Basics of Drip Irrigation Systems

by Bob Schultheis
Natural Resource Engineering Specialist

Site Considerations

- Labor & layout
  - Who will be doing the work?
    - Tractor & vehicle access?
    - Disability access?
  - What do you & your family like to eat?
  - How do you plan to use the produce?
    - Eat fresh vs. preservation
    - Don’t plant more than you can manage

- Light
  - Needed for healthy plants & maximum yield
  - Leafy vegetables & root crops tolerate some shade
  - 8-10 hours best for beans, okra, tomatoes, peppers, melons, cucumbers, squash and other fruiting vegetables

Do surrounding trees or buildings cast shadows?
Run rows N-S for best sun exposure & air circulation; low-growing plants on South end

- Elevation & slope
  - Good air drainage for frost prevention
  - South slopes warm first in spring
  - Affects planting dates
  - Affects cost of getting water to site & distributing it

- Trees & buildings
  - Affects air currents downwind at least 10X tree height
  - Can block cold winter wind from N or W; moderate hot summer wind from S or W
  - Tree roots can stunt or kill vegetables (walnut)

- Water
- Utilities
- Roadway access
- Trees & buildings
- Size
- Soil

Site Considerations
Site Considerations

Size
- Allow enough space for plants at maturity
- See MU Guides
  - G6201 Vegetable Planting Calendar [extension.missouri.edu/explorepdf/agguides/hort/g06201.pdf]
  - for space requirements, amounts to plant, recommended varieties, planting & maturity dates
- G6005 Fruit & Nut Cultivars for Home Plantings [extension.missouri.edu/explorepdf/agguides/hort/g06005.pdf]
- Rotation schedule to reduce diseases
- Room to expand?

Soil
- Good drainage; high organic matter
- Adapted to plants to be grown, i.e. pH
- Soil test to find modifications needed
- Adequate time for modifications to work
- Soil temperature near 60°F for warm-season crops

Site Considerations

Soil & Climate Properties
- Soils store 1.5”-2.5” of water per foot of depth (check county NRCS Soil Survey)
- Intake rate = 0.3”-2.0” per hour, rest is runoff
- Available water = 75% of total water in soil
- Summer E.T. rate is 0.25” per day
- A 2-ft. deep soil holds 9-15 day supply of moisture
- Southwest Missouri historical weather:
  - Rainfall = 41”-42” per year
  - Evaporation = 40” per year
- Ozarks has 3-4 week summer dry spell

Benefits of Using Compost
- Improves drainage & aeration of heavy clay soils
- Increases moisture-holding ability of sandy soils
- Increases earthworm & soil microbial activity that benefit plant growth
- Improves soil structure & makes it easier to work
- Contains nutrients needed for plant growth

USDA Soil Structure Classes
Soil structure influences infiltration rate of water

<table>
<thead>
<tr>
<th>Drainage Class</th>
<th>Matrix</th>
<th>Mottle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well</td>
<td>Bright red</td>
<td>None</td>
</tr>
<tr>
<td>Moderately well</td>
<td>Red</td>
<td>Gray</td>
</tr>
<tr>
<td>Somewhat poorly</td>
<td>Dull</td>
<td>Red</td>
</tr>
<tr>
<td>Poorly</td>
<td></td>
<td>All gray</td>
</tr>
</tbody>
</table>

Soil Drainage Classification
Color Indicates Drainage & Pans

- Captina Silt Loam
- Tonti Silt Loam
- Scholten Gravelly Silt Loam

Testing Soil Drainage
- Dig & fill with water several 12" deep holes
  - Good drainage = water drains in 2 hours
  - Fair drainage = water drains in several hours
  - Poor drainage = water still there after 8-10 hours

USDA Soil Texture Classes
- Particle size
  - Sand = 2.0-0.05 mm
  - Silt = 0.05-0.002 mm
  - Clay = <0.002 mm
- Characteristics
  - Sand adds porosity
  - Silt adds body to the soil
  - Clay adds chemical & physical properties

Determining Soil Texture
- By feel
  - Gritty, smooth, sticky
- Using the jar method
  - Fill a 1-quart jar ¼ full of soil
  - Fill the jar with water to ¾ full
  - Add 1 teaspoon of dishwashing detergent
  - Shake very well to suspend soil
  - Place on a flat surface and allow soil to settle for 2 days
  - Measure % thickness of each layer relative to all

Wetting Patterns (Drip)

Site Considerations
- Water
  - Easy access to reliable water source
  - Adequate volume for duration of plants
  - Avoid areas that accumulate runoff from rain or irrigation
  - Beware of “fragipan” on upland soils
    - Most plants don’t like “wet feet”
Site Considerations

