Blueberry Freeze Protection in North Carolina

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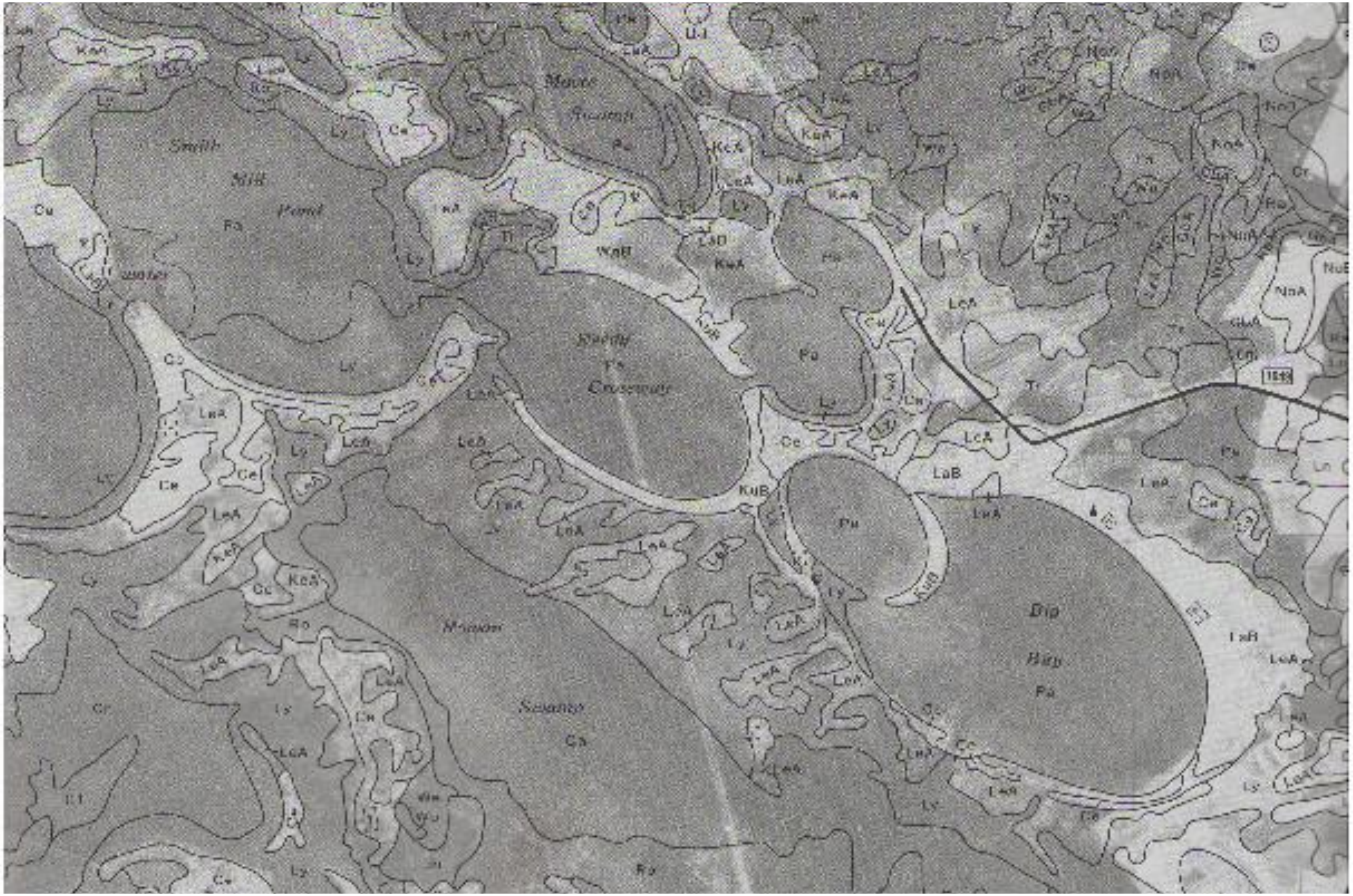

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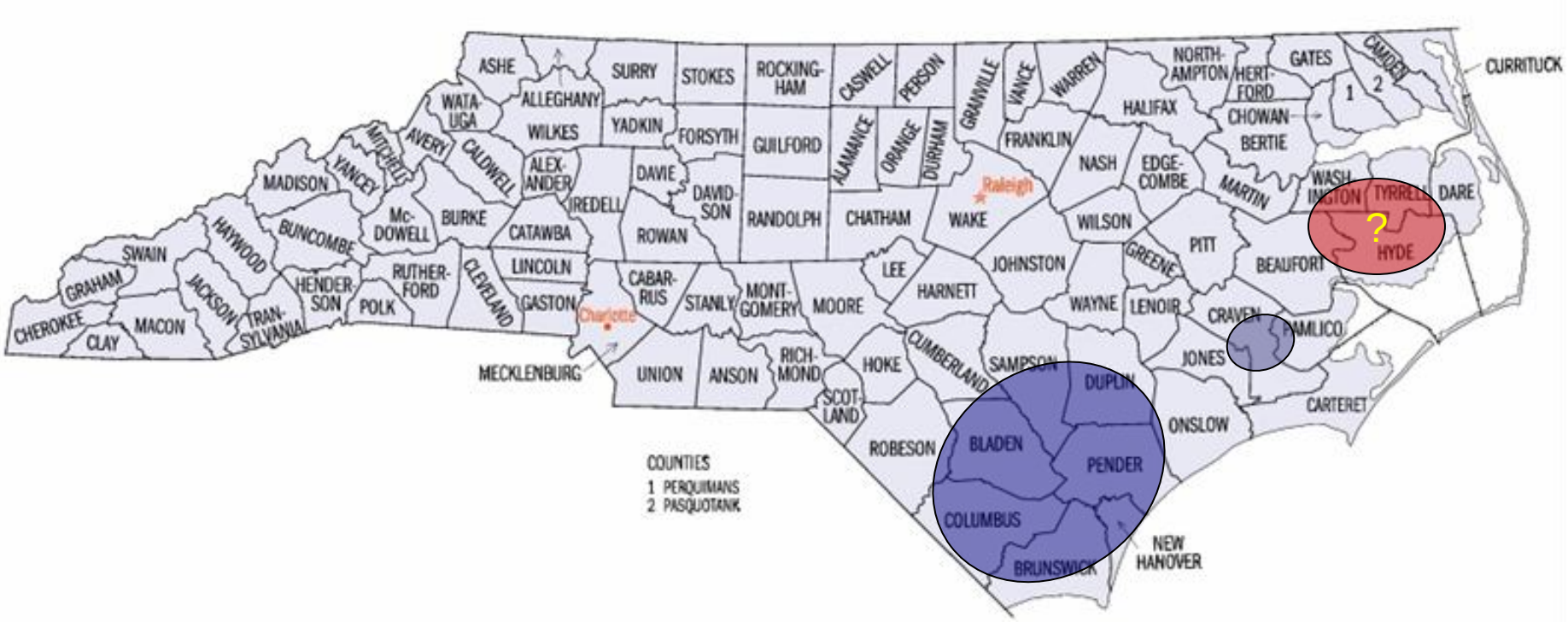
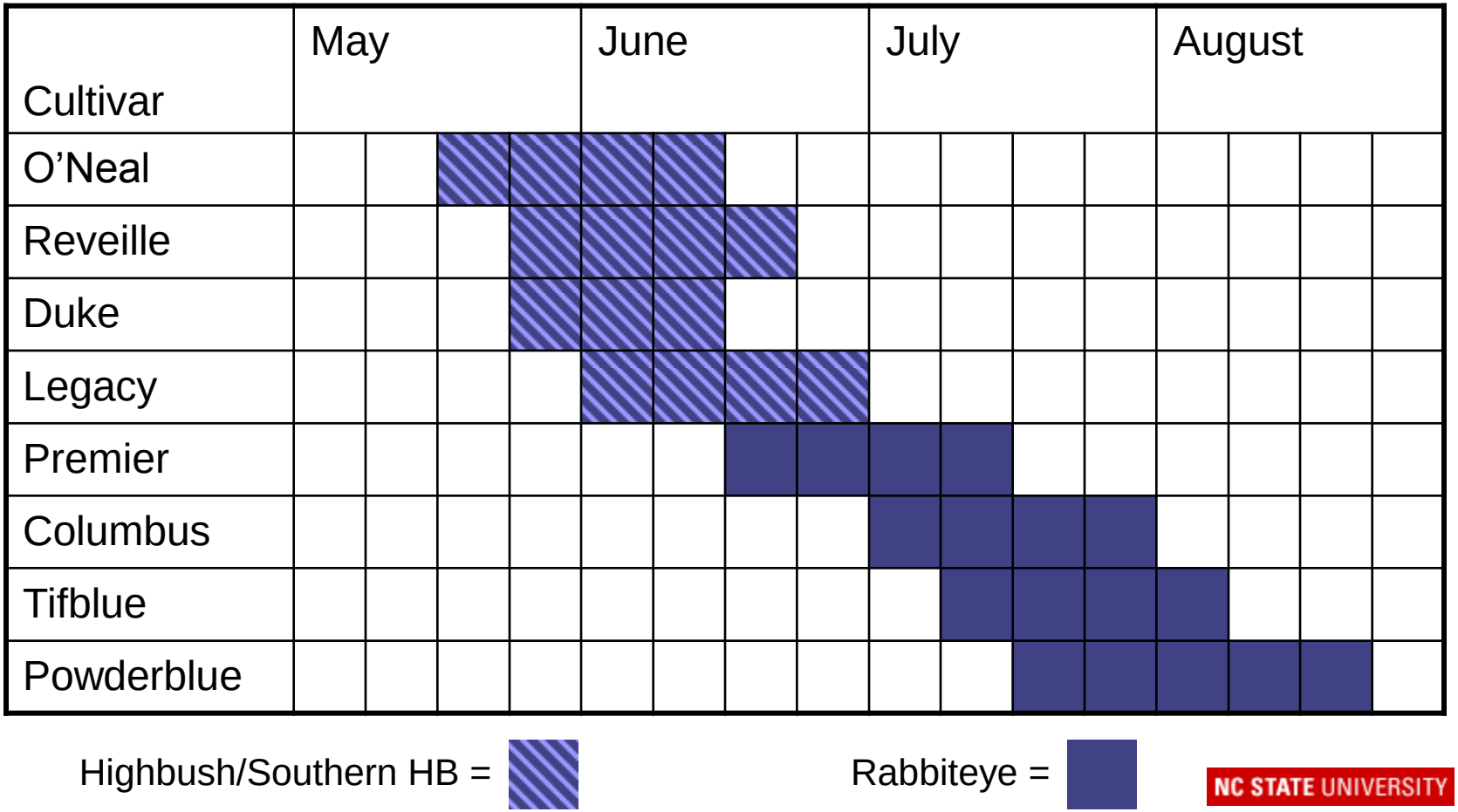
Small pick-your-own plantings exist throughout, but our main commercial area is SE NC (blue area) with annual farm gate value of $58M (2010). Potential for expansion in muck soils of the blacklands (red area). Limited to unique, low pH sand-based organic soils (Leon, Lynn Haven series), or organic muck soils (i.e., Carolina Bays).



