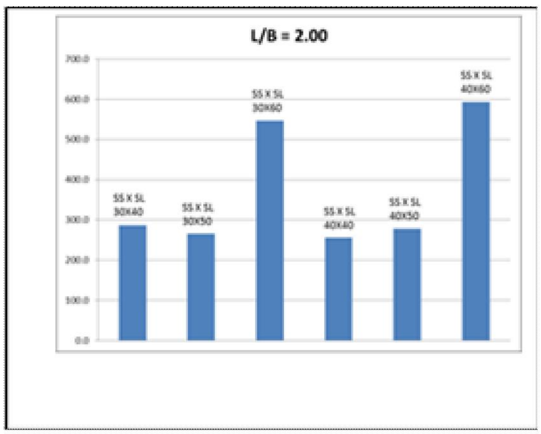


**Fig (8):** Hp when L/B ratio equals 2.00 according to alignments of sprinklers and laterals

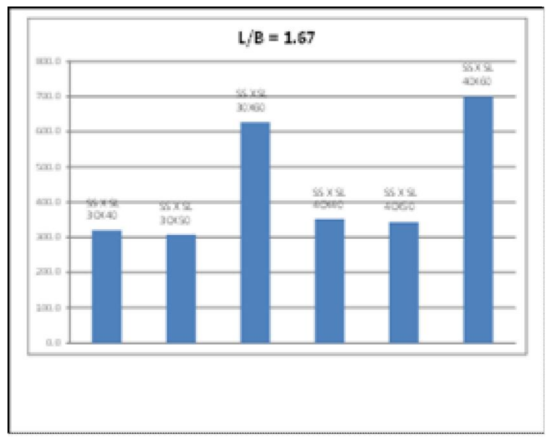


**Fig (9):** Hp when L/B ratio equals 1.67 according to alignments of sprinklers and laterals

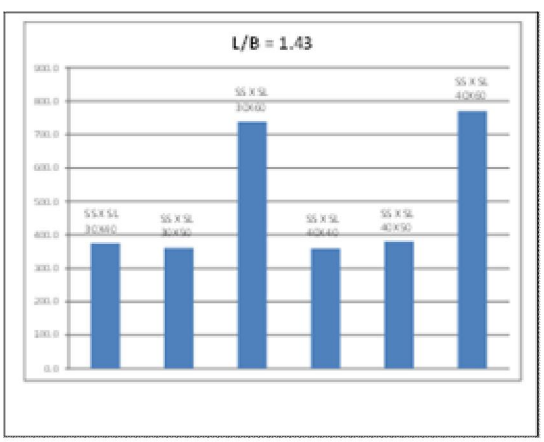


**Fig (10):** Hp when L/B ratio equals 1.43 according to alignments of sprinklers and laterals

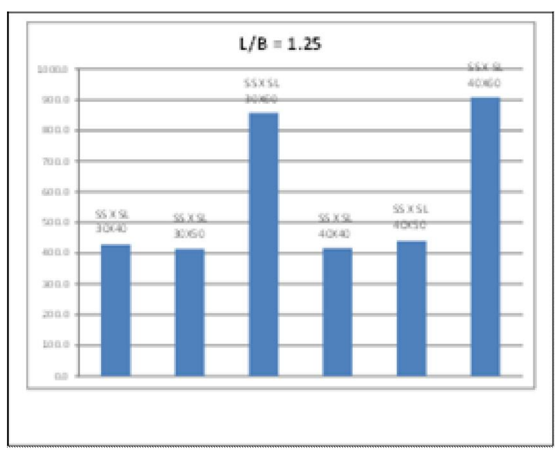


**Fig (11):** Hp when L/B ratio equals 1.25 according to alignments of sprinklers and laterals

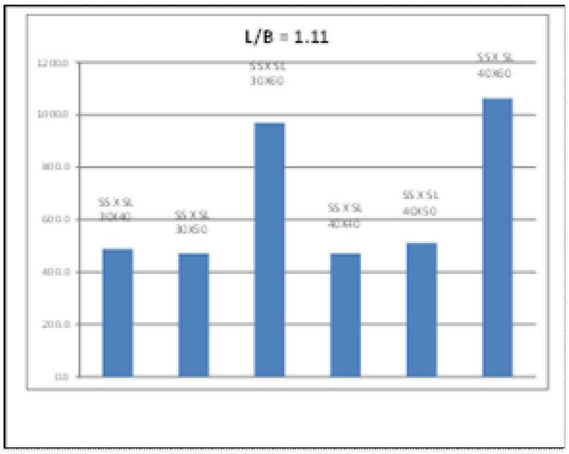