Utilities
- Overhead electrical wires
- Underground electrical or communication wires, gas or water lines, septic systems
- Easements

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Roadway access
- All-weather durability
- Adequate parking
- Security (vandals, food defense)

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- Overhead electrical wires
- Underground electrical or communication wires, gas or water lines, septic systems
- Easements

The Two Major Factors in Irrigation System Planning

1. How much water do you need?
2. How much time do you have?

Basic Watering Facts

- Plants need 1"-1.5" of water per week
- Can survive drought on half that rate
- Deep infrequent waterings are better than several light waterings
- Deeper roots require less supplemental irrigation
- Taller plants have deeper roots
- Lowers tendency to wilt
- Shades soil surface
- Controls weeds by competition
- Makes water "go farther"

When to Water

- Rainfall less than 1" per week
  - Keep a record of rainfall received
  - Check soil moisture with long screwdriver
- Water in early morning.
  Let plant leaves dry before evening to prevent diseases

Moisture Measurement

- "Feel" method - handful of soil
- Screwdriver method – force into soil
- Appearance of plants - wilt
- Calendar method - daily, 3rd day
- "Checkbook" method
  - Tally total rainfall + irrigation against daily water use of plants
- Tensiometers
  - Read scale of 0 (wet) to 100 (dry)
- Moisture resistance blocks
  - Buried at depths in soil, check with meter
Measuring Water Needs

- Catch cans
- 4-cycle timer
- Rain gauge

Plant Water Requirements 1

<table>
<thead>
<tr>
<th>Vegetable Crop (mature)</th>
<th>Gallons per 100 Feet of Row per Week</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum for plant survival</td>
<td>100</td>
</tr>
<tr>
<td>Lettuce, spinach, onions, carrots, radishes, beets</td>
<td>200</td>
</tr>
<tr>
<td>Green beans, peas, kale</td>
<td>250</td>
</tr>
<tr>
<td>Tomatoes, cabbage, peppers, potatoes, asparagus, pole beans</td>
<td>300</td>
</tr>
<tr>
<td>Corn, squash, cucumbers, pumpkins, melons</td>
<td>400-600</td>
</tr>
</tbody>
</table>

Plant Water Requirements 2

<table>
<thead>
<tr>
<th>Fruit Crop</th>
<th>Gallons per 100 Feet of Row per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strawberry</td>
<td>50</td>
</tr>
<tr>
<td>Raspberries &amp; Blackberries</td>
<td>75 Without mulch 100</td>
</tr>
</tbody>
</table>

Plant Water Requirements 3

<table>
<thead>
<tr>
<th>Fruit Crop</th>
<th>Plant x Row Spacing, Ft.</th>
<th>Sq.Ft./Plant</th>
<th>Plants/Acre</th>
<th>Gal/Plant/Day</th>
<th>Gal/Acre/Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apples</td>
<td>6 x 14</td>
<td>84</td>
<td>518</td>
<td>6</td>
<td>4144</td>
</tr>
<tr>
<td></td>
<td>18 x 26</td>
<td>468</td>
<td>93</td>
<td>42</td>
<td>3506</td>
</tr>
<tr>
<td>Peaches</td>
<td>15 x 20</td>
<td>300</td>
<td>145</td>
<td>28</td>
<td>4060</td>
</tr>
<tr>
<td></td>
<td>18 x 20</td>
<td>360</td>
<td>121</td>
<td>34</td>
<td>4114</td>
</tr>
<tr>
<td>Grapes</td>
<td>8 x 10</td>
<td>80</td>
<td>540</td>
<td>10</td>
<td>5440</td>
</tr>
<tr>
<td></td>
<td>8 x 16</td>
<td>128</td>
<td>340</td>
<td>16</td>
<td>5440</td>
</tr>
<tr>
<td>Blueberries</td>
<td>4 x 12</td>
<td>48</td>
<td>908</td>
<td>4</td>
<td>3632</td>
</tr>
</tbody>
</table>

Water Sources

- **Good**
  - Well = check pH & hardness
  - Municipal = may be expensive
  - Spring or stream
  - Pond water = sand filters
  - Pump to tank on hill
    - Elevation dictates pressure (2.3 feet of head = 1 psi pressure)
    - Watch for tank corrosion
  - Rain barrel
    - Limited volume & pressure

- **Poor**

Water Quality Analysis

- **Inorganic solids** = sand, silt
- **Organic solids** = algae, bacteria, slime
- **Dissolved solids**
  - Iron & Manganese
  - Sulfates & Chlorides
  - Carbonates (calcium)
- **pH**
- **Hardness**
### Plugging Potential of Drip Irrigation Systems