Blueberry harvest timing by cultivar and type in southeastern NC (selected cultivars)



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The best NC blueberry soils have a perched water table that is usually within 12-24” of the surface; fields are bedded to improve root aeration.

Impact-type sprinklers (usually brass) are used for overhead irrigation, evaporative cooling and freeze protection. Sprinklers deliver 5-6 gallons per minute and are spaced 63 x 60 feet apart.

Blueberry irrigation systems in southeastern NC rely on surface water from dug ponds. The water table is close to the surface, so for more water – dig a bigger pond.

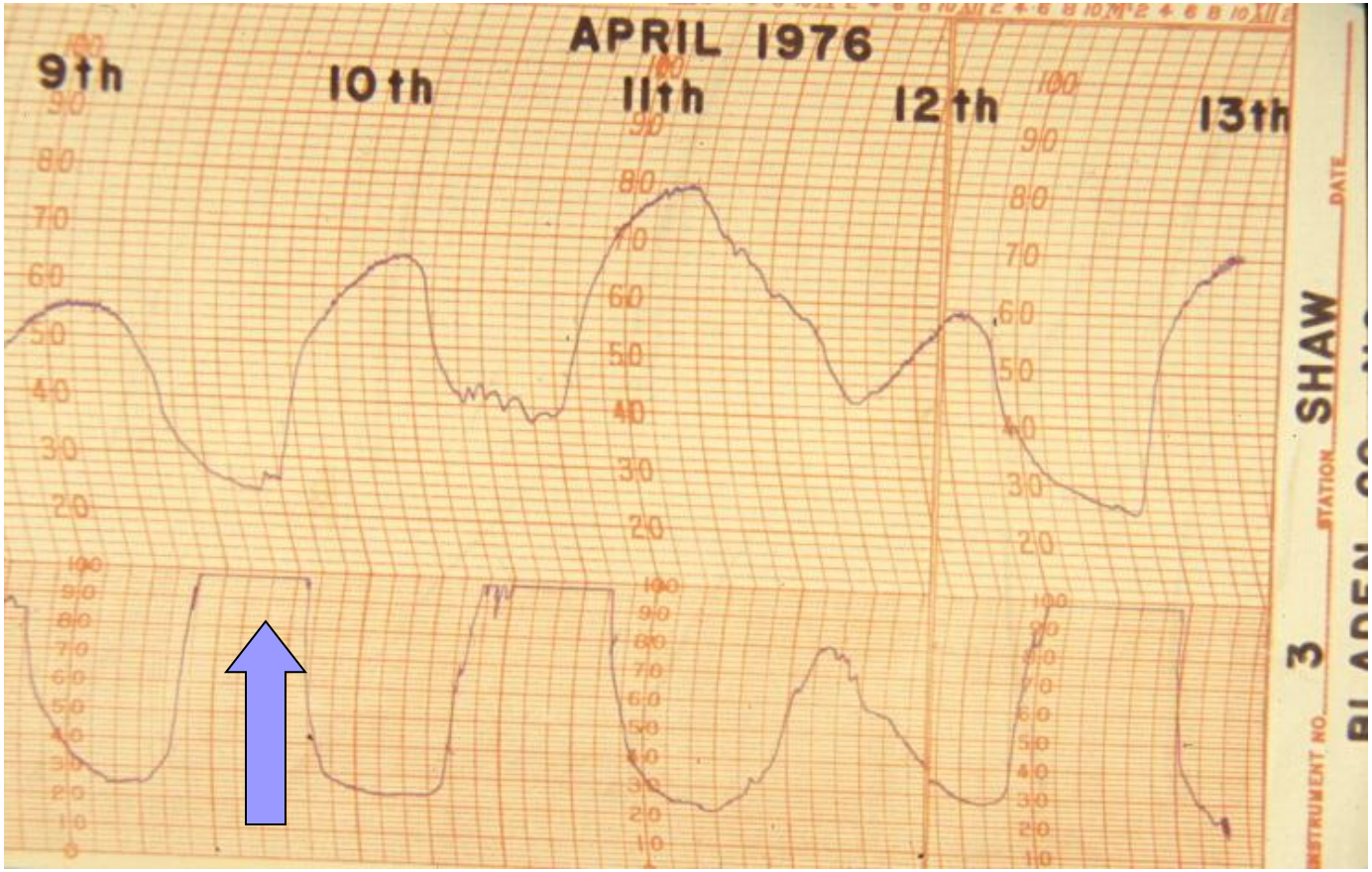
A single pump/pond combination may irrigate 25-30 acres in a typical system.

In addition to drought relief, Overhead irrigation can provide protection from both freezing and overheating:

- Freezing water to ice gives off 80 calories per gram (Latent heat of fusion = 80 calories of heat)
- Evaporation of water takes up 600 calories per gram (-Latent heat of vaporization = 600 calories of cooling)

These young developing berries are encased in ice. Damage would occur at 28 degrees F, but as long as ice is constantly forming, flowers and berries under freeze-protection irrigation never fall below 32 F.

NC Blueberry News **"The freeze of 1976 occurred on the morning of April 10th. . . . . At that time, the 5-year average production, 1971-75 was 7.4 million pounds. In 1976, as a result of the freeze, production was 1.5 million pounds. This was an 80% reduction below the average. The 20% that was harvested came primarily from warm fields in Duplin County."**



(Photo courtesy Mike Mainland)

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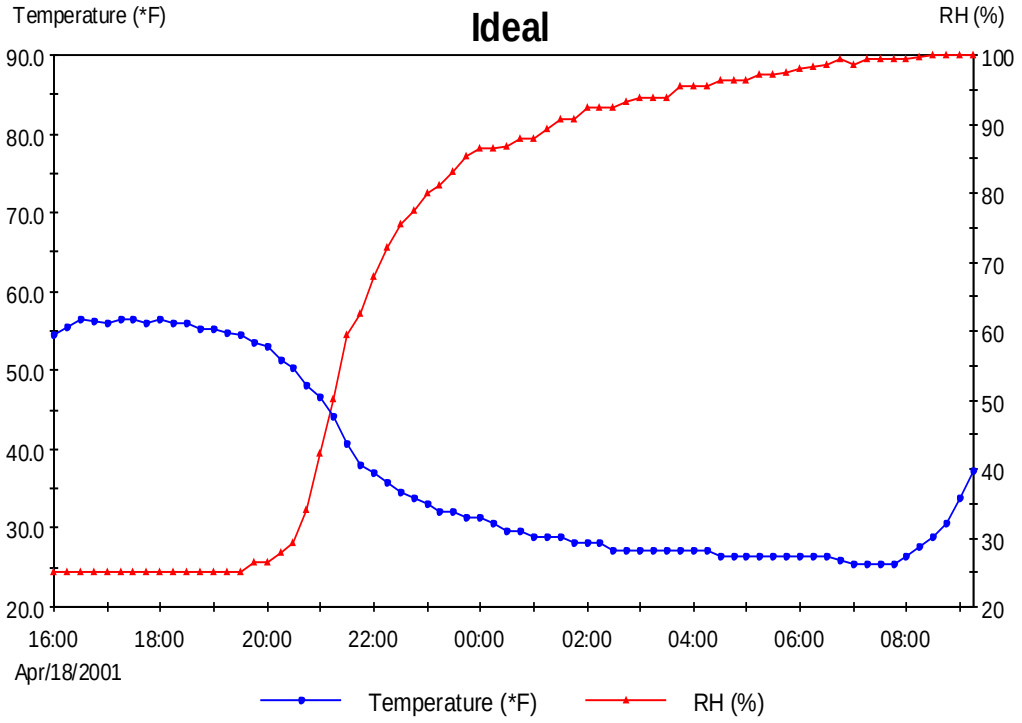
Conditions on the morning of April 19, 2001 (shown below) were very similar to those of 1976. Both were typical radiation freezes, with no wind. However, this time instead of an 80% loss statewide, the loss was probably less than 30%. The difference was irrigation for freeze protection. Almost no damage occurred in fields with irrigation protection. Without irrigation many fields lost the entire crop.



Cultivar Powderblue at harvest in July 2001, following a late spring (post-bloom) freeze event on April 19th.

Unprotected 19 Apr 01

Freeze protected 19 Apr 01

2007 “Easter Freeze”– Over half the NC blueberry crop was lost. Prior to the freeze, the crop was estimated at over 30 million lbs. Surviving production in 2007 was 14.8 Million lbs. Sites with three- to four-night capacity for overhead freeze protection irrigation, AND with minimum temps at 20^{o}F or above were saved.

Healthy berry with white ovules (left) versus freeze-damaged. Note browning of ovules in the berry at right.

Healthy undamaged flowers (left), cut open to show green ovary and style. Severely damaged flowers (right) are water-soaked after 48 hrs.

Botrytis flower blight on ‘Duke’ following freeze injury

Near-frozen berries may ripen yet have hollow, soft or corky internal damage (right).

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Late freezes cause “frost rings” around the calyx that cause berries to split. Shown 48 hr (right) and 1 month later.

Blueberry growth stages

Flower bud development				Leaf bud development		
Tight bud	Bud swell	Bud break	Tight cluster	Early green tip	Late green tip	Shoot expansion
						
No visible swelling; bud scales completely closed.	Visible swelling of buds; scales separated. Can tolerate 10 to 15°F (-12 to -9°C).	Bud scales separated, tips of flowers visible. Can tolerate 15 to 20°F (-9 to -6°C).	Individual flowers distinguish-able. Can tolerate 20 to 25°F (-6 to -4°C).	1/16 to 3/16 inch (1 to 5 mm) of green leaf tissue visible; leaves still rolled up.	1/4 to 1/2 inch (6 to 13 mm) of green leaf tissue visible; leaves starting to unfold.	Shoots expanding and leaves enlarging.

