

Protocol for Okanagan winegrape phenology set-up and monitoring

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1 Objectives

We aim to characterize the phenology of seven of the most commonly planted winegrape varieties in vineyards throughout the Okanagan Valley in British Columbia. Our primary goal is to

improve grower models of plant development with relation to climate. To this end, we will monitor a diversity of varieties that capture differences in phenology. We will record the phenology for selected vines for 2-3 growing seasons from budburst through the summer to veraison. We will also track fruit development through periodic Brix measurements after veraison.

2 Set up Protocol

2.1 Sampling Population

Varieties sampled: Merlot, Pinot noir, Chardonnay, Riesling, Sauvignon blanc, Syrah (Shiraz), Cabernet-Sauvignon

Arterra sites: McIntyre, Dark Horse, NK'MIP Cellars

Quails' Gate sites: Quails' Gate Estate vineyard, Mannhardt

2.2 Choosing Vines

Using the maps and rootstock information provided, we chose the blocks with the following considerations in mind:

- Sample all of our target varieties.
- We chose blocks of different varieties near each other if possible to reduce walking distance/time.
- If a vineyard had multiple blocks of a variety and the blocks were different parts of the vineyard, we sampled one block in each general area to capture environmental variation within the site. If the blocks are close together, we chose to sample just one block.
- If we sampled multiple blocks of a variety in a vineyard, we would usually sample 24 vines in each block rather than 36 to reduce time.
- We preferentially chose blocks with common rootstocks - 3309, 101-14, S04 - in order to reduce effect of rootstock.
- We avoided blocks with unknown clones or varieties and were able to avoid all of the self-rooted blocks except one (Dark Horse block G, the other Pinot noir block was recently planted).
- When weather station locations were known, we chose rows or blocks near them.
- Within blocks, we aimed to capture environmental variation in block, keeping in mind time needed to walk between location. Often this meant that we would sample at the bottom and top of block in the same rows if we flagged 24 plants. If we flagged 36, we would add a middle location in a different set of rows.
- We sampled 6 plants per row in each location. We aimed for plants to be next to each other but sometimes had to skip plants if they were too young or if they did not have a cordon with 2 spurs/cane with 2 buds. Such cases are marked in the Plant ID spreadsheet.
- Flagged vines are at least 6 plants in from the end of the row so we avoid edge effects.
- We always chose to sample two rows next to each other in each location so there were 12 plants (6 per row) in each location.

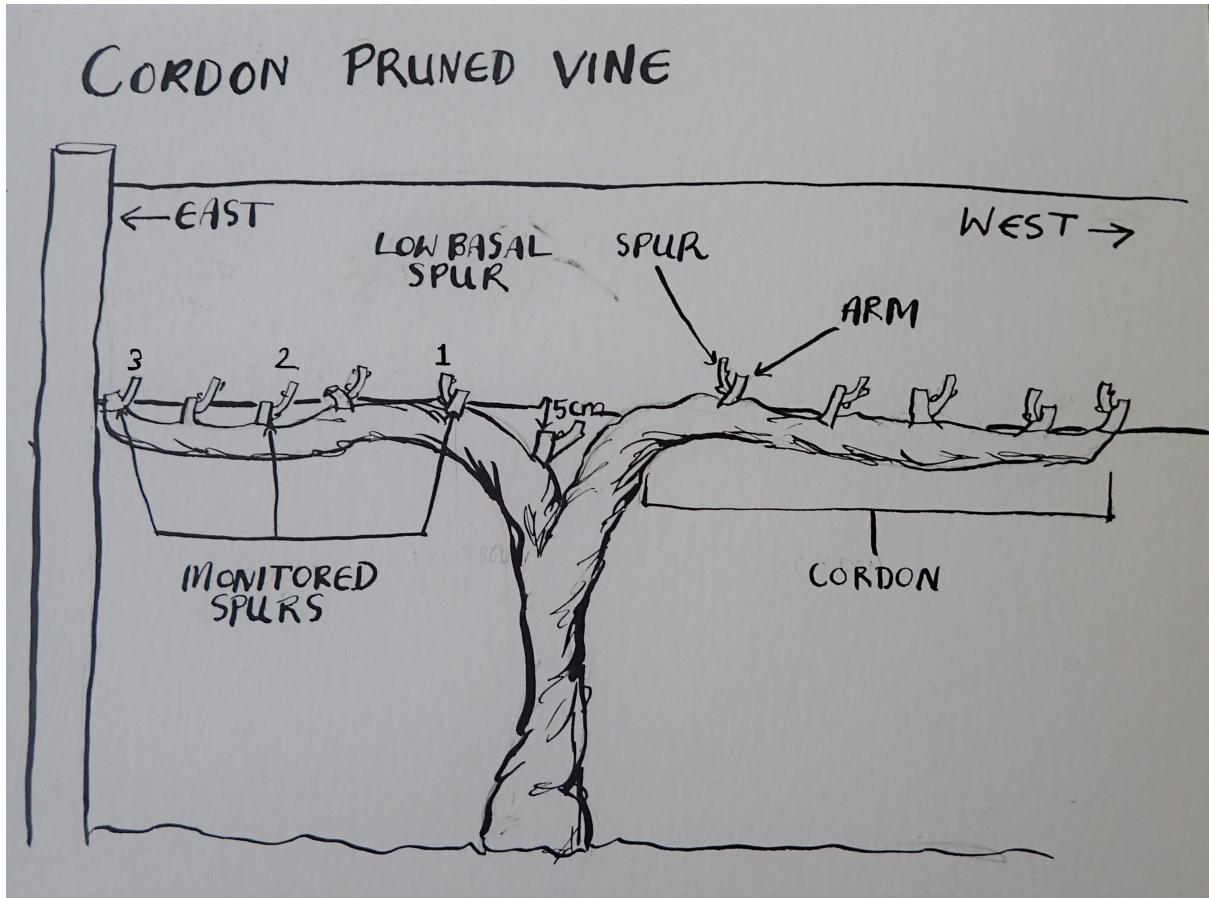


Figure 1: A diagram of a cordon pruned vine, showing which spurs we would monitor and their numbering. Any spur that's base was more than 5cm below the wire the cordon was trained on was not sampled.

- 36 or 24 vines were flagged per block.

Tip for when selecting buds each year: If you are not flagging all the buds at once, flag the final bud/spur as this one will always be monitored. Doing this saves time because otherwise you may have to move the flag to another spur. We would recommend flagging with flagging tape all the buds at once to save time.

The location of each plant we monitor, as well as which side of the plant we chose to monitor, (see Choosing Buds below) is recorded in the `plantsinfo.csv` file on the repo.

3 Choosing Buds

If plant was either cordon pruned (Figure 1) or cane pruned (Figure 2, we flipped a coin to determine which side was flagged (heads = south or east, tails = north or west). If one side of the plant did not have enough buds, we chose the other side. When the cordons were clearly different ages, we chose to sample the larger/stronger cordon because it will be more representative of

