RUSSIAN RIVER FROST PROTECTION

BMP GUIDE: Introduction

More economic losses occur due to freeze damage in the United States than to any other weather related hazard. Consequently, considerable effort to reduce damage is expended.

This can result in multiple landowners diverting water from a single watercourse causing a rapid decrease in stream flow. Diversions that rapidly decrease stream flow, particularly those related to frost protection, may strand and kill threatened and endangered salmonids. As of 2010, there are 1,778 miles of potential salmonid habitat and 60,640 acres of vineyard and 4,910 acres of orchard crops in the Russian River watershed.

This Russian River Frost Protection Best Management Practices Guide has been developed pursuant to Chapter 11 of the Sonoma County Code. All design, installation, and modification of active frost protection systems in the Russian River watershed under any Frost Protection Installation Permits, and all operations of active frost protection systems under any Frost Protection Operating Permits shall comply with the best management practices stated in this Guide. The BMPs are designed to foster sustainable frost protection practices for agricultural crops in need of frost protection while avoiding impacts to fisheries and other aquatic resources.

Radiation Frost
Radiation frosts are common occurrences. They are characterized by clear skies, calm winds, and temperature inversions. Under clear, nighttime skies, more heat is radiated away from an orchard or vineyard than it receives, so the temperature drops. The temperature falls faster near the radiating surface causing a temperature inversion to form (temperature increases with height above the ground).

Advection Frost
An advection frost occurs when cold air blows into an area to replace warmer air that was present before the weather change. It is associated with moderate to strong winds, no temperature inversion, and low humidity. Advection frosts are difficult to protect against, but fortunately are rare in California fruit growing regions.

Critical Temperature
Cold injury to green growth begins at air temperatures of 31 degrees for a duration of one-half hour. Air temperatures of 26 to 28 lasting several hours kill all actively growing green parts, including buds that have opened. Cold damage is caused by the plant cells rupturing when they freeze and expand. They expand 8 to 9 percent when freezing occurs. After freezing, they can no longer control their liquid contents and dehydration takes place.

Factors Influencing Frost

Temperatures and expected durations, occurrence and strength of inversions, soil conditions and temperatures, wind (drift) directions and changes, cloud cover, dew point temperatures, critical bud temperatures, vine condition and age, grape variety, land contours, and vineyard cultural practices must all be evaluated. Both passive and active methods to protect against cold injury may be required.

Wind
Cold, dry wind increases evaporation rates from wet surfaces and can cool wet plant parts to damaging temperatures. Sprinkler irrigation provides protection because, if sufficient water is applied, the net gain of heat from freezing water is greater than the loss due to evaporation. However, if the sprinklers stop or if the precipitation rate is insufficient, wet plant parts can cool well below air temperature.

Dew Point
The dew point temperature is defined as the temperature at which the air becomes saturated with water vapor. When the air temperature is at the dew point, the number of water molecules evaporating from a pure, flat water surface is equal to the number condensing on the surface.

Humidity
Humidity is an important factor in freeze protection because moist air absorbs more radiant energy. When the surface temperature drops to near the dew point temperature, condensation can occur releasing latent heat and reducing the rate of temperature drop. Also, air with high water vapor content is a better absorber of long waveband radiation, so air with higher humidity cools slower than drier air.

Latent and Sensible Heat
When water condenses, cools, or freezes, the temperature of the environment around the water rises because latent is changed to sensible heat and the air temperature rises. When ice melts, water warms, or water evaporates, sensible heat is changed to latent heat and the air temperature falls.

Soil Water Content
Thermal conductivity and heat content of soils are affected greatly by the soil water content. On a daily basis, heat is transferred into and out of approximately the top 0.3 m (1 ft) of soil. When the soil is wet, heat transfer and storage in the upper soil layer is better, so more heat is stored during daylight for release during the night. Therefore, wetting the soil surface is prudent when limited precipitation has occurred along with dry windy conditions for several weeks prior to frost season.