Schilder, et. al, 2004

Blueberry growth stages

Flower development				
Early pink bud	Late pink bud	Early bloom	Full bloom	Petal fall
				
Partly expanded flowers are readily visible and have separated; corolla tubes (petals) short and closed. Can tolerate 23 to 25°F (-5 to -4°C).	Individual flowers fully developed and separated; corollas expanded but still closed. Can tolerate 24 to 27°F (-4 to -3°C).	Some corollas completely expanded and open; many flowers still closed. Can tolerate 25 to 28°F (-4 to -2°C).	Most flowers on the bush have opened and can tolerate 28°F (-2°C).	Corollas are falling off, revealing small green fruit; this is the stage most vulnerable to frost damage, which can occur at 32°F (0°C).

Schilder, et. al, 2004

Blueberry growth stages

Fruit development and postharvest				
Green fruit	Fruit coloring	~25% blue	~75% blue	Bud set for following year
				
Berries are expanding; fruit may vary from small to large pea-size in the same cluster.	Berries are changing from green to pink to blue.	First crop of berries is ripe and ready for harvest.	Berries are picked several times as they ripen. There may be 2 to 5 pickings. Berries may be hand- or machine harvested.	After harvest, the blueberry plant stores reserves and sets buds for next year's growth until leaf fall.

Schilder, et. al, 2004

“FREEZE” or “FROST”?

- The “FROSTED” object is below freezing (32^{o}F) but MAY not be damaged.
- Serious damage to highbush blueberry flowers and young fruit does not occur until temperatures drop below 28^{o}F.
- There may or may not be ice crystals we call “FROST” on the bush at the critical 28^{o}F.

From the National Weather Service GLOSSARY:

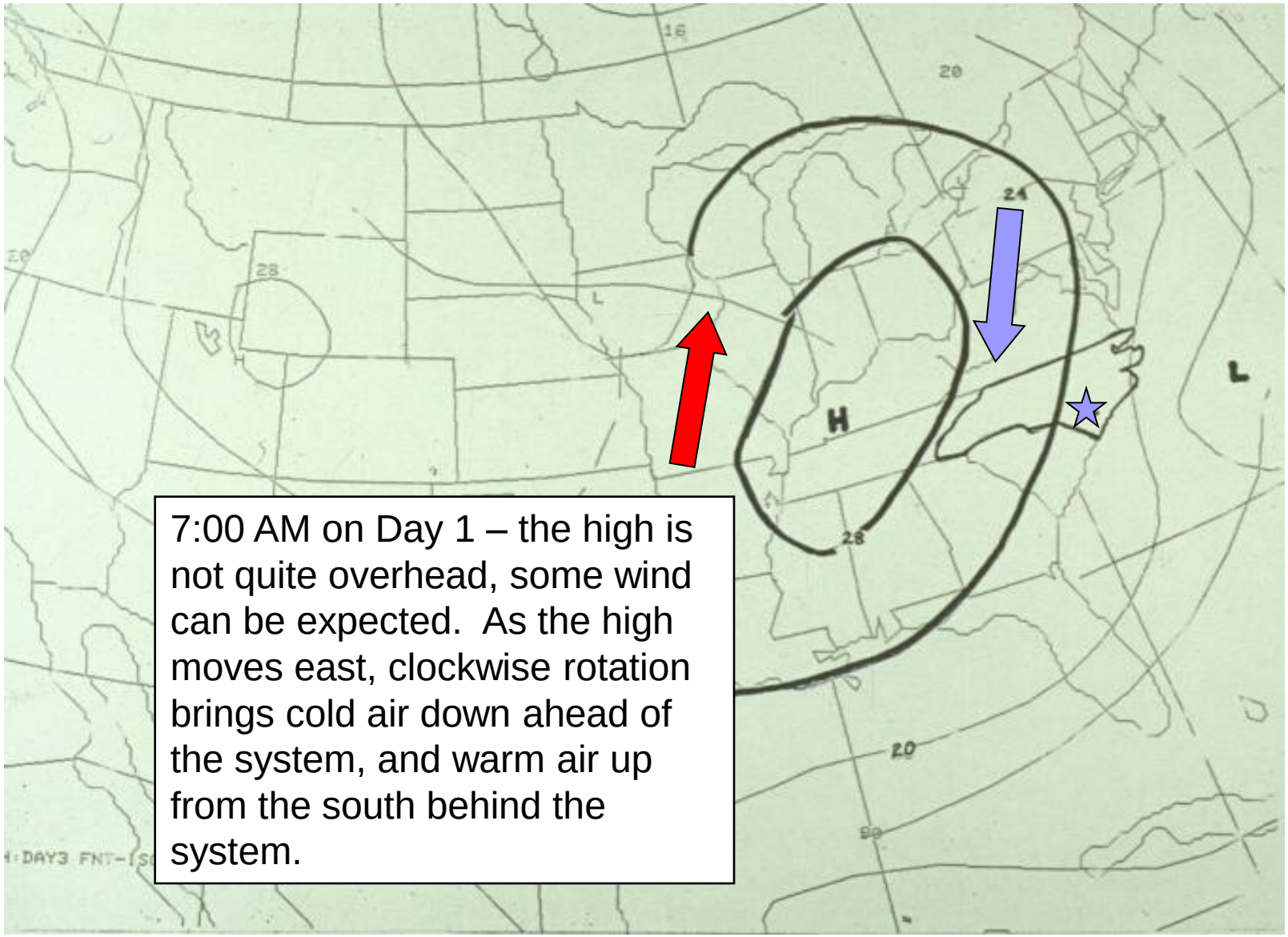
- FROST (Abbrev. FRST) - Frost describes the formation of thin ice crystals on the ground or other surfaces in the form of scales, needles, feathers, or fans. Frost develops under conditions similar to dew, except the temperatures of the Earth's surface and earthbound objects falls below 32 F. As with the term "freeze," this condition is primarily significant during the growing season. If a frost period is sufficiently severe to end the growing season or delay its beginning, it is commonly referred to as a "killing frost." Because frost is primarily an event that occurs as the result of radiational cooling, it frequently occurs with a thermometer level temperature in the mid-30s.

- Frost Advisory Issued during the growing season when widespread frost formation is expected over an extensive area. Surface temperatures are usually in the mid 30s Fahrenheit.

- Freeze A freeze is when the surface air temperature is expected to be 32 F or below over a widespread area for a climatologically significant period of time. Use of the term is usually restricted to advective situations or to occasions when wind or other conditions prevent frost. "Killing" may be used during the growing season when the temperature is expected to be low enough for a sufficient duration to kill all but the hardiest herbaceous crops.

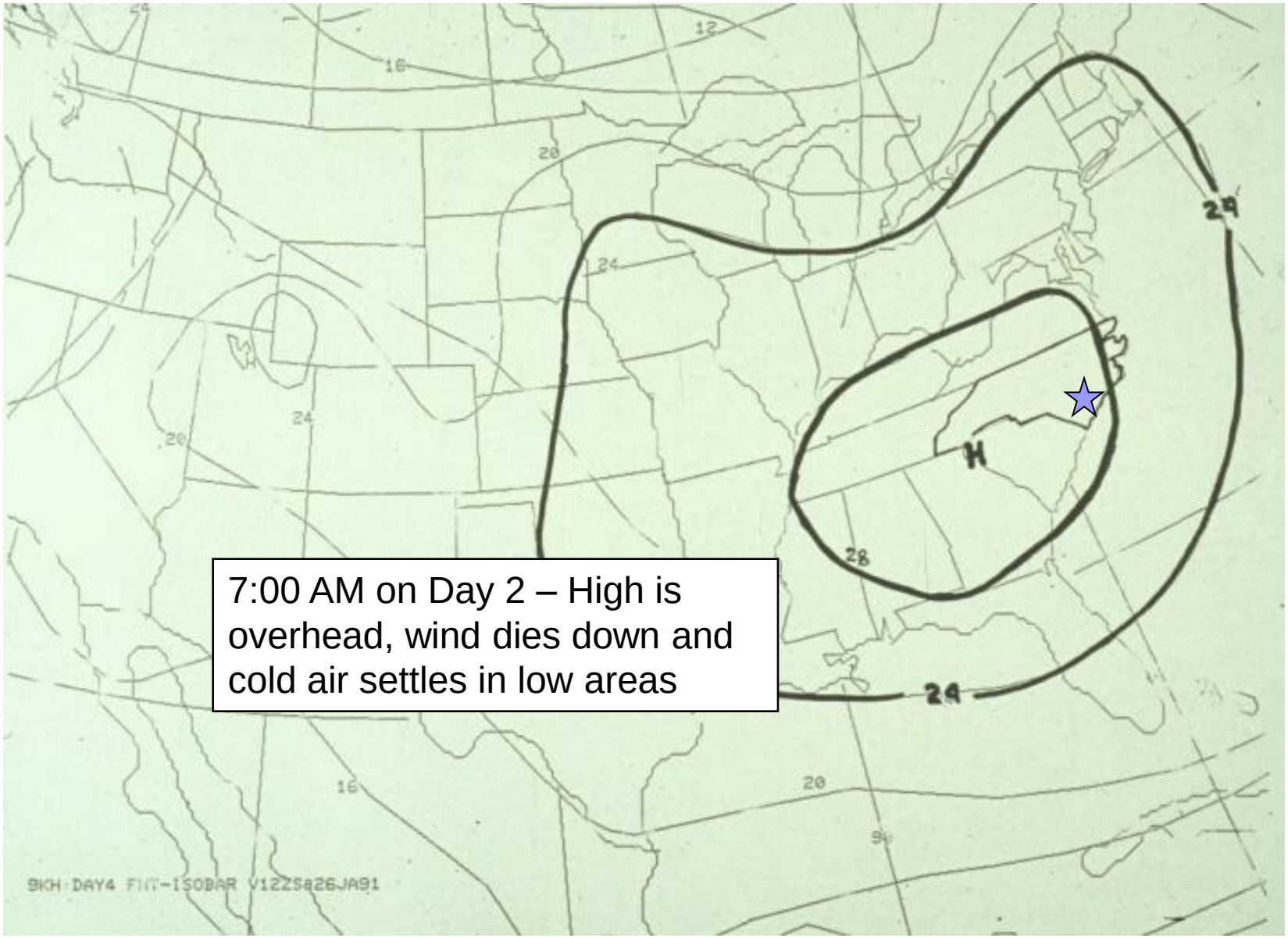
Blueberry freeze events in NC

- Greatest threat in April and May (during and after bloom).
- Mostly radiation freeze events (center of high pressure system, no wind).
- Blueberries in NC are grown in low-elevation sites – fields can be 5-10 degrees colder than predicted low temps.