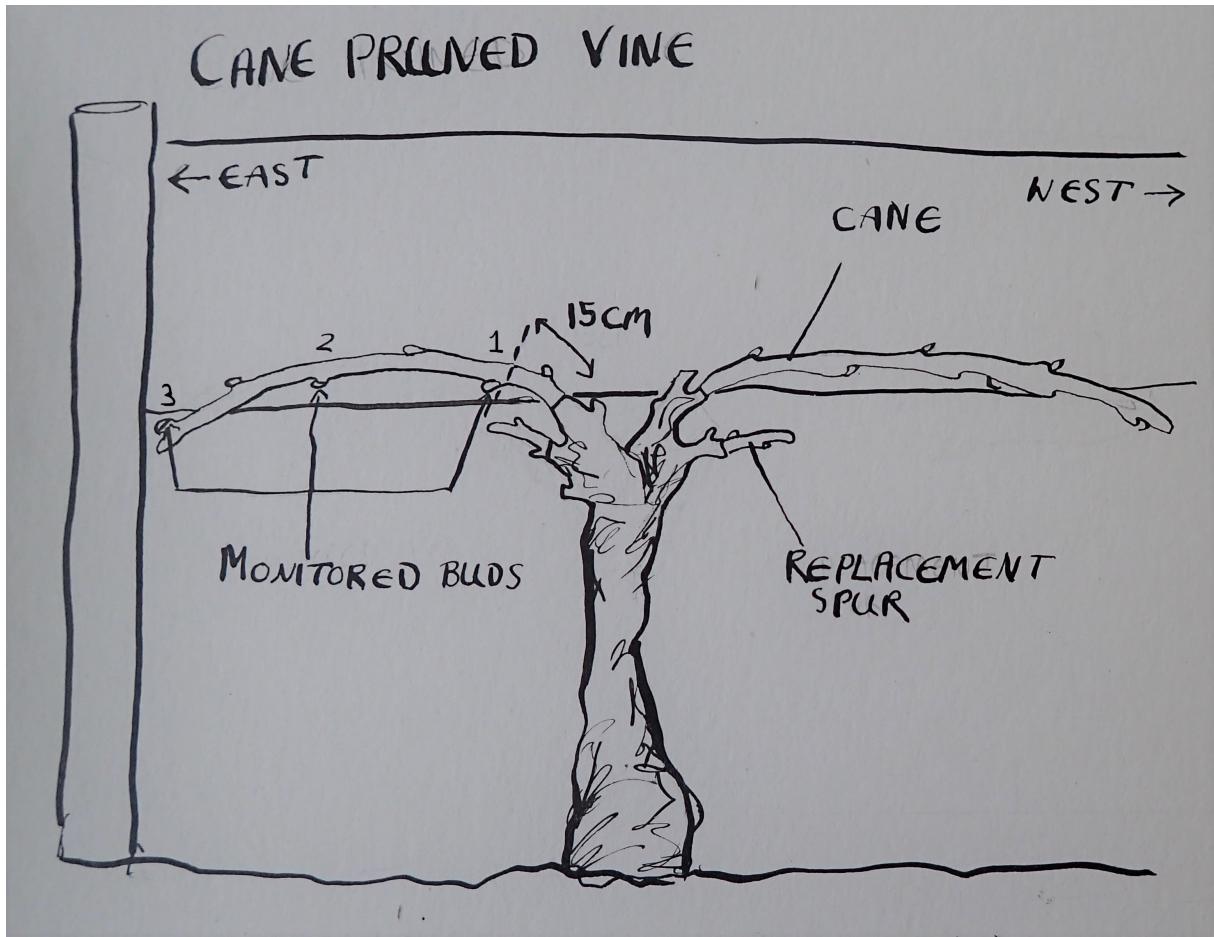


Figure 2: A diagram of a cane pruned vine, with the buds we would monitor and correct bud numbering. Note that we do not sample buds too close to the head of the vine.



Figure 3: When there is both a cordon and a cane, you sample the cordon unless the cordon has less than three spurs.

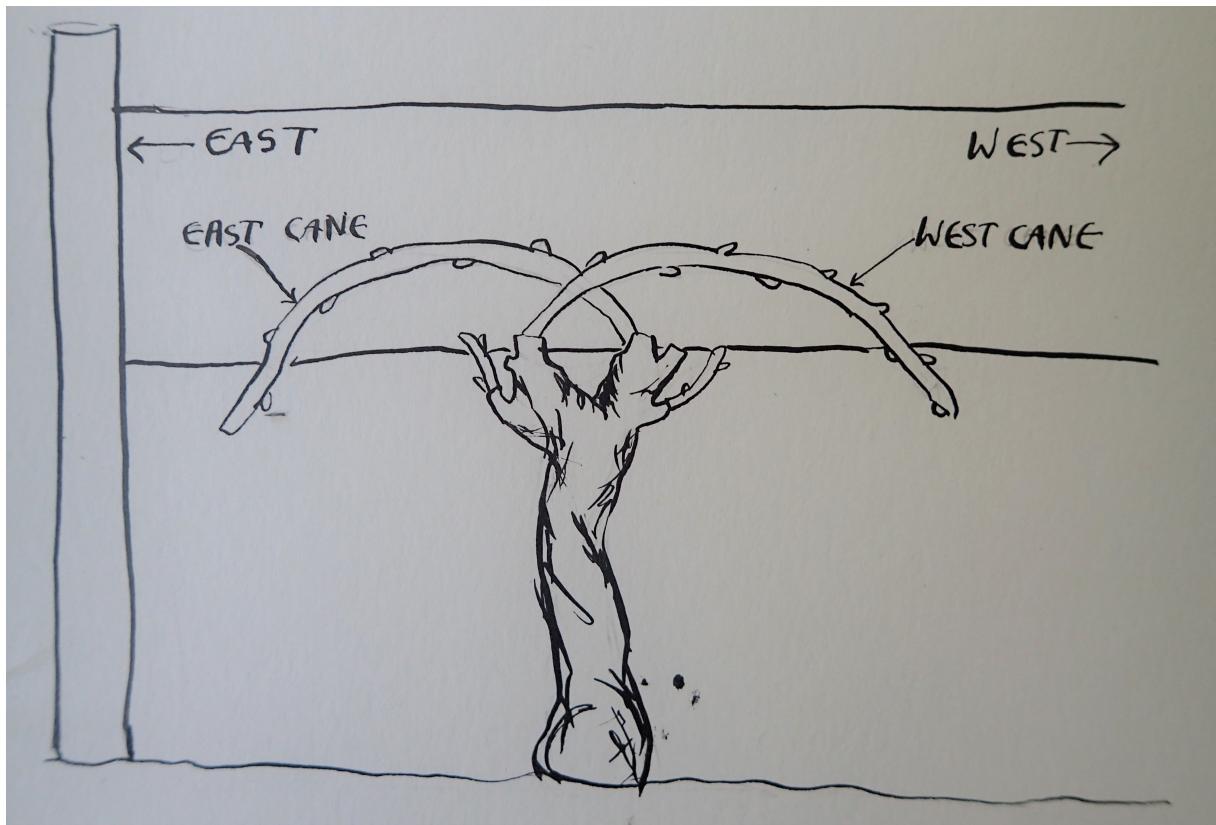


Figure 4: Sometimes the canes are crossed. If they do, we use the end of the cane to decide which side is east/west or north/south.