<table>
<thead>
<tr>
<th>Factor</th>
<th>Moderate (ppm)*</th>
<th>Severe (ppm)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suspended solids</td>
<td>50-100</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Chemical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH**</td>
<td>7.0-7.5</td>
<td>&gt;7.5</td>
</tr>
<tr>
<td>Dissolved solids</td>
<td>500-2000</td>
<td>&gt;2000</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.1-1.5</td>
<td>&gt;1.5</td>
</tr>
<tr>
<td>Iron</td>
<td>0.1-1.5</td>
<td>&gt;1.5</td>
</tr>
<tr>
<td>Hardness***</td>
<td>150-300</td>
<td>&gt;300</td>
</tr>
<tr>
<td>Hydrogen sulfide</td>
<td>0.5-2.0</td>
<td>&gt;2.0</td>
</tr>
</tbody>
</table>

* ppm = mg/L  ** pH is unitless  *** Hardness: ppm = gpg x 17

### Estimating Water Quantity

- Household water demand
  - GPM = Total count of toilets, sinks, tubs, hose bibs, etc. in home
- Excess is available for irrigation
  - Contact pump installer for capacity data
- Is pressure tank large enough?
  - Stay within cycle limits of pump, OR
  - Run the pump continuously

### Home Water Flow Rates

<table>
<thead>
<tr>
<th>Number of Bathrooms in Home</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedrooms</td>
<td>Flow Rate (Gallons Per Minute)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>8</td>
<td>10</td>
<td>--</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>--</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>12</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>--</td>
<td>13</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>6</td>
<td>--</td>
<td>--</td>
<td>16</td>
<td>18</td>
</tr>
</tbody>
</table>

Source: MU Guide G1801

### Pump Cycling Rate, Max.

<table>
<thead>
<tr>
<th>Horsepower Rating</th>
<th>Cycles/ Hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25 to 2.0</td>
<td>20</td>
</tr>
<tr>
<td>3 to 5</td>
<td>15</td>
</tr>
<tr>
<td>7.5, 10, 15</td>
<td>10</td>
</tr>
</tbody>
</table>

### Pressure Tank Selection

<table>
<thead>
<tr>
<th>Tank Size, gallons</th>
<th>Average Pressure, psi*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40</td>
</tr>
<tr>
<td>42</td>
<td>5</td>
</tr>
<tr>
<td>82</td>
<td>11</td>
</tr>
<tr>
<td>144</td>
<td>19</td>
</tr>
<tr>
<td>220</td>
<td>29</td>
</tr>
<tr>
<td>315</td>
<td>42</td>
</tr>
</tbody>
</table>

* Cut-in pressure = 10 psi = Avg. Pressure = Cut-out pressure = 10 psi

### Pressure Tanks

- Larger tank
- Multiple tanks
- OR variable pump speed controller
**Using Ponds for Irrigation**
- Pond 8' deep, 100' dia. holds 280,000 gallons of water.
- One-half of water volume is usable for irrigation. Rest is seepage & evaporation.
- 20 GPM demand for 20 hrs/day uses 24,000 gal/day.
- Pond holds about 6-day water supply.
- Water is least available when most needed!!

**Pond Water Quality**
- Grass filters sediment & nutrients
- Copper sulfate controls algae & slime

**Drip Irrigation 1**
- Also known as:
  - Trickle irrigation
  - Micro-irrigation
  - Low-volume irrigation

**Drip Irrigation 2**
- 2-5 GPM/acre for water supply
- Point use gives less runoff, less evaporation, easier weed control, saves 30%-50% water
- Low pressure of 6-20 psi means smaller pumps & pipes
- Can fertilize through system
- Do field work while irrigating

**Drip Irrigation 3**
- Can automatically control
- Susceptible to clogging
- Must design system to carefully match equipment to elevation
- Requires diligent management
- Cost = $900 - $1200 for 1st acre; $600 - $800/acre for rest

**Example Layout of Larger Drip Irrigation System**
Drip Irrigation Workshop, Mt. Vernon, MO 4/27/2011

Drip Irrigation Components 1
- **Power Supply**
  - Electric = 1st choice
  - Gas, diesel, propane = 2nd choice
  - Gravity = ram pumps
- **Pump system**
  - Higher elevation = lower horsepower
  - Size to elevation & system pressure
  - Pressure tank vs. throttling valve control