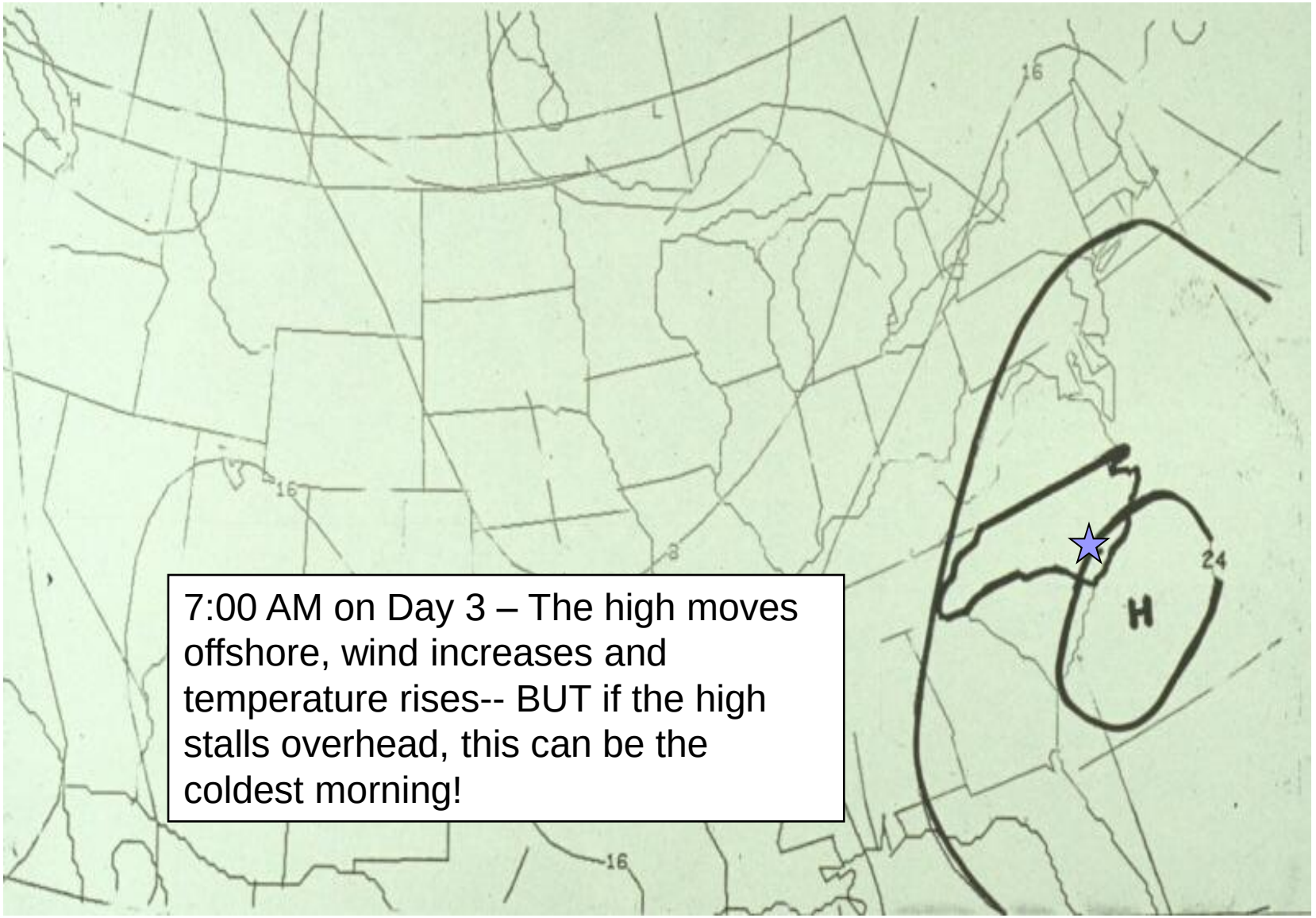
7:00 AM on Day 1 – the high is not quite overhead, some wind can be expected. As the high moves east, clockwise rotation brings cold air down ahead of the system, and warm air up from the south behind the system.

(Photo courtesy Mike Mainland)



7:00 AM on Day 2 – High is overhead, wind dies down and cold air settles in low areas

(Photo courtesy Mike Mainland)



7:00 AM on Day 3 – The high moves offshore, wind increases and temperature rises-- BUT if the high stalls overhead, this can be the coldest morning!

(Photo courtesy Mike Mainland)

Precipitation rates (inches per hour) for blueberry freeze protection at various temperatures and wind speeds. Shaded rates generally require a sprinkler spacing closer than 60x60 feet.

	Wind Speed (mph)		
Min. Temp. °F	*0-1*	*2-4*	*5-8*
27	0.10	0.10	0.10
26	0.10	0.10	0.14
24	0.10	0.16	0.30
22	0.12	0.24	0.50
20	0.16	0.30	0.60
18	0.20	0.40	0.70
15	0.26	0.50	0.90

Source: Gerber, J. F. and J. D. Martsolf. 1965. Protecting citrus from cold damage. Univ. Fla. Agr. Ext. Circ. 287.

Precipitation rates (Inches/Hr) for selected nozzle capacity and sprinkler spacing.									
Sprinkler Spacing (ft.)	Gallons per minute/Sprinkler								
	2	3	4	5	6	8	10	12	15
30 x 30	.21	.32							
30 x 40	.16	.24	.32						
40 x 40		.18	.24	.30					
40 x 50		.14	.19	.24	.29				
40 x 70		.12	.16	.20	.24	.32			
50 x 50		.12	.15	.19	.23	.31			
50 x 60			.13	.16	.19	.26	.32		
60 x 60				.13	.16	.21	.27	.32	
60 x 70					.14	.18	.23	.28	.34

Source: Tyson, A. W., et al. Frost/freeze protection by sprinkler irrigation. http://www.smallfruits.org/Weather/frost_freeze.htm

★ = standard blueberry rate in NC is approx 0.15 in/hr

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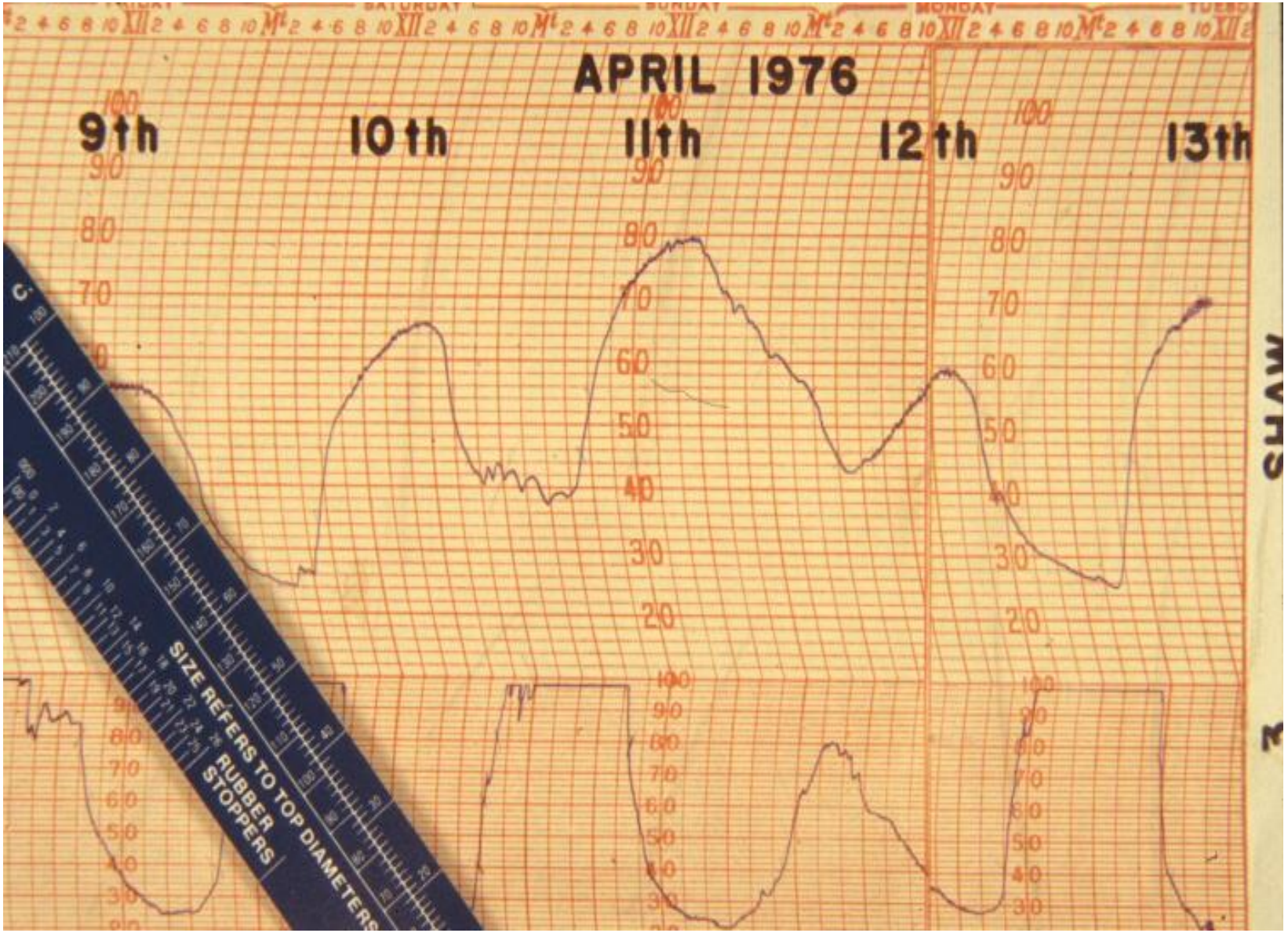
Table 3. Pumping capacity required (gallons per minute/Acre) for various precipitation rates (inches per hour).