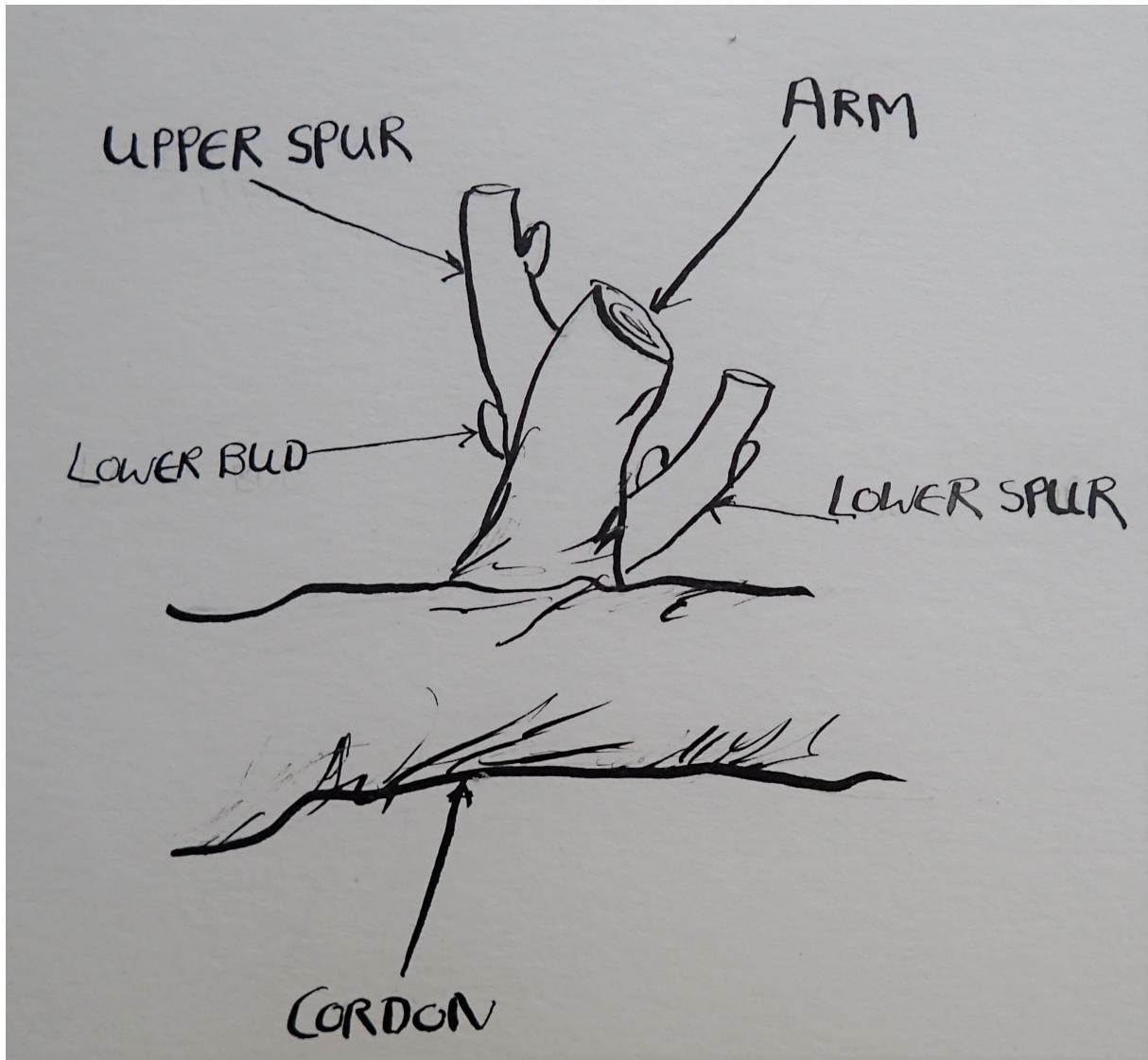


Figure 5: A diagram of an arm of a cordon that had two spurs on it. In this case we chose to focus on the lower bud of the higher of the two spurs for monitoring.

the plant. If a plant had a cane and a cordon (Figure 3), we flagged the cordon unless it did not have at least three spurs, then the cane was flagged. Occasionally, a cane would be trained back to the trunk in a loop or had come loose from the wire. In these cases, we flagged the other cane. If the cane started on one side but was trained to cross over and end on the other side, we used the direction of the end of the cane. (Figure 4)

3.1 Cordon Buds

We flagged the spur (or arm if it was present) on the furthest from the trunk, a middle spur, and the first spur on the cordon with a base less than 5cm below the wire (Figure 1). Spurs 5 cm or more below the wire were considered basal. If there was an even number of spurs, a coin flip determined which middle spur was chosen.

If there was more than one spur on an arm (Figure 5) then we focused on the higher spur. We monitored the lowest bud on this spur.

3.2 Cane Buds

We flagged the bud furthest from the trunk, the middle bud, and the first but that was farther than 15 cm from the trunk (Figure 2). If there was an even number of middle buds, a coin flip determined which bud was chosen.

If there were two buds in the same place in a position that was flagged, we chose to monitor the bud that was more upright. If both buds were equally upright facing, we monitored the one in a southerly or easterly direction.

4 Numbering Buds

For the first set of data collection, Mira and Faith numbered the buds on each cordon or cane from 1 to 3 in ascending order from either the south or the east. This caused confusion in the field so we decided to change the numbering protocol.

For the Dark Horse monitoring protocol and future years, use the following protocol:
Number buds 1 to 3 with bud 1 being the bud closest to the trunk (see Figures 1 & 2).

5 Choosing Clusters

From each bud selected for monitoring during budburst, a cane will arise bearing one or more clusters of grapes. For the remaining pheno stages (bloom, veraison, Brix), we want to select a specific cluster for monitoring rather than a cane. Select the basal cluster (the lower one, originating closest to the ground) on the chosen cane (which will arise from the lowest bud position on the flagged arm, see Choosing Buds section) (Figure 6). This will generally be the strongest cluster; especially in warm climates, there may be a big developmental difference between upper



Figure 6: The basal cluster (right) should be flagged rather than the second cluster (left)

and lower clusters on the same shoot (Figure 7).

This cluster will first be visible during the first pass for bloom. Note the lowest cluster on the first pass and make sure the same cluster will be monitored throughout the rest of the season. If you feel it will be difficult to keep track of the monitored cluster you can loosely (**loosely!**) flag it. Do not flag tightly before this as it can prevent the growing tissue from maturing regularly. If a flagged cluster dies, disappears or somehow becomes no longer suitable for monitoring: Re-flag nearest cluster and note in datasheet. In no case should you select, flag, or sample from a cluster that is more than 3-4 nodes along the cane (such a 'second crop' cluster will not be representative).

Once the green vines become woody (this is often after flower set or post-scatter, that is when you can shake the cluster and a few berries fall off) you can flag the cluster normally. You will take all remaining phenological samples from this cluster. It is important to flag the cluster to ensure repeatability in subsequent samplings by the same observer across different days (or by different observers). If possible, use the flag from the bud. It may seem obvious at this early stage, but the selected cluster can get a lot more confusing with subsequent growth throughout the season.

6 Monitoring

Our goal is to have standardized observations of phenological stages for analysis. There are four main widely observed stages for winegrapes: (1) budburst, (2) flowering, (3) veraison, and (4) ripening and harvest. For the first stage, budburst, we will use the stage numbers from the Modified Eichorn-Lorenz system (see Figure 8). For flowering and veraison, we will estimate the percent occurrence of the stage (proportion of berries on a selected cluster have gone through the stage of flowering or color change/softening, respectively). We will measure ripening quantitatively, using a refractometer to measure Brix.

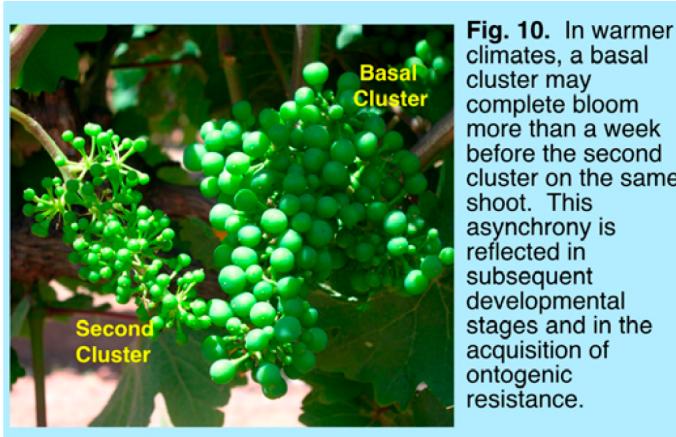


Figure 7: (labeled Figure10 in image). Source: Gadoury et al. 2012, <http://grapesandwine.cals.cornell.edu/cals/grapesandwine/appellation-cornell/issue-11/loader.cfm?csModule=security/getfile&PageID=1074171>

6.1 Sampling Frequency and Timing

1. We monitor four phenological stages:
 - Budburst (approx. mid-April - mid-May): Until EL stage 12, record the EL stage of buds on three spurs. Once EL stage is at 12 you can stop recording until flowering starts (note that you may need to record higher than stage 12 at times in order to record whatever stage you see after 11, even if it is 13 or such if you have not yet recorded stage 12, more on this in Monitoring Instructions).
 - Bloom (approx. June 1-30)
 - Veraison (approx. July 15-Aug 15)
 - Ripening (Brix - approx Aug 15-Sept 30)
2. We estimate that observing pheno stages for each vine (budburst, bloom, and veraison) will take approximately 90s per vine.
3. Once at least 5% of the phenological stage (i.e., 5% bloom) is seen, go out to the field until stage is complete for all varieties being monitored.
4. During peak sampling, we will aim for techs to make pheno observations every 3 days (2x/week) *if possible*.
5. Following the end of one pheno stage, techs will do a weekly vineyard walk-through starting 2-3 weeks before the anticipated beginning of the next stage, to make sure to catch early varieties entering the next stage. **Let us know how this goes!** This is the first time the lab has worked in such a large climate gradient so we are unsure how much time there will be in the end between events (i.e., will there a period when no plants are undergoing flowering or veraison or will veraison start for early varieties in the south when flowering is still happening in the north?).