Frost Protection Methods
Frost protection methods are often separated into passive and active. Passive methods are those that work within the natural environment and utilize practices that are implemented prior to the frost event. Passive methods discussed in this guide are site selection, late versus early budding varieties, cover crops, and time and method of pruning. Active methods discussed in this guide are sprinklers, wind machines and heaters.
CHAPTER ONE: Passive Frost Protection Measures

Soil Cultivation, Cover Crops, Pruning

Cultivation of soil can greatly affect heat storage. Cultivation, or turning of the soil, reduces heat capacity and conductivity and it removes heat from the soil because water brought to the surface evaporates and takes heat away in the process.

Cover crops inhibit solar radiation from reaching the ground surface which reduces the amount of heat stored in the soil. This results in a lower minimum soil surface temperature and less radiation from the ground surface being available to warm the air and crop during a frost. Cover crops also slow the transfer of heat from the soil to the crop at night. However, cover crops have other beneficial uses.

Late or double pruning is a management practice, particularly useful in dry years, that can delay bud break and thereby reduce frost damage.

**Environmental Concerns**

Surface runoff can carry sediment, nutrients, and pesticides directly to a stream where they affect salmonids and their habitat. Protecting bare soil surfaces with cover crops is one of the best ways to prevent sediment, nutrients, and pesticides from entering a stream.

**Site Evaluation**

Note areas where surface runoff could enter a stream. Inventory all areas prone to frost damage such that only those areas are mowed. Cold air is denser than warm air, so it flows downhill and accumulates in low spots much like water in a flood. When the soil water content is near field capacity (i.e., a day or two after thoroughly wetting the soil), soils have conditions that are most favorable for heat transfer and storage. Plant cover crops in the fall before the start of the rainy season.

**Best Management Practices:**

**All Years**

1. Mow frost prone areas before bud emergence (two weeks ahead of time, if possible) or, when conditions are too wet for standard tractor mowers / mulchers, use chemical-mowing techniques in accordance with all label restrictions.
2. Maintain perimeter erosion control by leaving avenues and headlands unmowed.

3. Where irrigation systems are installed, apply water to create a moisture content near field capacity in the top foot of soil prior to a predicted frost event. Wet soil surfaces store and conduct heat better than dry ones.

**Dry and Critically Dry Years**
(per State Water Resources Control Board's Decision 1610 or the then current decision that determines hydrologic conditions for in-stream flow requirement purposes in the Russian River)

1. Mow the cover crop in frost prone areas no higher than 3 inches.

2. Retard bud break by late pruning or double spur pruning. Conduct the final pruning after the more apical buds have pushed.

3. Avoid cultivation of the soil until later in spring after the threat of frost is passed.
CHAPTER TWO: Frost Protection Systems
Layout and Design

Proper site selection and layout of a new vineyard/orchard can substantially affect the impact of frost or avoid frost damage entirely. Vineyard/orchard site selection should be planned to take advantage of natural topography and utilization of passive frost protection methods that work within the natural environment.

Factors to consider include topography, microclimate conditions, soil types, grape/tree varieties, vineyard/orchard row orientation, natural barriers, sun exposure and water source. Careful consideration of these factors can reduce the dependency on water resources for frost protection.

Environmental Concerns

Coho salmon in the Russian River watershed are listed as "endangered" under the Endangered Species Act (ESA). Chinook salmon and steelhead are also found in the watershed, and are listed as "threatened" under the ESA. It is illegal to unlawfully "take" - meaning to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect - or to attempt to engage in any such conduct with any species protected by the ESA.

The use of water for protection of grape vines and orchards from frost poses risks or potential conflicts to federally threatened and endangered salmonids in the Russian River watershed.

Proximity of vineyard/orchard blocks to habitat suggests easy access to surface diversions and potential impacts from instantaneous reductions in flow during the frost protection season and this demand is greatly enhanced by drought and or below normal seasonal rainfall (spring).

Riparian areas provide stability to the natural drainage features of the land and are an important habitat component of streams. These riparian areas, if located at the bottom of a vineyard/orchard block, can restrict air flow and increase frost damage to lower vine/tree rows.