Inches/Hr:	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.20
GPM/Acre:	49.8	54.3	58.8	63.4	67.9	72.4	76.9	81.5	86.0	90.5

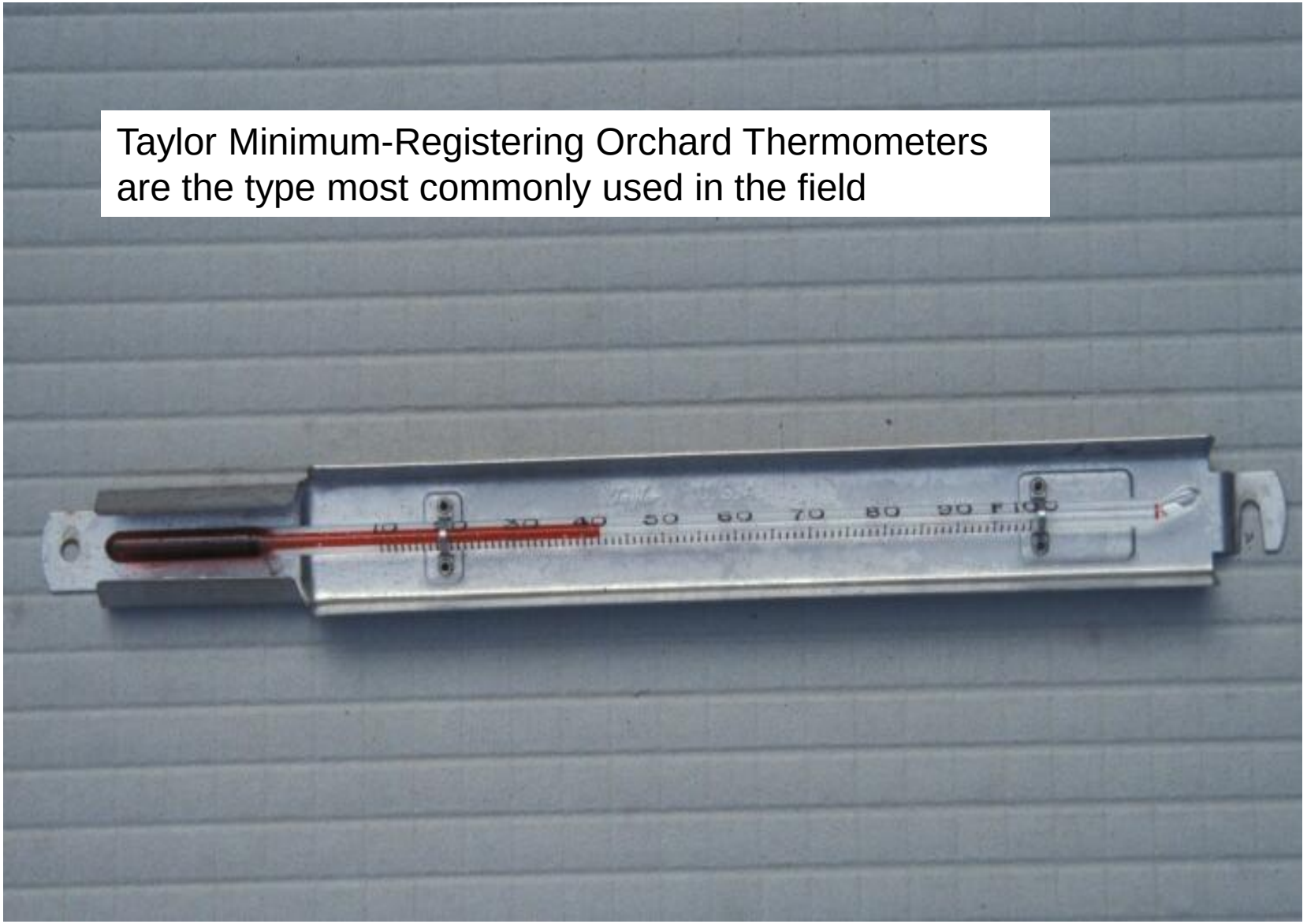
Source: Tyson, A. W., et al. Frost/freeze protection by sprinkler irrigation. http://www.smallfruits.org/Weather/frost_freeze.htm

= standard blueberry rate in NC is approx 0.15 in/hr, 68 gal/min/A



(Photo courtesy Mike Mainland)

Taylor Minimum-Registering Orchard Thermometers are the type most commonly used in the field



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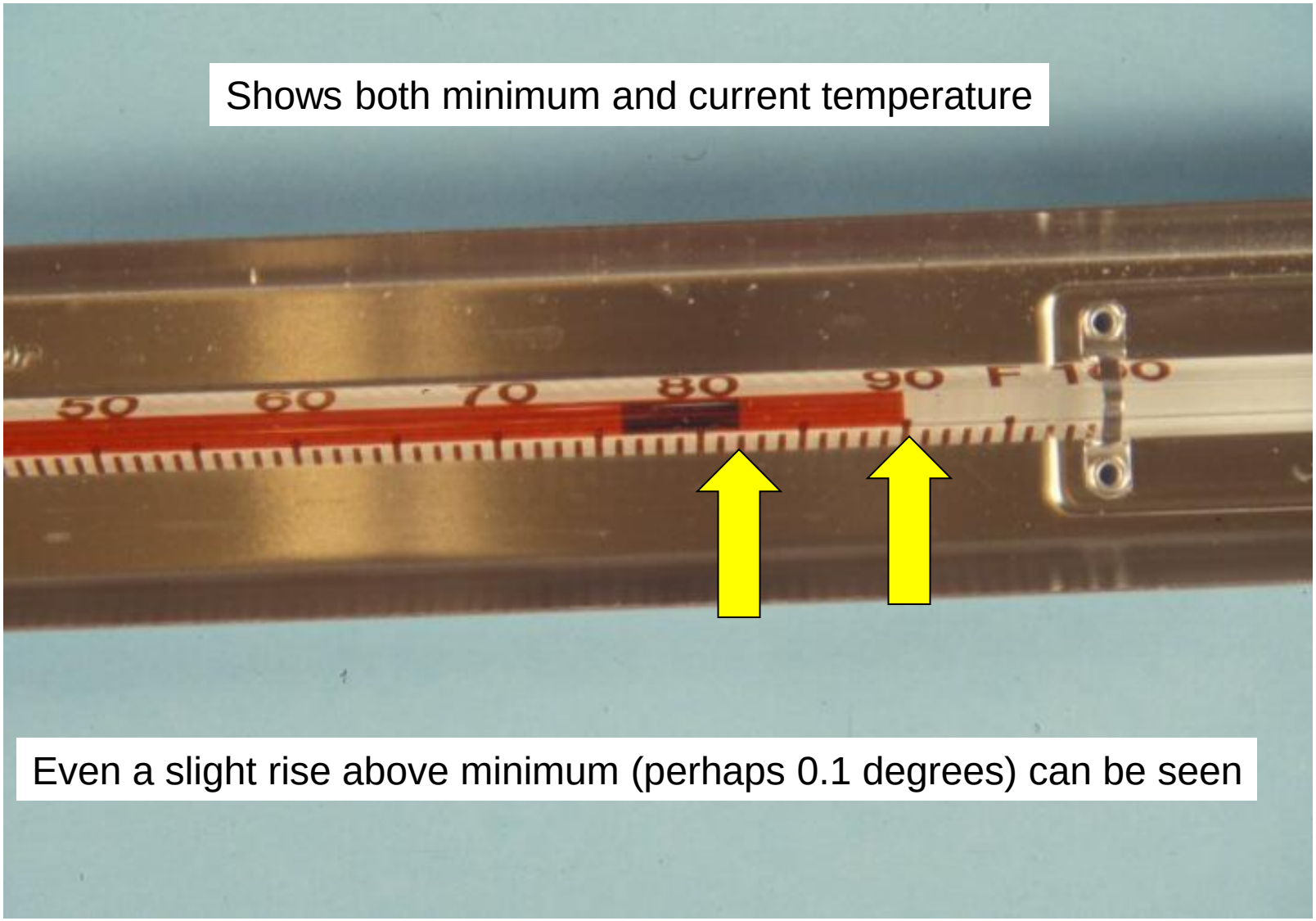

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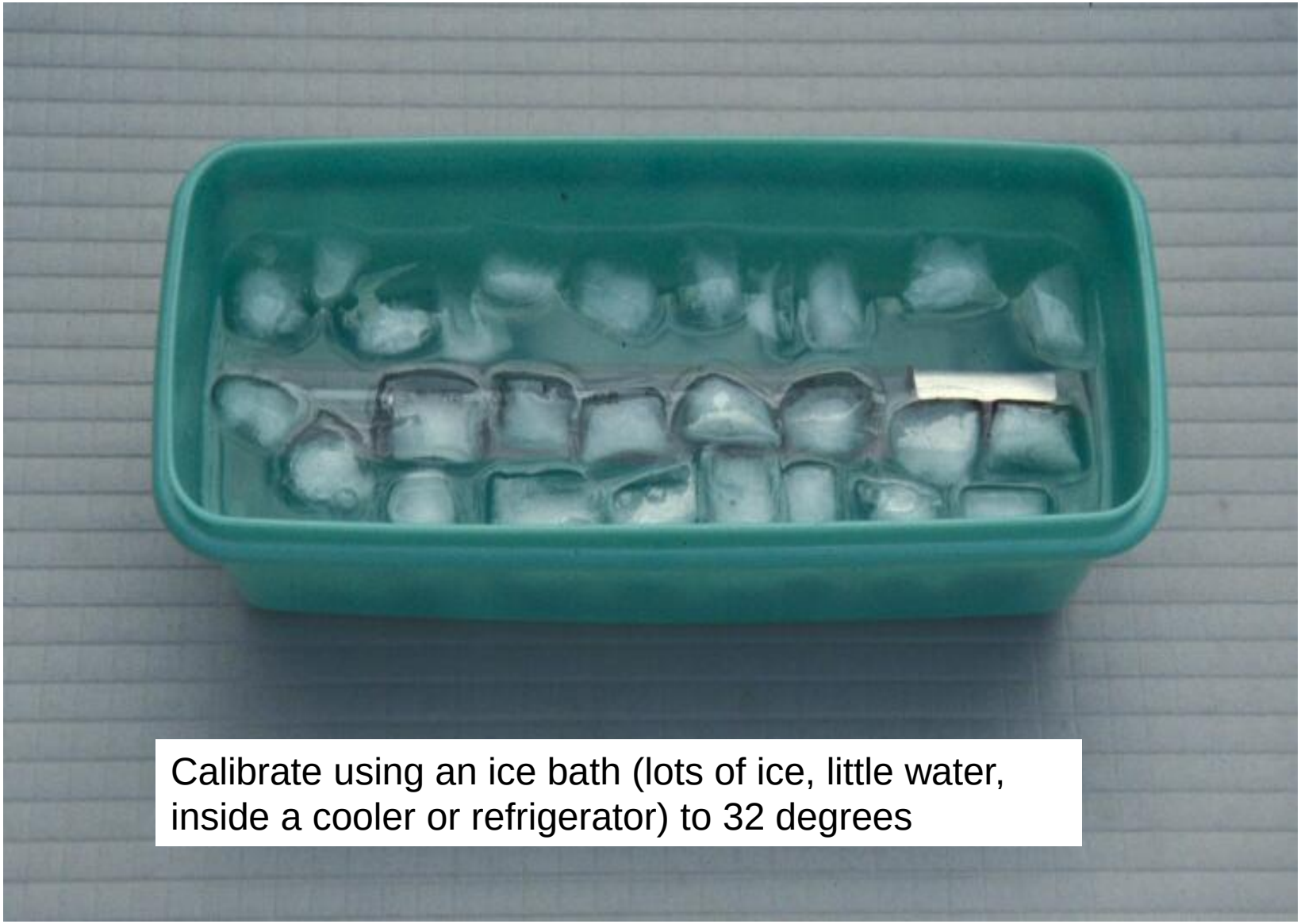