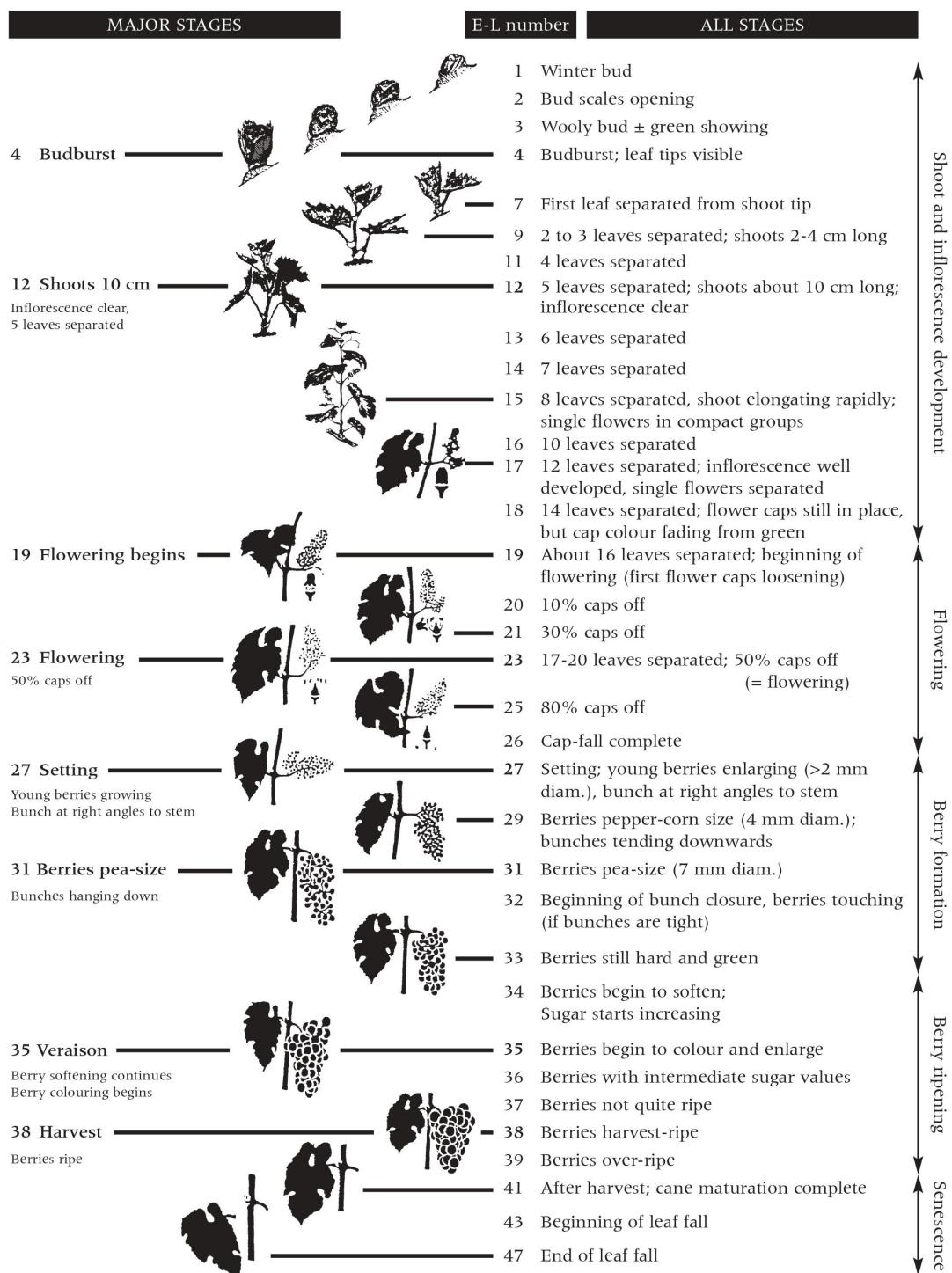


Figure 7.3 Modified E-L system for identifying major and intermediate grapevine growth stages (revised from Coombe 1995). Note that not all varieties show a woolly bud or a green tip stage (May 2000) hence the five budburst stages in the modified original 1995 system have been changed slightly by removing stage 4 and allocating the definition of budburst to what was formerly stage 5. Revised version of "Grapevine growth stages – The modified E-L system" Viticulture 1 – Resources. 2nd edition 2004. Eds. Dry, P. and Coombe, B. (Winetitles)

Figure 8: Modified Eichorn-Lorenz (EL) scale that our lab uses for monitoring phenology until flowering. There are different versions of Eichorn-Lorenz so please follow this one!

6.2 Fieldwork Prep

Be sure to coordinate with vineyards before you visit to make sure you can access the vines. Generally the main issue is avoiding vines after spraying.

Field work materials:

- Vineyard map
- Sampling protocol
- Description of grapevine phenological stages (see Figure 8, Modified Eichorn Lorenz system)
- Field tablet for recording data
- Pen/paper and data entry sheets as backup if tablet fails (print-outs of .xls files)
- Field notebook
- Sharpie pens
- Camera to record each stage for reference
- Paper tags with attached string (like larger versions of yardsale pricetags) to help with labeling plants for photos
- Flagging tape for marking selected arms and clusters.
- During ripening (August-September): Ziploc bags for berry collection.
- Nice to have: paper towels & handy wipes for cleanup (especially during Brix)
- Hand sanitizer for use when touching any communal equipment, for example gates or portable washrooms.

6.3 Monitoring Instructions

For each vine:

1. Stand facing the vine. Double-check Plant ID (labeled on one of the flags), block, and row number before recording in correct place on data sheet that we will provide. You do not need to record information about the varieties on the datasheets.
2. Bud numbers are not written on the flags but are numbered 1 to 3 with Bud 1 being the bud closest to the trunk.
3. **For pre-bloom (we record EL stages)**, record the appropriate E-L stage of the shoot that was flagged, or the shoot closest to the flagging that matches our selection criteria laid out in the section above.
 - Record its EL stage (number from “1”: still dormant, to “17”: twelve leaves separated (see Figure 8) until EL stage 12).
 - Once EL stage is at 12 you can stop recording until flowering starts (note that you may need to record higher than stage 12 at times in order to record whatever stage you see after 11, even if it is 13 or such if you have not yet recorded stage 12).
 - You should count even small leaves at the very base of the shoot.

- However, do not count lateral shoots, which start as one leaf and grow into a separate shoot, as these will be removed later. Lateral shoots can be distinguished by the fact that they have more than one leaf (see Figure 2 above, where an emerging lateral shoot is visible in the axis of a leaf).
- It may happen that more than one shoot grows from the bud on the arm. In this case, the non-dominant shoot will usually be removed later (the one that will not bear clusters).
- Feel free to take photos of the various stages as a reference, and ask questions if you are unsure!

4. For flowering (we record percentages) (EL 23) look at each cluster (#1, #2, #3) and visually estimate the percent (from 0-100%) of berries on the sample cluster that have achieved that stage.