Site Evaluation
Carefully review a topographic map of the site noting all areas where cold air could settle and where natural air drainage is impeded by either natural barriers or constructed obstacles. Identify slopes, swales and low lying areas on the property. Use weather stations, data loggers, and remote sensors to study the site specific microclimates. Identify all designated and undesignated riparian zones as described in the Sonoma County General Plan.

Include in the site evaluation a review of how to use passive frost protection measures that may be available. Alternatives include planting on upland slope areas and not in low spots where cold air can collect; orienting rows to favor natural cold air drainage out of the cropped area; planting on South and West facing slopes as they tend to be warmer; avoiding the planting of early budding varieties in frost prone areas (e.g. near trees or buildings); or avoiding planting in areas where existing riparian vegetation, trees, brush, topographical features, manufactured obstacles or other air dams that could trap air and prevent cool air from flowing out of the vineyard/orchard are present.

Take into consideration soil type. Loams and clays have high conductivity and tend to absorb more heat in the daytime, resulting in prolonged re-radiation of heat during the night. Soils with low conductivity, like sand, will heat quickly during the day but also lose heat rapidly at night resulting in pools of cold air.

In the design and planning process for new systems, describe and evaluate the full range of alternatives available. Design blocks such that areas that may need water during a frost event can be turned on separate from blocks that may not need frost protection. Consider using wind in warmer blocks.

**Best Management Practices: Applicable to County's Installation Permit**

1. Avoid the construction of any new direct diversions from surface streams, relying instead on frost water from another source or off-stream storage. Design and site wells to minimize effects on stream stage during frost events.

2. In accordance with the County Frost Protection Ordinance, plans for any proposed frost protection system that will use water must be prepared by a certified Irrigation Designer or civil engineer.

3. Uniform application of water is very important. Engineer frost protection systems to obtain a uniformity coefficient of not less than 80%. Include flow control nozzles on hillside sites. Provide means for measuring pressure at pump stations and at end of mains and subs and include flush outs on all laterals, subs, and mains.

4. Do not exceed an application rate for water of 0.12 inches/hour, which is 55 gallons per minute per acre.

5. Impact sprinkler heads should rotate at least once every 60 seconds. Pressures are typically 53.6 psi to 58 psi and should be uniform across the block. A faster rotation time of 30 seconds can obtain the same protection using less water.

6. Installation of wind machines should follow the recommended rate of 8-10 hp per acre. This amounts to two tower-mounted dual machines or four movable or ground-level machines per 40 acres. Movable units are shorter and only cover 8 acres.

7. Installation of heaters should follow the recommended rate use of 40 or more heaters per acre when used alone or 20-25 per acre when used in conjunction with wind machines.

8. Generally, any installed heaters should be evenly distributed over the crop being protected. However, they should be concentrated somewhat more in low spots and on the edge of the upslope or upwind of the crop.
CHAPTER THREE: Operations of Active Frost Protection Systems

Sprinklers

Application of water is widely used and is often the preferred method of growers to protect new growth on crops from damage associated with spring frost events. It can provide the highest level of protection. However, cold temperature protection by over-vine sprinkling requires large amounts of water, large pipelines and big pumps.

Continually applied sprinkler water protects grape vines by releasing heat as the water freezes to ice. The ice and water mixture maintains a protective temperature of 32 degrees on tender crop surfaces. The decision about when to start and stop the application of water should be based on both temperature and humidity.

During each frost event, a timely and appropriate response is critical. To avoid cold damage and protect the crop's tender new growth, the entire frost system must perform uniformly. It is important to monitor current conditions including dew point, changes in temperature and stream stage.

Environmental Concerns

Precipitation is strongly seasonal in the region and, in some years, there can be naturally low stream flows in Russian River tributaries during spring and summer.

Overhead application of water for frost protection can persist for several hours and often occur simultaneously across all areas exposed to the risk of frost. This can create large instantaneous demands and therefore pose risks of impacts to threatened and endangered salmonids, particularly in small streams with little flow.