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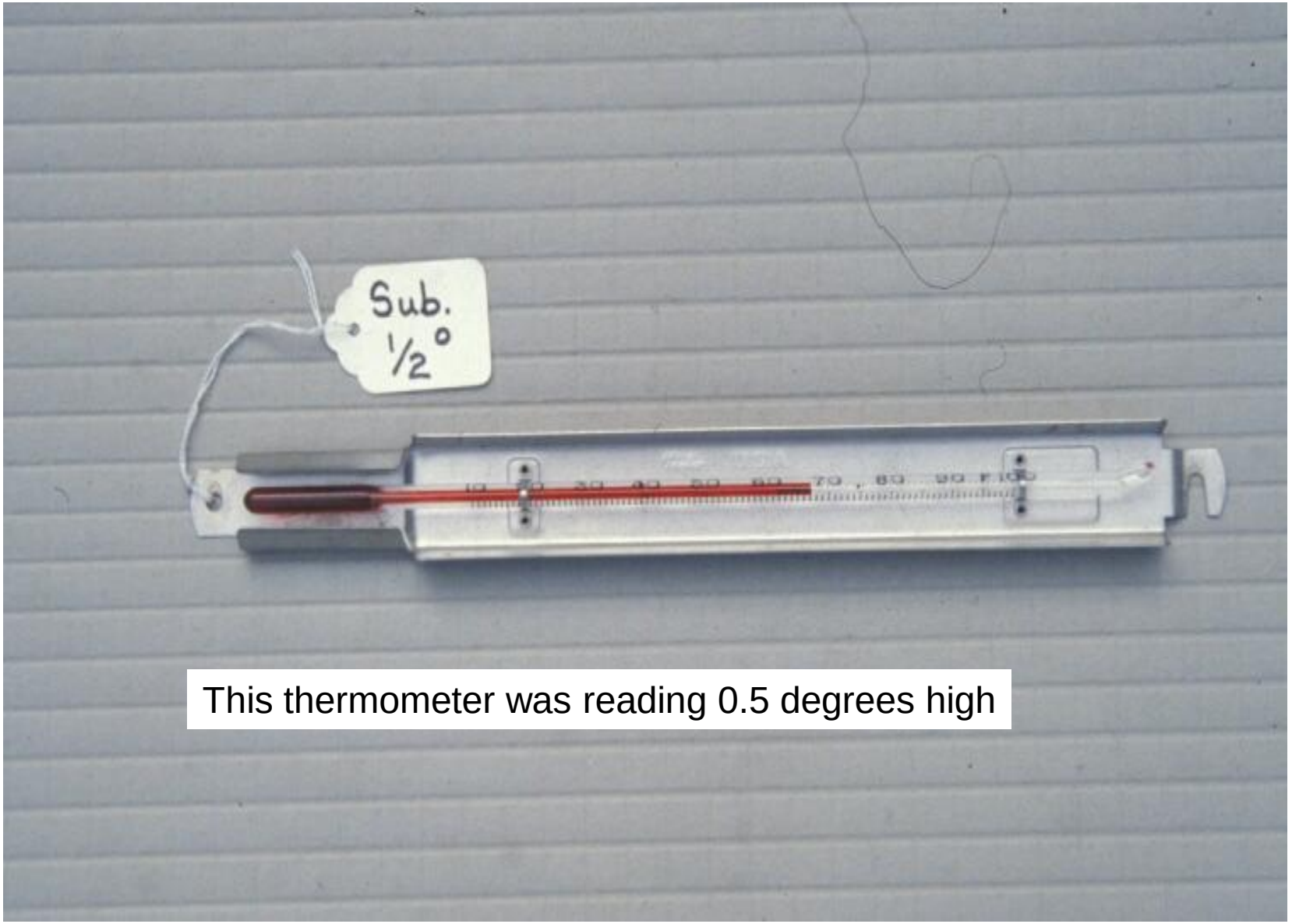

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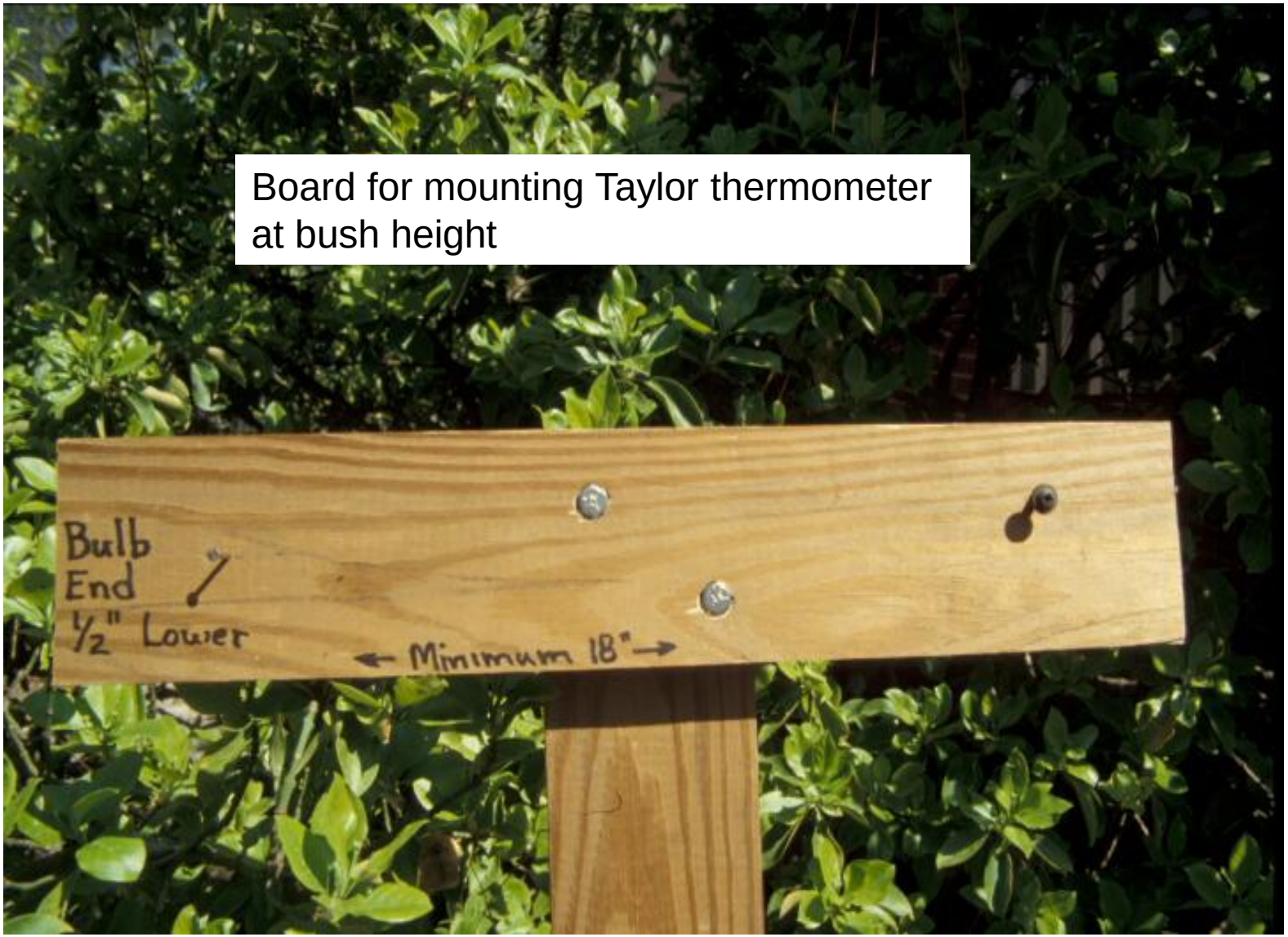