- We record the percent of all buds on the cluster in flower (from 0-100%), in units of 5% (i.e., no need to estimate 3% or 34%, just report 5% and 35% ... aim to be accurate within 10% but most important is consistency and taking photos). Figure 10 gives a visual guide for percent cover up to 50%.
- Grapevine flowers are botanically “perfect” (they include both male parts (anther and stamen) and female parts (pistil and stigma). Early in development, all of these flower parts are covered by the closed flower petals. During bloom, the flower petals separate from the base of the flower and form a “cap” on top of the flower structure. These caps eventually dry out, going from green to yellow or brown as shown with labeled flower anatomy in Fig 9.
- We record bloom as anytime after all parts of the flower are exposed.
- Take photos of a full series of your percentages (5%, 25%, 50%, 75%, 95%).
- Note in data sheet when a certain variety is “done” (past desired phenological stage) and skip it on all further visits during sampling of that phenological stage. Put another way, once a cluster has reached 100% bloom you can make a note in your datasheet and skip recording it on future dates when you are monitoring bloom. You can also skip clusters that have been at 95% for more than two visits.

5. For veraison (we record percentages) (EL 35), look at each cluster (#1, #2, #3) and visually estimate the percent (from 0-100%) of berries on the sample cluster that have achieved that stage.

- We record the percent of all berries on the cluster that have undergone veraison (from 0-100%), in units of 5% (i.e., no need to try to estimate 3% versus 5% ... hope to be accurate within 10% but most important is consistency and taking photos). Figure 10 gives a visual guide for percent cover up to 50%.
- We will count veraison as any detectable color change (e.g., a light pink berry is counted as well as a dark purple one) of the berries. If color change is not obvious, you may need to feel the berries (give them a light pinch) to detect if veraison has begun, as evidenced by softening (grapes that have not gone through veraison will be very hard to the touch). See *Understanding Veraison* below for more information.

- Take photos of a full series of your percentages (5%, 25%, 50%, 75%, 95%) for both red and white varieties.
 - Try to note softness on red grapes too and if you find any that have changed their softness before color please make a note in the notes field of the datasheet.
 - Note in data sheet when a certain variety is "done" (past desired stage) and skip it on all further visits during sampling of that phenological stage. Put another way, once a cluster has reached 100% veraison you can make a note in your datasheet and skip recording it on future dates when you are monitoring veraison. You can also skip clusters that have been at 95% for more than two visits.
6. Take photos of representative illustrations for different varieties of target % at stage (e.g., clusters at 5%, 25%, 50%, 75%, 95% flowering) for different varieties. Aim for 3-5 photos of each percentage taken across a diversity of varieties and across a couple different sampling dates, and make sure vine number and date are visible in photo for identification. **Label the filename with the percent.** If possible, you can also use tags to label the percent in the photo.
 7. For ripening, we collect berries so we can analyze Brix. We will aim to collect samples starting around 12-15 Brix until commercial harvest.

Note that vineyards usually cluster thin lateral shoots and prune extra canes before bloom to preserve good light and air circulation in the canopy. Some of the flagged buds/clusters may be removed. If this happens, simply flag the closest replacement bud/dominant cluster for observation and note the change in the datasheet.

Note that in counting leaves to determine EL stage, you should count even small leaves at the very base of the shoot (see figure 6). However, do not count lateral shoots, which start as one leaf and grow into a separate shoot, as these will be removed later. Lateral shoots can be distinguished by the fact that they have more than one leaf (see Figure 11, where an emerging lateral shoot is visible in the axis of a leaf). Additionally, it may happen that more than one shoot grows from the bud on the arm. In this case, the non-dominant shoot will be removed later (the one that will not bear clusters).

7 Understanding Veraison

Veraison is a physiological change in the grape where sugar accumulation begins, and the berries begin to enlarge, soften, accumulate sugars and lose acids, and change color (this is quite noticeable in red varieties, and more subtle but still visible in white varieties). At veraison, water transport from the xylem into the berries ends, and the phloem takes over this role.

Some French colleagues have noted to us that a couple red varieties sometimes become soft before they turn color—and the softness seems to coincide with Brix change. This is about 1-2