Stranding of juvenile salmonids can occur when rapid decreases in stream flow result in receding water levels. This has the greatest potential to occur in low gradient areas consisting of gravel and cobble substrate. The frost season occurs at the same time streams are naturally dewatering as flows are diminished from the lack of rainfall and when percolation rates exceed the natural flow.
Wind Machines

Wind machines are a non-water frost control method that mixes an upper warm air layer with the cold air layer near the crop. Cold air is heavier and tends to settle near the ground. If the air above is warm enough and low enough, a wind machine will circulate it into the lower cold air surrounding the crop.

Heaters

Heaters provide non-water frost protection by two mechanisms. The hot gases emitted from the top of the stack initiate convective mixing in the crop area tapping the warm air source above in the inversion. About 75% of a heater’s energy is released in this form. The remaining 25% of the total energy is released by radiation from the hot metal stack.

Environmental Concerns

Wind machines and heaters are already in extensive use in Sonoma County, and neither this BMP Guide nor the County Frost Protection Ordinance requires or mandates increased installation or use of these frost protection options. Rather, this Guide specifies best management practices for all frost protection practices chosen by farmers. These measures are intended to increase efficiencies and address environmental concerns, and thus result in a net benefit to protected salmonid species and other environmental resources.

For wind machines, possible environmental concerns include noise and the movement of cold air into surrounding areas. Heaters can create smoke if not operated and maintained properly and use more energy per hour than wind machines. Mishandling of fuel for either wind machines or heaters could lead to fuel contaminating surface runoff that could affect salmonids and their habitat can create a noise nuisance and push cold air into surrounding areas.

Site Evaluation
Note hillside areas as they may need special pressure compensating nozzles for sprinklers. For all areas, inventory type of sprinkles, nozzle sizes and rotation times, irrigation efficiency, flow meters, location of pressure gauges, weather stations, frost alarm system and flush outs.

Inventory low-lying frost prone areas so as to place wind machines and heaters in the proper places. Learn if an inversion layer exists on cold nights in these areas. Be aware of surrounding land uses in the area.

Inventory instrumentation and review frost forecasting methods. Good instrumentation along with accurate local frost forecasts allows for good management of a frost protection system. For labor intensive systems, review the availability of staff and vehicles to perform routine maintenance and to turn on/off frost systems.

All individuals carrying out active frost protection should be very familiar with the standards and best management practices set forth in this guide and be informed of protection requirements for salmonids in state and federal law.

**Best Management Practices**

1. Use existing sprinkler system so that only blocks needing frost protection are turned on.

2. Operate the frost system only when needed to minimize energy needs (gas, diesel, and propane) and water use. Turn off sprinklers when the temperature is 34 degrees or greater or there is the absence of ice on crop tissue.

3. Operate a system using frost protection water so that it does not create a temporary barrier to fish migration, that is, do not create or contribute to unnatural dewatering of the stream.

4. Record total volume of water for each frost event using either a meter at each frost water pump station or calculated based on pump curve or number of sprinkler heads per acre and hours logged.

5. Use well-maintained and calibrated frost monitoring thermometers and alarms.

6. Agree, if randomly selected, to perform an individual test or to provide access to a qualified professional to evaluate the uniformity of system's water application rate.

7. Provide adequate personnel and training to reduce the length of time needed to test the system or perform routine maintenance. Increase staffing or vehicles to reduce the amount of time sprinklers are operating during frost events.

8. If wind machines are used, operate when temperature at the 5-foot height is above the critical damage temperature, or before the temperature at the 5-foot height falls much below the temperature at 33-foot height.


10. Maintain and operate heaters to minimize smoke. Do not physically modify heaters.

11. Comply with all existing codes and Hazardous Materials Permits to avoid fuel contaminating surface runoff that could affect salmonids and their habitat.