**Fig (12):** Hp when L/B ratio equals 1.11 according to alignments of sprinklers and laterals

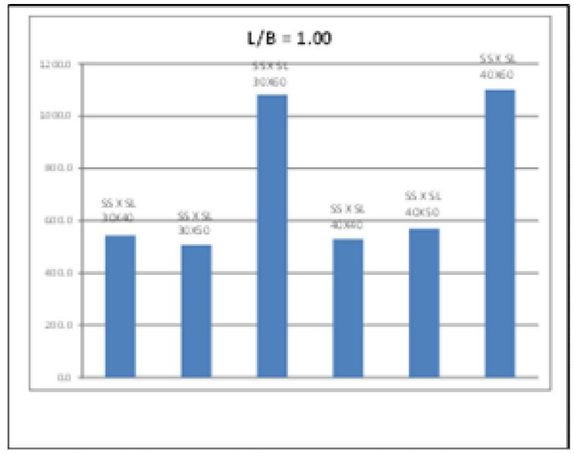


**Fig (13):** Hp when L/B ratio equals 1.00 according to alignments of sprinklers and laterals

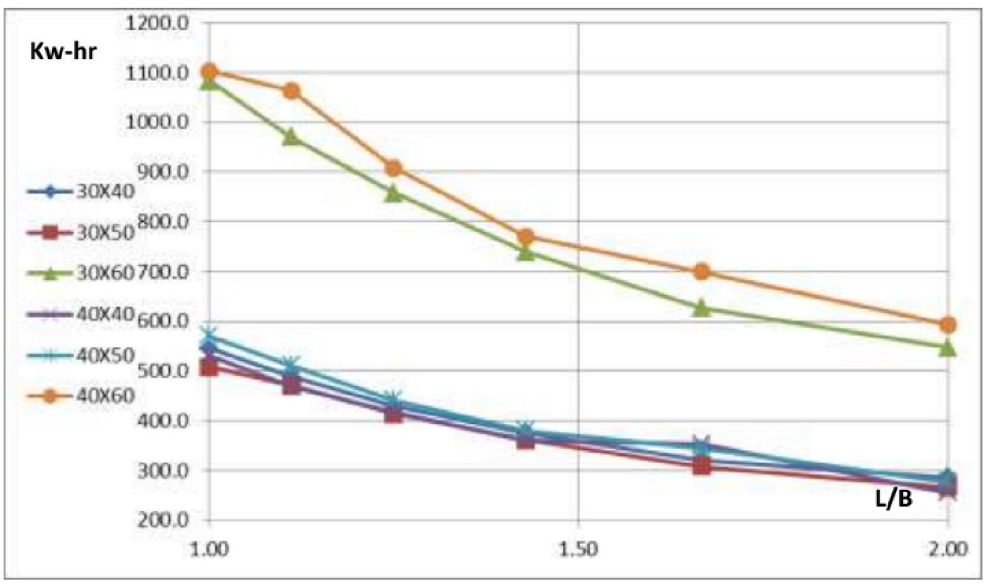


**Fig (14):** Minimum power of pump for the field
(soil texture sandy loams, climate zone cool dry continental, water salinity = 2000 ppm, field length = 1000m, DZ=2%, Z=1%, wind speed 4.0 mph, cultivated crops are Barely and Soybeans, Main pipe are H shape and pump on center of field)