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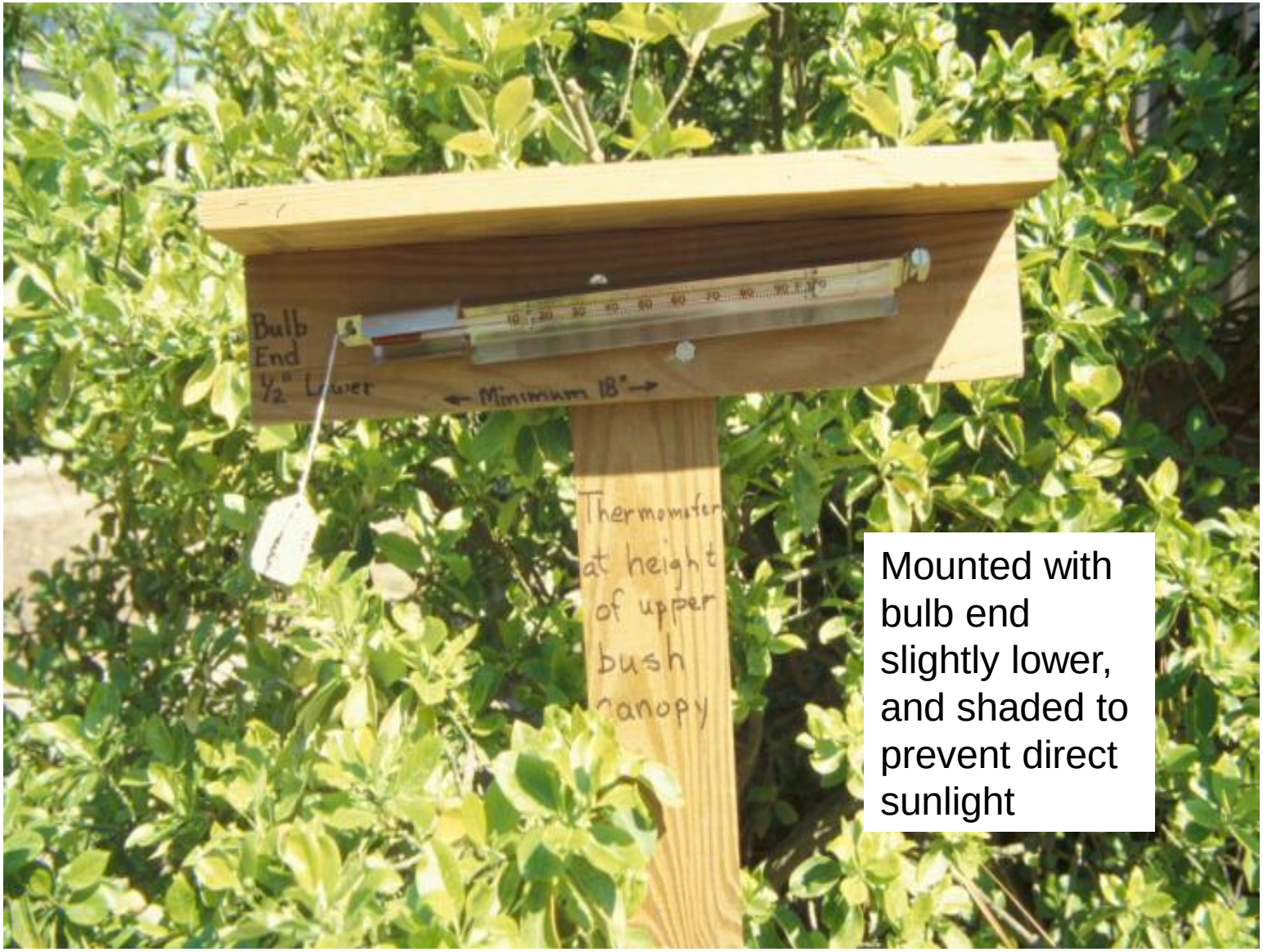
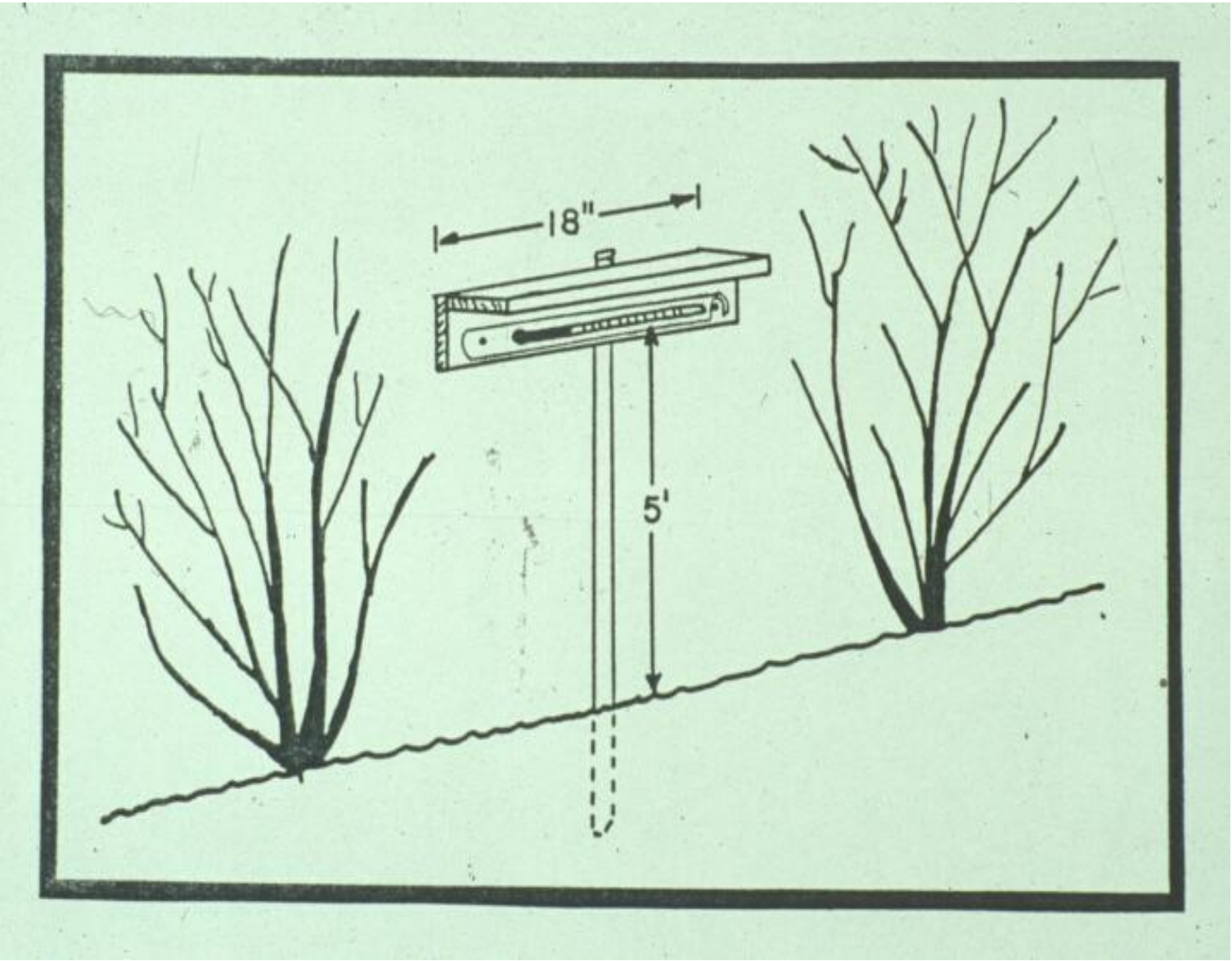


Mounted with bulb end slightly lower, and shaded to prevent direct sunlight

(Photo courtesy Mike Mainland)



(Photo courtesy Mike Mainland)

1. Considerations for Successful Freeze Protection

- System that will provide at least 0.15” of water/acre/hour (68 gal/min).
- Sprinklers usually spaced 63’ (every 7th row with 9’ rows) x 60’ in the row.
- Sprinklers with 5/32” nozzles that will provide a wetted diameter greater than 90’.
- A design and pump that will deliver at least 55 psi with less than 10% sprinkler variation

Capacity and Water Requirements

- Water for more than one night of operation. Desirably 3 nights of 12 hours (31 hours from pond and 5 hours from a well).
- A well with the capacity for 5 hours of irrigation after 31 hours will provide 1.5” of water/week during drought.
- A well capacity of 4 gal/min/acre is needed.
- The 2007 Easter Freeze -- 4 of 5 consecutive nights in most blueberry fields!!

2. Preparation the day before a possible freeze

- Run and check system, repeat if >1% clogs.
- Have rain suits, boots, high-intensity spotlights, wires to unclog sprinklers, ½” wrench to remove nozzles, spare sprinklers.
- Check drainage around the field.
- Check shielded minimum thermometers.

3. Starting Running and Stopping

- Only begin if <28 F is expected for highbush and southern highbush, <30 F for rabbiteye.
- On a still night with high humidity, get pumps running by 33 F. With low humidity 36-38 .
- Thoroughly wet bushes, then reduce pressure to 40 psi. Increase pressure as temp. drops. Be up to 50 psi by 27 F and 55 psi by 25 F. As 20 F is approached use full pressure.
- Run until ice begins to melt and temperature goes above 40 F. Ice should slip freely on stem. If temperature rises slowly and wind begins, be sure ice does not freeze again.

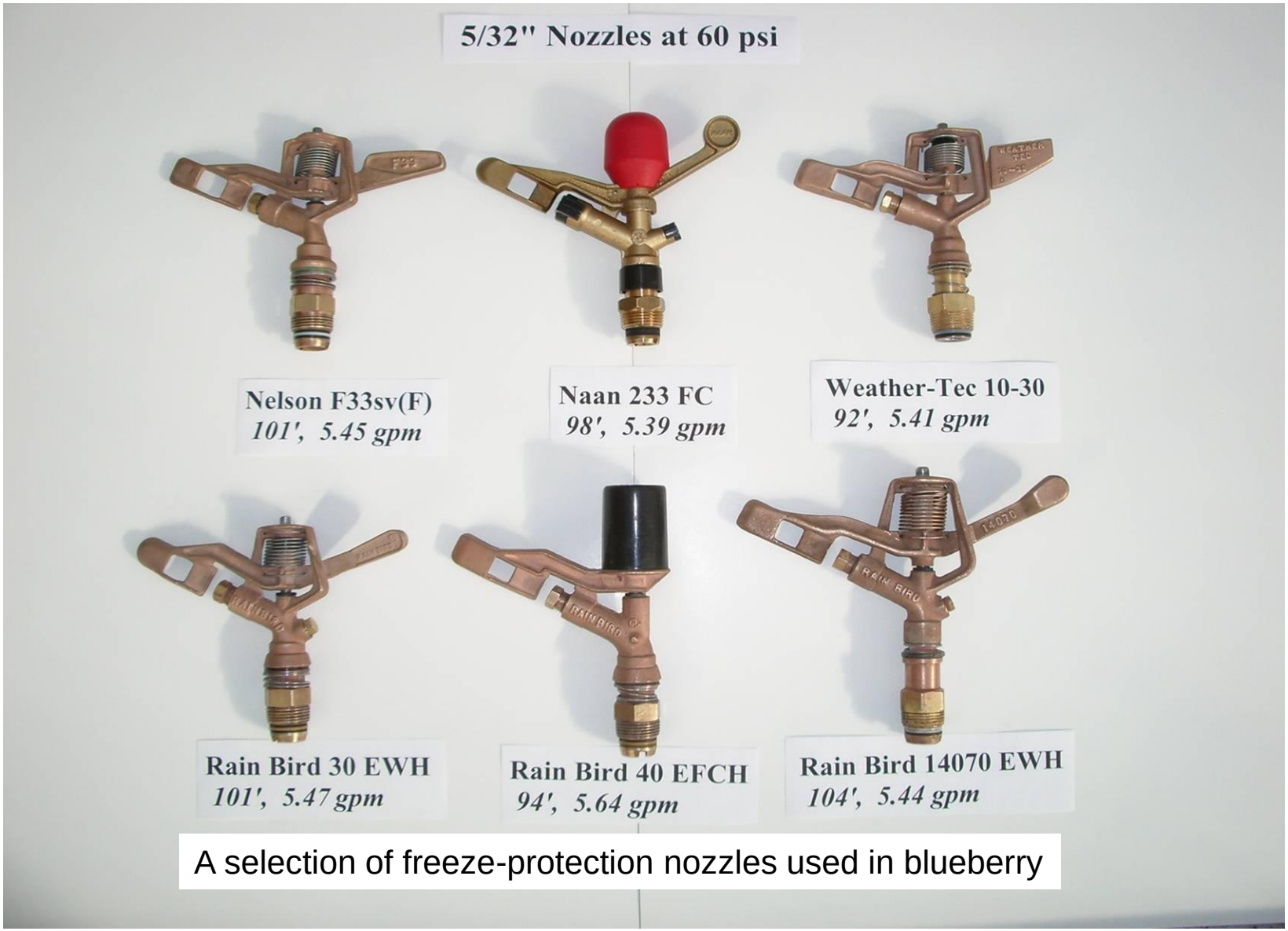
If not done properly, freeze protection irrigation can be more damaging than doing nothing, sometimes resulting in complete crop loss. Causes of failure might include:

- Poor system design
- Too cold
- Too windy
- Started protecting too late
- Shut down too soon
- System failure
- Ran out of water

Morning after a successful night of freeze protection. System paid for itself in a single night.