Most frost forecasts include the dew point temperature of the air. Use dew point values to determine the threshold for sprinkler start-up. The following chart is a guide for starting overhead sprinklers:

- Dew point greater than 35°F: - Little chance of frost damage.
- Dew point of 24°F or higher: - Turn on sprinklers at 34°F air temp.
- Dew point between 20 and 23°F: - Turn on sprinklers at 35°F air temp.
- Dew point of 19°F or lower: - Turn on sprinklers at 36°F air temp.
CHAPTER FOUR
Region-wide Cooperation

Substantial effort is required to provide protection for fish resources. The threat is large and beyond the reach of any one individual, parcel or watershed.

Tangible conservation actions are needed in important tributary streams. Existing state and federal resource agencies have and will exercise their authority and responsibility to enforce limits.

At the local level, individual landowners by acting together can collect and assemble necessary data, equip priority monitoring locations, share insights and make improvements in priority areas in the watershed.

The effects of frost protection on listed salmon and steelhead are influenced by a variety of factors including stream stage, severity of frost, and the method, timing, and duration of diversion. The National Marine Fisheries Service (NMFS) has a five-tiered priority scheme for the conservation of salmonids in the Russian River (Figure 1).

A Comprehensive Monitoring and Reporting Program will be developed by the Agricultural Commissioner in consultation with the Sonoma County Water Agency, UC Cooperative Extension and state and federal resource agencies. The Program will be carried out under contract with a non-profit corporation. Data will be evaluated by a Science Advisory Group. The non-profit will collect and report data, conduct education and outreach, and implement and manage the region’s program through a contract with the County. Solutions may range from increasing the efficiency of water use on individual properties to conversion to alternative frost protection methods. Other options may include increasing water storage capacity by creating or expanding ponds, or coordinating the timing and duration of diversions.
Environmental Concerns

Figure 1. National Marine Fisheries Service's salmonid fishery resource prioritization map for the Sonoma County portion of the Russian River.

Three species of salmonid spawn, rear and migrate in the Russian River basin: coho salmon, Chinook salmon and steelhead. All are listed as threatened or endangered under the Federal Endangered Species Act and each is sensitive to the effects of stream water diversions.

NMFS Priority Streams include the following:

Crane  Crocker  Dutcher  Foote  Franz  Gill  Gird
Grape/Wine  Green Valley  Kellogg  Maacama  Mark West  Mill  Miller
Peña  Redwood  Sausal  Yellow Jacket

Measures are needed to ensure that streams are monitored on a scale commensurate with the scope of the impacts and that monitoring results guide water use decisions.

Data will be gathered at key locations in the watershed. Strategically placed gages will provide a means to evaluate local impacts of frost protection diversions on stream flow to ensure they are reasonable relative to salmonid needs.
Site Evaluation

The U.S. Geological Survey (USGS) operates a system of gages in the Russian River watershed that monitor flow and/or stage height.

Stream flow in the tributaries of the Russian River is generated as a function of physical features such as rock and soil types, slopes, shape of the drainage, vegetative cover and rainfall patterns as well as human land and water uses. This complexity requires analysis and study of priority tributary basins.

Regional data collection and management systems can provide a degree of confidentiality for individual properties. A non-profit frost water use organization and a Science Advisory Group will work together to provide protocols and mechanisms for managing and reporting such information within each region.

Building and utilizing off-stream reservoirs, in addition to coordinating water diversions, to meet frost demands will assist in more evenly distributing the demand on the system.

Best Management Practices

1. Record the time period, volume of water, and the number of acres receiving water during each frost event within the year.

2. All active frost protection permittees using water shall participate in and pay applicable fees to fund a comprehensive monitoring and reporting program for the Russian River stream system developed and implemented by the Agricultural Commissioner in consultation with the Sonoma County Water Agency, University of California Cooperative Extension and state and federal resource agencies.

3. Gages are important for understanding overall stream conditions. Growers in key locations, as specified by the Science Advisory Group, should provide access for stream gages in these locations.

4. Participate in region-wide programs promoting the use of effective, lowest water usage sprinkler systems and in efforts to establish weather stations within the watershed.