**Table (5):** Minimum power of pump per feddan

| B (m) | L/B | A fedd | Minimum pump head per feddan ( kw-hr ) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | SS X SL (ft) | | | | | |
| | | | 30x40 | 30x50 | 30x60 | 40x40 | 40x50 | 40x60 |
| 500 | 2.00 | 119.0 | 2.40 | 2.23 | 4.60 | 2.16 | 2.33 | 4.99 |
| 600 | 1.67 | 142.9 | 2.24 | 2.15 | 4.39 | 2.47 | 2.41 | 4.89 |
| 700 | 1.43 | 166.7 | 2.25 | 2.17 | 4.44 | 2.15 | 2.28 | 4.62 |
| 800 | 1.25 | 190.5 | 2.25 | 2.17 | 4.50 | 2.19 | 2.31 | 4.77 |
| 900 | 1.11 | 214.3 | 2.28 | 2.20 | 4.53 | 2.19 | 2.38 | 4.96 |
| 1000 | 1.00 | 238.1 | 2.29 | 2.13 | 4.55 | 2.23 | 2.40 | 4.63 |

(soil texture sandy loams, climate zone cool dry continental, water salinity = 2000 ppm, field length = 1000m, DZ=2%, Z=1%, wind speed 4.0 mph, cultivated crops are Barely and Soybeans, Main pipe are H shape and pump on center of field)

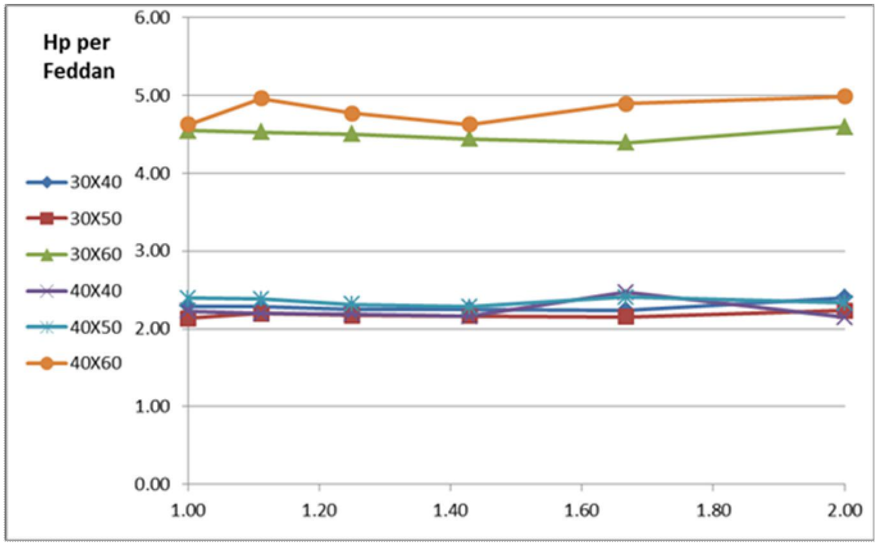


**Fig (15):** minimum power of pump per feddan
(soil texture sandy loams, climate zone cool dry continental, water salinity = 2000 ppm, field length = 1000m, DZ=2%, Z=1%, wind speed 4.0 mph, cultivated crops are Barely and Soybeans, Main pipe are H shape and pump on center of field)

**Conclusion**

The study presents that sprinkler and lateral spacing and field dimensions ratio affect the operating head of pump, the Hp of pump which considered one of the major initial and running cost of any land reclamation project, and the study gives the following data:

Minimum power per feddan at alignment 30x50, which needs 2.13 at L/B=1.0.

Alignment 30x40 gives minimum power of 2.24, which exceeds 5% at L/B=1.67.

Alignment 40x40 gives minimum power of 2.15, which exceeds 1% at L/B=1.67.

Alignment 40x50 gives minimum power of 2.28, which exceeds 5% at L/B=1.43.

The ratio of L/B gives low power per feddan when using lateral and sprinkler alignments SSxSL (30x40, 30x50, 40x40 and 40x50), and should avoid using alignments SSxSL (40x60 and 30x60). The Hp per feddan varies according to L/B ratio in a wavy irregular shape according to lateral and sprinkler alignment, in other words:

Alignment 30x40 gives minimum power at L/B= 1.67.

Alignment 30x50 gives minimum power at L/B= 1.00.

Alignment 40x40 gives minimum power at L/B= 1.67.

Alignment 40x50 gives minimum power at L/B= 1.43.

Therefore, L/B for minimum operating power recommended being between 1.00 and 1.67 for alignments 30x40, 30x50, 40x40 and 40x50. And avoid using alignment 30x60 and 40x60.

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