Figure 9: The anatomy of winegrape flowers. Source: Hellman 2012

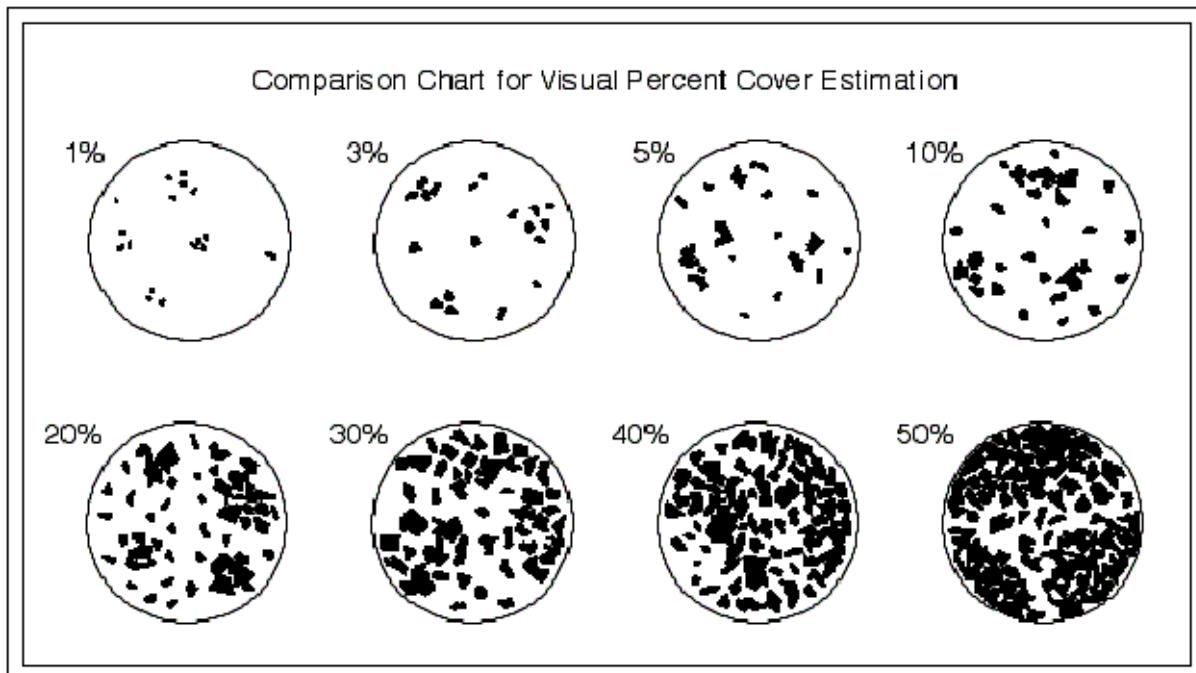


Figure 10: Guide for estimating percent cover. Source: www.nature.nps.gov

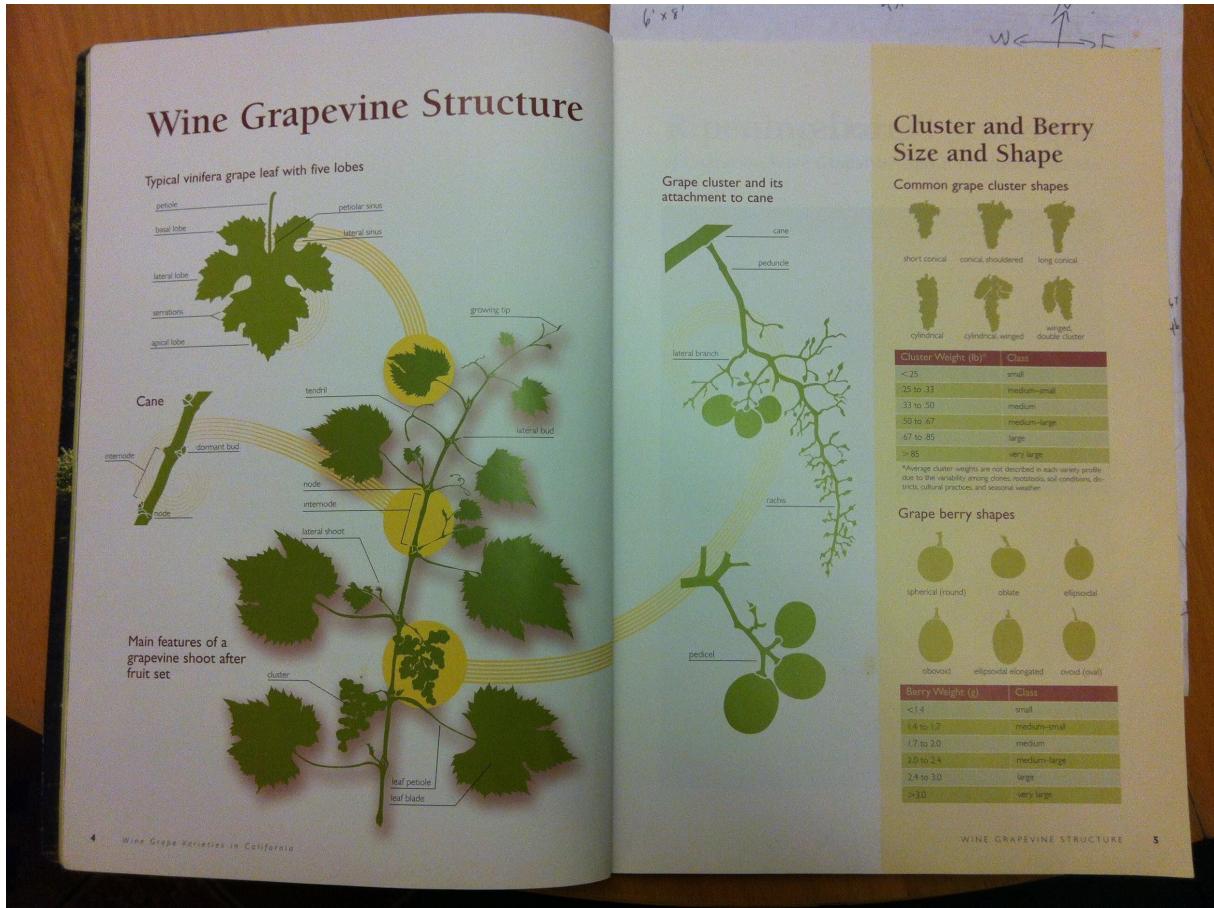


Figure 11: An informative diagram of winegrape shoot and berry structure. Source: Bettinger et al., 2003, Wine Grape Varieties in California.

out of 50 varieties so it's rare, but try to note softness on red grapes too and if you find any that have changed before color please make a note in the notes field of the datasheet.

8 Site Directions and Access

Quails' Gate: Main Estate vineyards

The main Quails' Gate vineyard is easy to find using Google Maps if you use the Quails' Gate Wineshop as the destination. From BC-97 North, turn right onto Gellatly Rd then left on Boucherie Rd. Quails' Gate Wineshop is about 5.5 km up the road. The parking lot for the main vineyard is a little bit before the Wineshop and is labeled with a "Staff Parking Only" sign (see Figure 12. You can park here for the upper and lower vineyards (just across the road). We do not drive in the estate vineyards.



Figure 12: The sign marking the vineyard parking lot

There is no gate to the parking lot and no gate to prevent people from walking through the vineyard so as long as you have permission from Judy Wanbon to be in the vineyard, access at any time is easy.

Quails' Gate: Mannhardt Vineyard

Mannhardt Vineyard is close to Quails' Gate. From Boucherie Rd, turn right on to Sunnyside Rd (turn is just after the Wineshop parking lot), left at the stop sign to Kelly Dr, and right at Aubrey Rd. Turning right on Aubrey essentially takes you into the vineyard. We have been driving around this vineyard.

Mannhardt does not seem to be gated. Technically, there is a gate but it has never been closed when we are there and non-vineyard people often walk through the site. You should only need permission from Judy and should be able to access it at any time.

Arterra: NK'MIP Cellars

This site is easy to find using Google Maps if you set NK'MIP Cellars as the destination. From

BC-97 South, turn left on BC-3 E/Main Street and left onto 45 St. The 45 St corner has a Petro-Canada and a sign for NK'MIP Resort. Follow this road up to the resort and once in the resort parking lot, turn right and follow the road passed the sculpture of the turtle and man to the parking lot on the left. Across the road you should see the NK'MIP Cellars building and a garage/equipment shed.

One section of the vineyard is at along the parking lot. The main vineyard is across the road - the gate is between the winery building and equipment shed. There is an additional gate from the resort parking lot that is obvious and decorative. I think it is best to use the other gates if possible. The spray board is on the equipment shed.

Mike Watson gave us a key that opened both gates to be returned at the end of the season. Get permission from Nelson Dutra to be in the vineyard.

Arterra: Dark Horse

Easy to find with Google Maps if you set the destination to 4859 Mariposa Rd, Okanagan-Similkameen C, BC. From BC-97 South, turn right onto Rd 11 then left on Mariposa Rd. You should see the main office building and parking lot behind a hedge right after the turn. Across the road from the parking lot are blocks 1 and 2. Driving around these will take you to an exit at the intersection of Mariposa Rd and Rd 11.

Following the paved road passed the office will take you up the hill to the other blocks. There are signs marking Dark Horse (Figure 13). The spray board is on the side of the equipment shed.

I do not think the vineyard itself is gated - it has always been open when we arrive if it is. We will check this next time we are there. Get permission from Mike Watson but always check the spray board before starting work.



Figure 13: The signs marking the entrance to Dark Horse Vineyard

Arterra: McIntyre

Can use 4181-4101 McKinney Rd, Oliver, BC V0H 1T0 to search on Google Maps. From BC-97

South, turn left on Tucelnuit Dr (Jackson Triggs winery is on the corner) continue until the road ends at McKinney Rd. Turn left onto McKinney Rd and follow it for about 1 km until you see McIntyre vineyard on the left. You will have to drive up the hill to get to the vineyard. The office is on the opposite side of the vineyard.

There is another exit/entrance on Arrow Head Rd between blocks A and C. Turning right out of block C (left from A) will take you out to McKinney Rd where you take a left and drive passed the main entrance to return to Tucelnuit Dr.

Get permission to be in the vineyard from Scott Carlson - he will tell you when they have sprayed. There should also be a spray board on the office according to Mike Watson.

9 Contacting vineyards

Please ask Mira and/or Faith to introduce you before reaching out to these folks! If you have any issues, let us know.

Quails' Gate

Head Viticulturalist: Chad Douglas (250) 317-3006 (Chad Douglas, Quails Gate as of 2020), Email: Chad@sfewine.com (cdouglas@quailsgate.com)

Assistant Manager for Quails' Gate Estate and Mannhardt vineyards is Judy Wanbon (250)-317-8305 (email: Jwanbon@quailsgate.com)

Arterra

Dark Horse contact and Head Viticulturalist

Mike Watson (250) 498-9391

mike.watson@arterracanada.com

Nk'mip –

Nelson Dutra - Vineyard Manager

250.485.8085 (Email: nelson.dutra@arterracanada.com)

McIntyre and Whitetail –

Contact FIRST is the vineyard supervisor:

Scott Carlson 250.485.7920 (Email: scott.carlson@arterracanada.com)

Vineyard Manager is Manjit Deol: 250.485.8215

10 Glossary

- **vine**: an individual plant of *Vitis vinifera*.
- **permanent part of the vine**: vine parts which are not pruned, and persist from year to year (ex: trunk and cordons).