Costs of 63'x60' vs. 54'x50' Sprinkler Spacing for a 15 acre system, Jan. 2006.

	63'x60'	54'x50'
Pipe & fittings	$13,106	$16,149
(180 & 253 sprinklers@$11)	($874/A)	($1,077/A)
Installation at $1.00/ft	$11,797	$13,263
(11,797' & 13,263')		
Pump & fittings (1500 gpm)	$14,000	$14,000
TOTAL excluding pond	$38,903	$43,412
Cost/Acre	($2,594)	($2,894)



A selection of freeze-protection nozzles used in blueberry

(Photo courtesy Mike Mainland)

(Photo courtesy Mike Mainland)

Naan 233 FC with hand- removable nozzles. New to U.S. market. Color coded range nozzles 9/64, 5/32, 11/64, 3/16, 7/32, ¼.

(Photo courtesy Mike Mainland)

Vanes or straighteners for extended distance. Left: Naan, Center: Weather-Tec, Right: Rain Bird

(Photo courtesy Mike Mainland)

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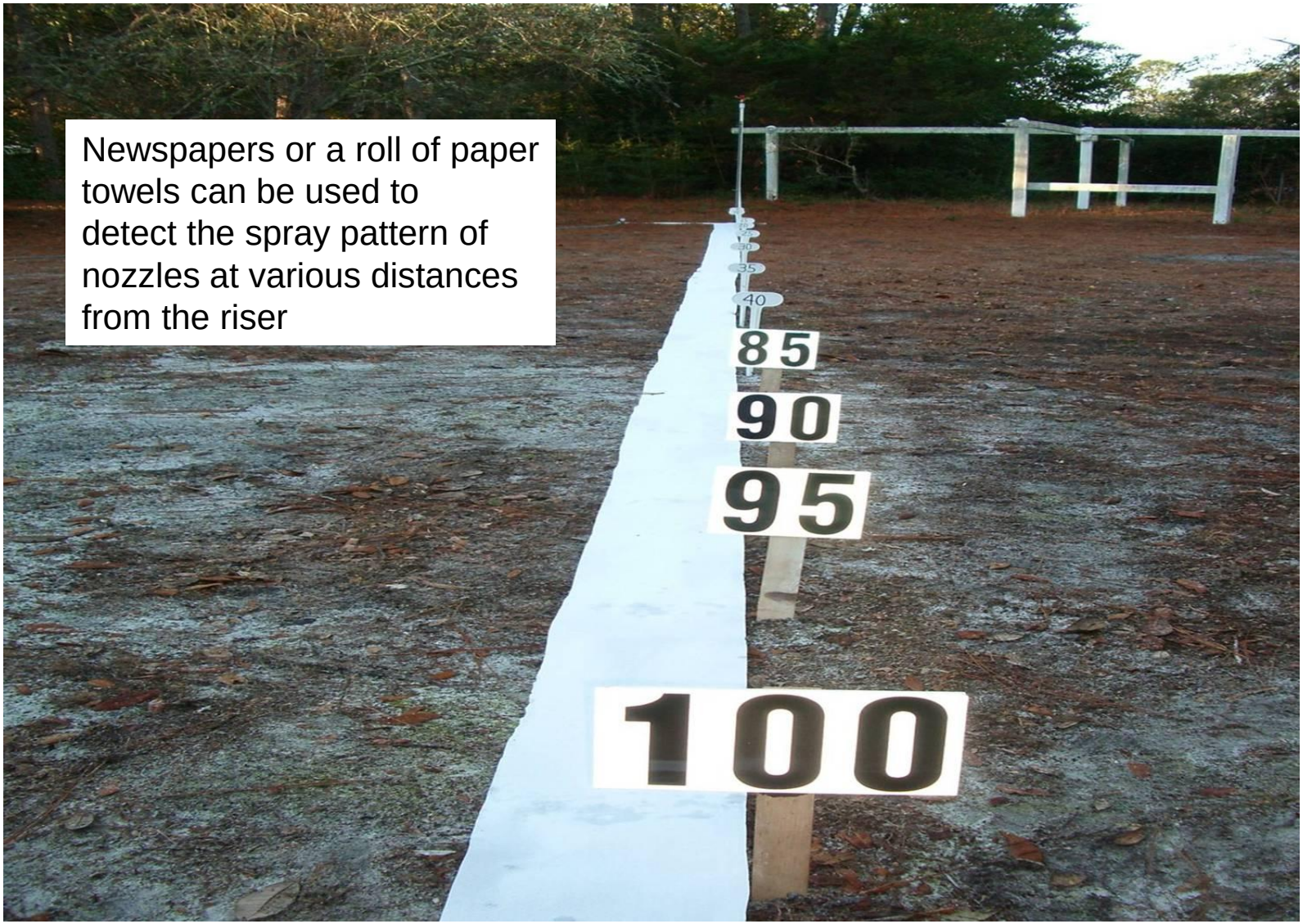

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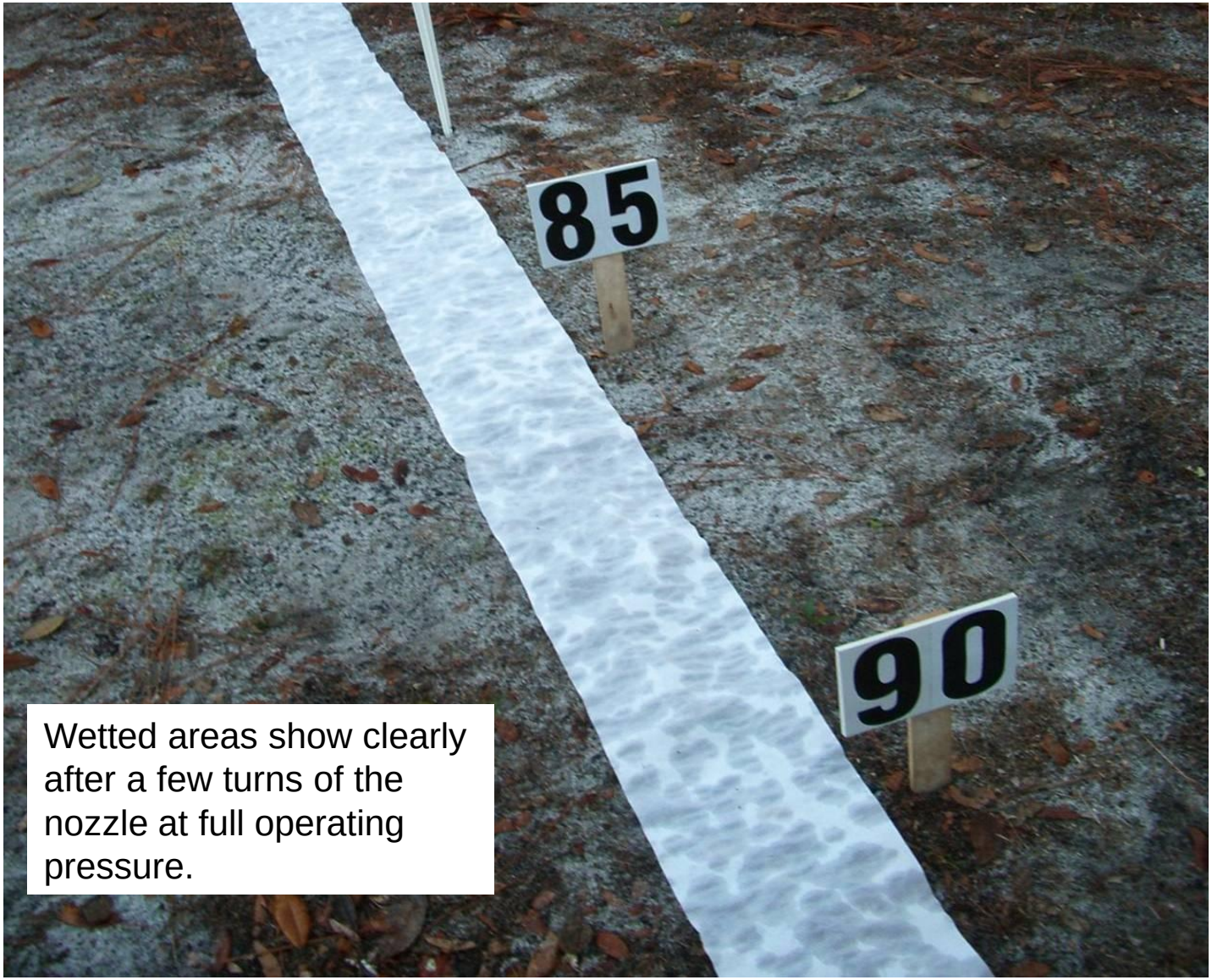

Wetted areas show clearly after a few turns of the nozzle at full operating pressure.

(Photo courtesy Mike Mainland)

Sprinkler Characteristics, 5/32 nozzles, 40 psi

Sprinkler	Rotation Speed sec.	Diameter Max	Diameter Full	Stream Height	Splash Distance
Naan	48	98’	87’	19’	11’
Nelson F33F	32	97’	85’	16’	11’
W.-Tec 10-30	54	99’	90’	15’	15’
RB 40 EFCH	38	95’	84’	18’	16’
RB 14070	86	102’	93’	18’	30’
RB 30 – Did not have					

(Table courtesy Mike Mainland)