Drip Irrigation Components 2
- **Check valve(s)**
  - Stop backflow into water source
  - Critical if fertigating
- **Filter system**
  - 100-150 mesh screen
  - Manual or automatic backflushing
  - If you can see particles, the system can plug

Filter Selection 1
- **Cartridge filter**
  - Best with well water on very small systems
  - Made of paper or spun fiber
  - Disposable or washable
  - Install in pairs to avoid service downtime
  - Clean when pressure loss exceeds 5-7 psi

Filter Selection 2
- **Screen filter**
  - 150-200 mesh, 3/4" to 6" dia.
  - Slotted PVC, perf. or mesh stainless steel or nylon mesh
  - Manual or automatic flush
- **Disc filter**
  - Stack of grooved wafers
  - Provides more filter area than screen of same size

Filter Selection 3
- **Sand media**
  - 14" to 48" diameter
  - Use swimming pool filter for smaller systems
  - Use pairs of canisters for larger systems
  - Work best at < 20 GPM flow per square foot of media
  - Follow with screen filters
  - Backflush to clean

Drip Irrigation Components 3
- **Pressure regulation**
  - Depends on field slope & pipe layout
  - In-line regulators
  - Pressure tank(s) = match to pump cycle rate to avoid pump burnout
- **Solenoid valves**
  - Low-voltage water control valves
  - Mount above ground for easy service
**Solenoid Valves**
- Low-voltage water control valves
- Mount above ground for easy service

**Controller**
- Protect controllers from weather & pests
- Use proper wiring (Type UF or USE)

**Drip Irrigation Components**
- Controller
  - Time clock switches solenoid valves
- Mainline
  - Carry water to each irrigation block
  - Buried 1.5" - 3" dia. PVC pipe
- Manifolds
  - Meter water from mainlines to laterals
  - Buried 3/4" - 2" PVC or PE pipes

**Drip Irrigation Components**
- Laterals
  - Carry water down rows to the plants
  - Surface or buried 3/8" - 3/4" PE pipe
  - Thin-wall “tape” for close-growing crops
- Emitters
  - Deliver water to the plants
  - 0.5 - 2 GPH "in-line" or "on-line" units
  - Pressure-compensating or not

**Laterals & Emitters**
- Operating pressure in laterals
  - Thin-wall “tape” = 4-8 psi
  - Non-P.C. emitters = 8-15 psi
  - P.C. emitters = 10-60 psi
- Max. pressure variation in plant block = 20 psi (+/- 10 psi)

**Drip Tape**
- Low pressure
  - 4-8 psi
- Inexpensive
  - Lasts 1-2 years
- Needs flat sites
- Needs filter
- Good for gardens
- Prone to animal damage
**Laterals & Emitters 2**

- Extend laterals 10-20 ft. past row end to serve as debris trap.
- Use air relief valve at high point of each plant block to stop shutoff suction.

**Laterals & Emitters 3**

- Split water flow for low-use plants.
- Roll up & store laterals at end of season.

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**Pumping Head Calculations**

- Total head in feet is the sum of:
  - Elevation from water source to high point
  - Pipe friction loss
  - Discharge pressure
  - Miscellaneous friction loss of elbows, risers, valves, etc.
- Remember conversion of: 2.31 feet = 1 psi

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**Pipeline Design – Elevation**

Elevation from pump to field:
(2.31 feet = 1 psi pressure)

23 feet = 10 psi

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**Pipeline Design – Friction Loss**

- Gravity systems
  - Limit head to 1.5 ft. per 100 ft. of pipe
  - Minimum pipe size = 1¼-inch diameter
- Pressure systems
  - Limit head to 2.3 ft. (1 psi) per 100 ft. of pipe
  - Rule of thumb: Pipe diameter x 2 = 4X flow rate

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**Plastic Pipe Friction Loss**

<table>
<thead>
<tr>
<th>Pipe Diameter, inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.75&quot;</td>
</tr>
<tr>
<td>GPM</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>15</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>25</td>
</tr>
<tr>
<td>30</td>
</tr>
</tbody>
</table>
Plastic Pipe Friction Loss

Design Considerations 1
- Water supply capacity
- Hours of operation per day
- Field size, shape & elevation
  - 2.3 feet elevation change = 1 psi pressure change
  - Design for +/- 10% or less flow variation
- Plant spacing
- Row spacing

Design Considerations 2
- Emitter selection & location
- Clogging control - air relief valve
- Burial and draining
  - Frostline depth = 24" - 30"
  - Flush with air
- Pipe protection under roadways
- Animal damage
- Expansion

Planning Your System 1
- Make a field plan
  - Show field size, shape, elevation contours
  - Show distance to water source, electricity
  - Note soil type, climate, air drainage
  - Example: Two acres apples
    a. 290' x 300' field, 4.0% slope across rows, 2.3% along row
    b. 20 rows 14' o.c., 50 plants per row 6' o.c.