- **cordon:** parts of the vine that extend horizontally from the trunk, parallel to the ground, along a horizontal training wire in the trellis. (See Figure 1) They are a permanent part of the vine, may be many years old, and develop bark.
- **arm:** a vertical permanent protuberance with bark arising from a cordon. Age three or more years. (Labeled in Figures 1 & 5). Arms are also called '**positions**' on the grapevine, as they are selected and maintained to have good spacing, light, and airflow through the canopy, etc.
- **cane:** developed shoots grown this year ('one-year-old' by the end of the growing season). Over the course of the season, this year's leaves and clusters grow from buds on the cane. There are differences in terms of cane management between cordon pruned vines (Figure 1) and cane pruned vines (Figure 2).
 - **For cordon pruned vines:** At the end of the season when the cordon pruned vines are pruned, a section of one cane on each arm from last year is retained (this will become a **spur**). This cane is cut to two buds on a vine of average vigor, one bud on a weak vine, and three on a strong vine, to match the growing points to the vine's capacity. The two buds kept will become next year's canes. The second cane (which grew from the upper bud kept from last year) is removed during pruning (Figure 5).
 - **For cane pruned vines:** a single full cane is retained at the end of each growing season to serve as bud for the following year (Figure 4). This cane will be removed at the end of the second growing season so a new cane can take its place. Extra canes may be retained at the head of the trunk to serve as a source of next year's cane.
- **spur:** two-year-old wood (meaning, what is left of last year's canes). This will be cut in pruning to retain just the lowest buds. (Labeled in Figure 2).
- **buds:** the compound buds, occurring at nodes, from which this year's growth will happen. This year's shoots will turn into canes, which will eventually bear leaves and clusters. Each of the buds marked 'buds for monitoring' in Figure 5 are what will go through budburst. These bud should be monitored for EL stages numbers 1-15, which refer to the vegetative part of the plant (leaves or shoots), not the reproductive part (clusters).
- **cluster:** (AKA **bunch** for table grapes when ripe; AKA **inflorescence**, botanically)– the fruit of the grapevine, consisting of many berries attached to a **rachis** (the skeleton left behind after you eat a bunch of grapes). The cluster consists of many flowers, which bloom and go through **set** (pollination), in the process shedding their '**cap**' covering the flowers. Flowers that have set go on to ripen into fruit, the individual berries on the cluster. Clusters are found on the 2nd and 3rd nodes (fruitful nodes) of a cane that grew this year from one of the two buds originally retained at pruning.

11 Misc

Tape colors for QG are orange and blue, avoid flagging with these colors
 Avoid orange and pink for Arterra - they seem to use most colors in their vineyards though
 Ask vineyards at beginning of the season what color they prefer we use

12 Vineyard Maps

Below are maps of the vineyards marked with locations marked for the vines we are monitoring.