Sample Field Plan 1

Slope Measurement by Elevation Change
- Two types of instruments
  - Builder’s level and measuring rod
  - Line level + string + tape measure + stake
- Slope in % = (vertical / horizontal) x 100
Slope Measurement by Direct Reading

Three types of instruments:
- Clinometer (Abney level)
- "Smart" level (electronic)
- Protractor + conversion table

Planning Your System

Calculate minimum pumping capacity needed & compare to water source:
- \( \text{GPD} = \text{Gallon/plant/day} \times \# \text{ of plants} \)
- \( \text{GPD} = \text{Gallon/100' of row/day} \times \# \text{ of rows} \times (\text{row length}/100) \)
- Example: Two acres 6' x 14' apples
  \( 8 \text{ GPD} \times 1036 \text{ plants} = 8288 \text{ GPD} \)
  \( = 345 \text{ GPH} \)
  \( = 5.8 \text{ GPM} \)

Planning Your System 2

Calculate area irrigated at once:
- \# of plants = Well capacity / GPH applic. rate
- Allow for home water demand
- Balance well cap. to row length & block size
- Example: 3 BR, 1.5 bath home & 19 GPM well
  a. Home needs 10 GPM, so field gets 9 GPM
  b. (9 GPM well cap. x 60 min/hr) / 2 GPH/plant = 270 plants
  c. 270 plants / 50 plants/row = 5.4 rows at once
  d. 20 total rows / 5 rows/block = 4 blocks
  e. 4 blocks x 8 GPD/plant / 2 GPH/em. = 16 hrs.

Friction Loss Design

Size piping for 1 psi or less pressure loss per 100 feet
Pipe friction may replace pressure regulators on downhill runs
Vary flowrate no more than 20% (+/- 10%) within each block of plants
Manifolds attached to mainline:
- at center if < 3% slope
- at high point if 3+% slope

Sample Field Plan

Troubleshooting Guide

Symptom | Possible Causes
---|---
Reddish-brown slime or particles near emitters | Bacteria feeding on iron
White stringy masses of slime near emitters | Bacteria feeding on sulfur
Green or slimy matter in surface water | Algae or fungi
White film on tape or around emitters | Calcium salts or carbonates
Presence of silt or clay | Inadequate filtration
### Chemical Injection 1

- Kill bacteria & slime
  - Chlorine needs "contact time"
  - Powdered HTH can plug emitters

### Chemical Injection 2

- Control pH with acid
  - Help acidify soil for plants (blueberries)
  - Dissolve Mn, Fe, Ca precipitates
  - Make chemicals work better

### Chemical Injection 3

- Apply fertilizer
  - Be sure it's 100% water-soluble
  - Always inject it two elbows before the filter for good mixing

### Resources

- Irrigation resources & equipment suppliers
  - [extension.missouri.edu/webster/irrigation](http://extension.missouri.edu/webster/irrigation)
- Water analysis (University of Missouri)
  - [soilplantlab.missouri.edu/soil/water.aspx](http://soilplantlab.missouri.edu/soil/water.aspx)
- MU Extension Publications
  - [extension.missouri.edu/publications](http://extension.missouri.edu/publications)
- Farmers’ market resources
  - [extension.missouri.edu/webster/farmersmarket](http://extension.missouri.edu/webster/farmersmarket)
- Fruit tree and small fruit resources
  - [extension.missouri.edu/webster/new/homegarden.shtml](http://extension.missouri.edu/webster/new/homegarden.shtml)

### Questions?

Robert A. (Bob) Schultheis  
Natural Resource Engineering Specialist  
Webster County Extension Center  
800 S. Marshall St.  
Marshfield, MO 65706  
Voice: 417-689-2044  
Fax: 417-488-2086  
E-mail: schultheisr@missouri.edu  
Web: [extension.missouri.edu/webster](http://extension.missouri.edu/webster)

Program Complaint Information
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- University of Missouri
  - MU Extension AA/EEO Office  
    109 F. Whitten Hall, Columbia, MO 65211  
    Voice: 417-859-2044  
    Fax: 417-468-2086  
    E-mail: schultheisr@missouri.edu  
    Web: [extension.missouri.edu/webster](http://extension.missouri.edu/webster)
  - MU Human Resources Office  
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    Voice: 417-889-5155  
    Fax: 417-889-5000  
    E-mail: hr@missouri.edu  
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