Dark Horse Vineyard

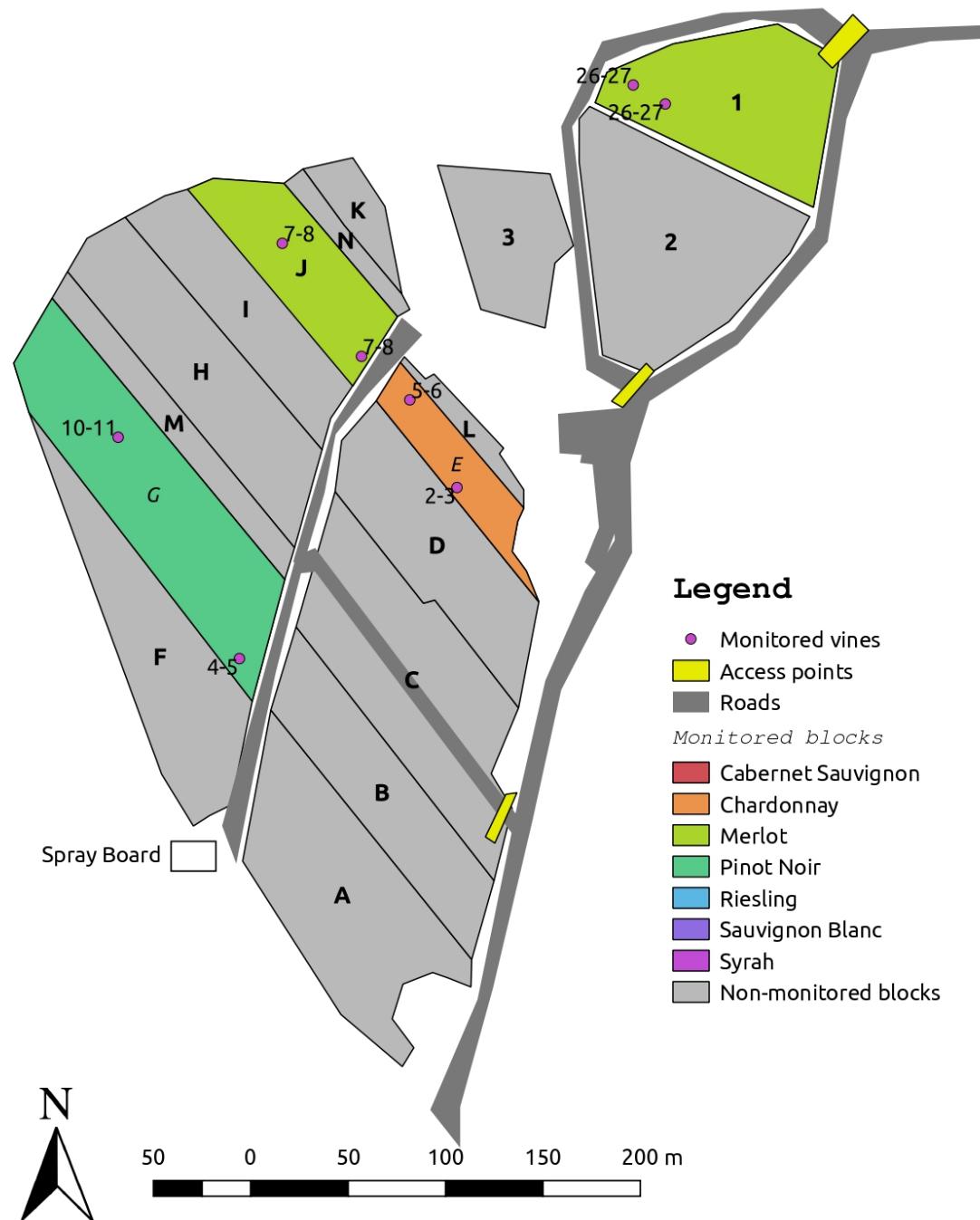


Figure 14: Map of Dark Horse Vineyard

McIntyre Vineyard

Legend

● Monitored vines

■ Access Points

■ Roads

Monitored blocks

■ Cabernet Sauvignon

■ Chardonnay

■ Merlot

■ Pinot Noir

■ Riesling

■ Sauvignon Blanc

■ Syrah

■ Non-monitored blocks



Figure 15: Map of McIntyre Vineyard

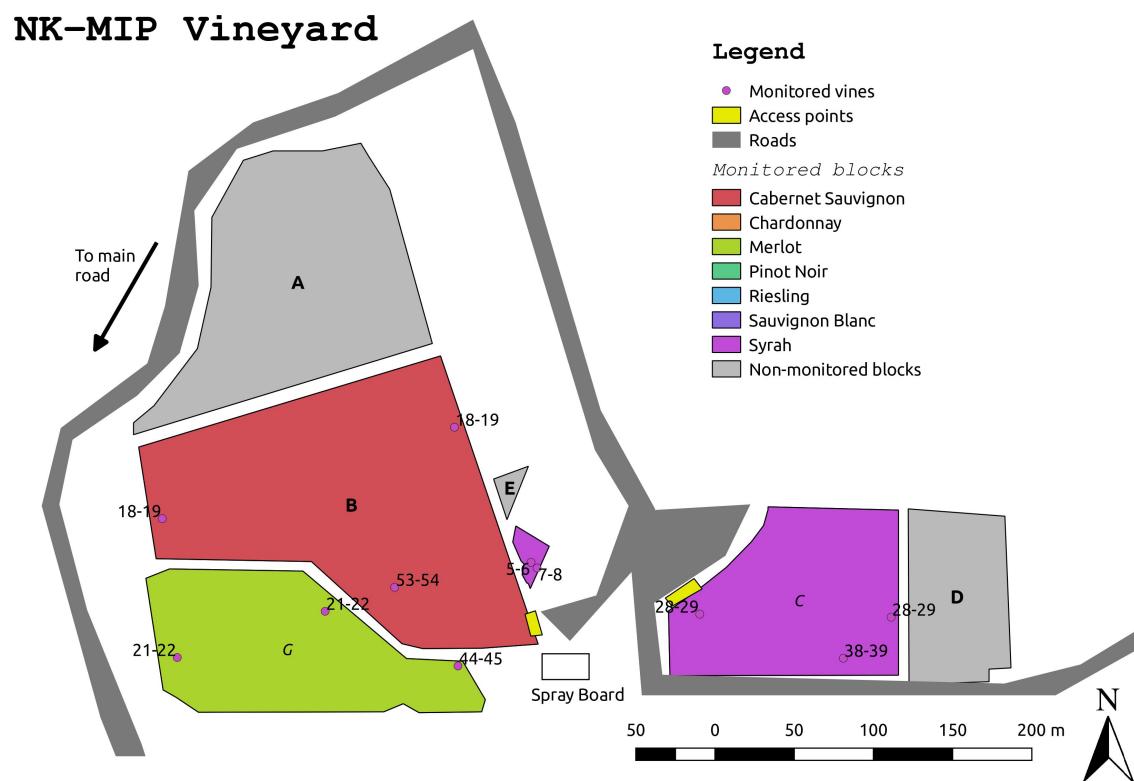


Figure 16: Map of Nk'Mip Cellars Vineyard

Quail's Gate Vineyard

Legend

- Vine Row Locations
- Access Points
- Roads
- Monitored Blocks*
- Cabernet Sauvignon
- Chardonnay
- Merlot
- Pinot Noir
- Riesling
- Sauvignon Blanc
- Syrah
- Non-monitored blocks

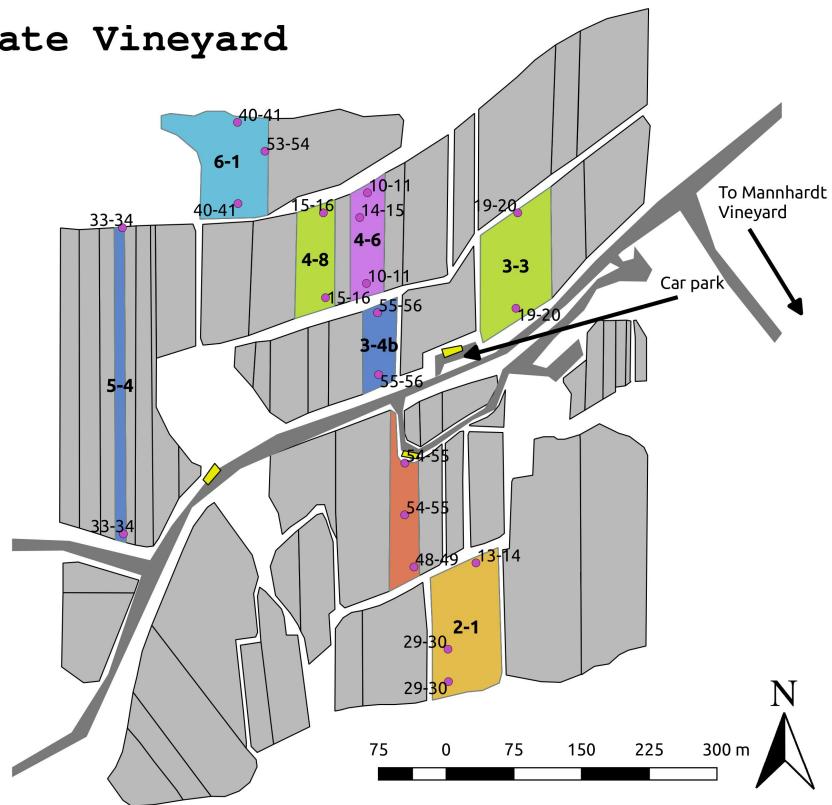


Figure 17: Map of Quails' Gate Estate Vineyard

Mannhardt Vineyard

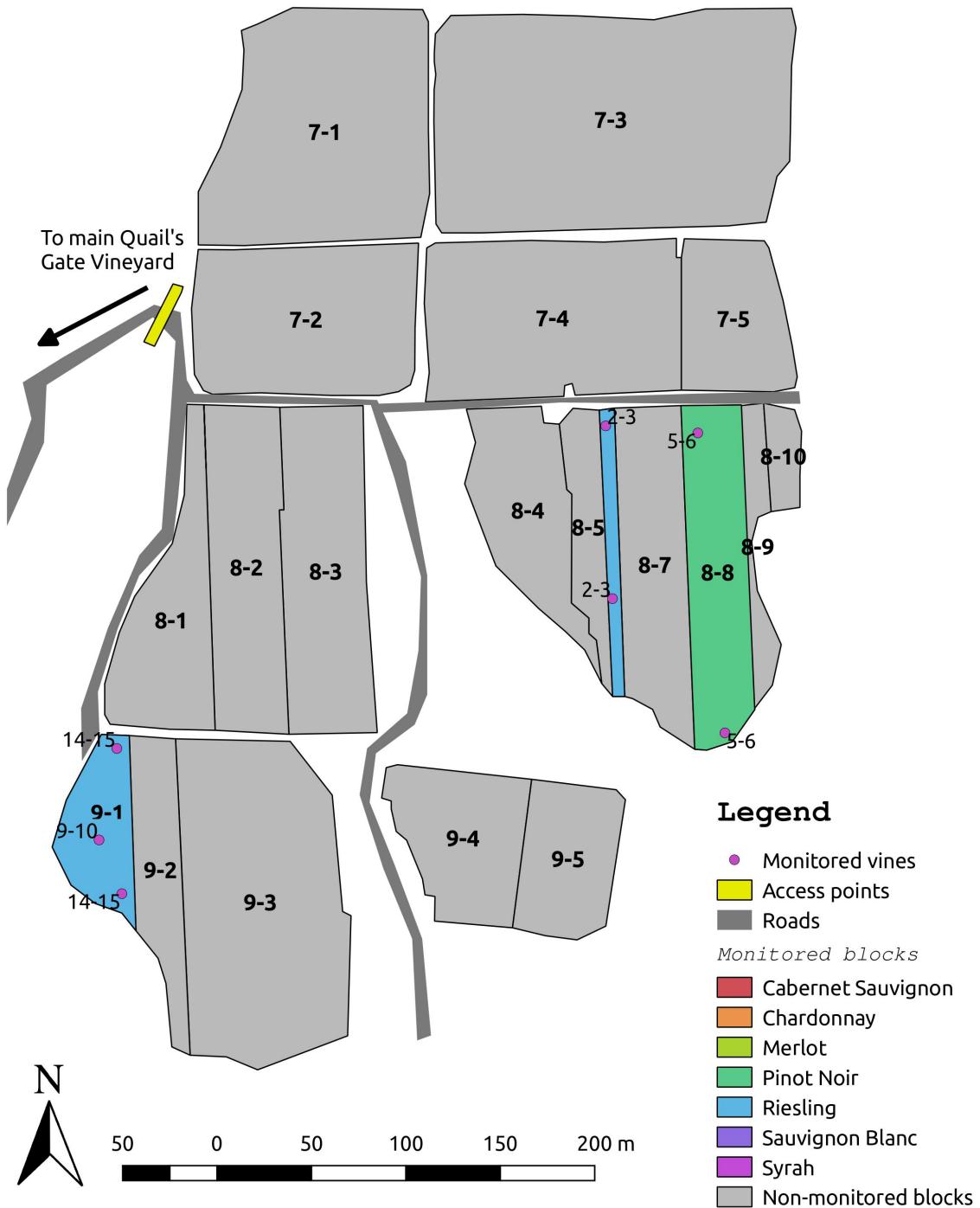


Figure 18: Map of Mannhardt Vineyard