Investigation of Viticulture Pollution on Residential Gardens

Mitigation Practices for Sulfur Pollution

Castiel Armanda Shepp

Investigation of Viticulture Pollution on Residential Gardens

Mitigation Practices for Sulfur Pollution

A senior project presented to the faculty of
Landscape Architecture at the University of California, Davis,
in fulfillment of the requirements for the degree of
Bachelors of Sciences in Landscape Architecture.

Accepted and Approved by:

____
Heath Schenker, Faculty Senior Project Advisor

____
Andrew Walker, Senior Project Advisor

____
Monica Perrone, Senior Project Advisor

____
Mark Francis, Faculty Senior Project Professor

By
Castiel Armanda Shepp
June 2010

Abstract

The tensions between the vineyard and the residential garden inspired me to research in depth the interactions of these elements, in particular the toxic effects of one upon the other. This project explores how these elements can be conceptualized into a thoughtful and creative landscape design by using a site-specific example. It is essential to consider the science behind the design when developing a space. My goal is to present landscape architecture with a different way of viewing the landscape. I will show how designing with a scientific approach, and integrating the natural elements thoughtfully over the landscape can create a functional and beautiful space. This project expresses my strong desire to present the science behind landscape design in an artistic manner.

Biographical Sketch

Castiel Armanda Shepp was born in Napa, California in 1988. As the eldest of two daughters, her artistic and loving parents encouraged imagination, adventure, open-mindedness, and a love of the arts whenever possible. Her life has been shaped by her rich childhood and freedom of exploration in education, sport, culture, and travel. She graduated from Napa High School in 2006, and began her life at the University of California, Davis, as a freshman studying Design.

After only one class in Landscape Architecture, she knew it would take her places, and she applied in her second year and was accepted. Landscape Architecture has proven to be the perfect combination of art, science, and the great outdoors. During Castiel's fourth year at Davis, she studied for a semester, Landscape Architecture and Urban Planning and Design at the University of Melbourne in Australia for a semester. Immediately after, she returned to Davis, to share her experiences with fellow students, and plans to attend graduate school abroad for a Masters in Landscape Architecture and Sustainable Planning.

Dedication

To my parents, Alan and Diane Shepp for providing everlasting love and inspiration, and for supporting me through every step of this adventure called life.

Acknowledgements

I would like to thank Heath Schenker, a professor and the faculty head of the Landscape Architecture Department at the University of California, Davis, for providing guidance and support throughout this project, and also for her constant support and encouragement throughout my experience at UC Davis. Many thanks are owed to Andrew Walker for giving me valuable advice and guidance throughout my project, as well as Monica Perrone for her creative influence and fresh, clear inspiration in both studio and this project. Thank you to my dear friend, Robin Brown-Ward, for being the helping hand and strong shoulder that supported me through to the end.

And a big thank you to all my fellow Landscape Architecture students. The past four years of critiques, marker-stained hands, last-minute prints, and late nights sleeping in studio will forever be experiences shared with you all that I will never forget. We are all a select group who can fully appreciate the time and effort it takes to do what we do, and how much we must love it to push through the 4am lull, and accomplish even the most challenging of projects. Luck and happiness to all of you. I look forward to the moments we will share together in the future.

i.1 - Farmer Fertilizing

All photographs and illustrations are by Castiel Shepp unless otherwise noted.

Introduction

The primary purpose of my project is to investigate the effects of the viticulture industry on surrounding residential gardens and to shed light on possible mitigation plans and design solutions to deal with sulfur pollution associated with this industry. The primary objective of this project is to research and analyze the effects on residential gardens from various substances used on vineyards, in particular sulfur. From this research I have developed multiple design solutions, and applied them to a one-acre residential site in the Napa Valley. This is an investigation into how the average homeowner can most effectively design their garden to account for agricultural runoff and overspray associated with viticulture.

Artist's Vision

This project bears significance in the practice of landscape architecture because it investigates a unique design constraint that relates to residential gardens located adjacent to vineyards that are affected by fungicidal sulfur drift via wind circulation. My vision for this project is influenced by natural movement, functional space, and artistic discovery. I intend to take a scientific approach to design, and to implement pollution mitigation practices for the site in an attractive, artistic manner.

Project Location

The design and some onsite research took place on a one-acre parcel in the Napa Valley at the Shepp residence. The vineyard, which borders the southwest side of the parcel is owned and operated by a large winery in the Napa Valley.

1.1 - Context Map

Site Context

1.2 - Fence Between Properties

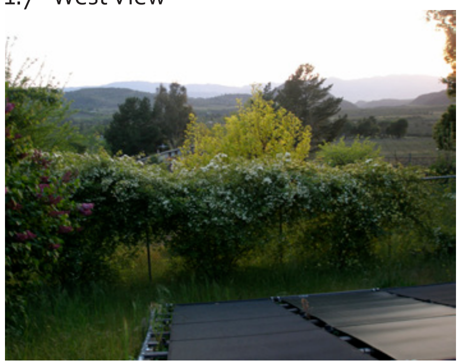
1.3 - Grape Arbor and Pool House

1.4 - Southeast Corner

1.6 - Informal Lawn Area

1.5 - Informal Stone Wall

1.7 - West View



1.8 - Fruit Tree Orchard

i. Viticulture: the science, study, and cultivation of grape vines or a vineyard (USDA, 2010)

ii. Agricultural Runoff: the drainage away from the surface of an agricultural site that contains water and substances such as chemicals and pesticides used on the site (USDA, 2010)

iii. Point source pollution: runoff that contains manmade contaminants such as pesticides or insecticides, that occurs on surfaces that are identifiable, such as a vineyard or agricultural site (EPA, 2008)

iv. Toxicity: the degree to which a substance is able to damage an exposed organism, such as a plant (EPA, 2008)

v. Phytotoxicity: Harmful or lethal to plants, a degree to which a chemical or other compound is toxic to plants. (Phytotoxicity, 2010)

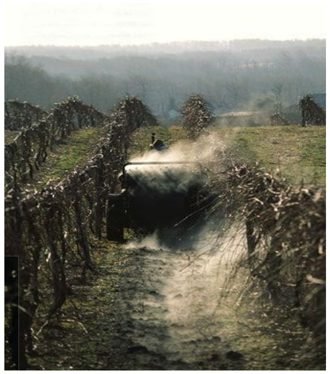
vi. Chlorophyll: molecule that absorbs sunlight and uses its energy to synthesize carbohydrates from carbon dioxide and water. This process is known as *photosynthesis* and is the basis for sustaining the life process of all plants. (Rull, 2003).

Why Sulfur?

Fungicides are used where disease-promoting conditions cannot be avoided and where crop species are highly susceptible. Fungicides can only protect infection of healthy plants, and are not useful on already infected crops (Subhash, teal). They can cause phytotoxicity, discoloring of plant material, or a stunting of growth under certain conditions. Among the pesticides used in the viticulture industry, sulfur is the most common and highly used fungicide in the United States ().

Purpose of Sulfur

Sulfur is a natural element found in the soil and plant systems. It has been used as a fungicide for decades, and is registered for pesticide use in the United States (EPA, 1991). Its primary use in viticulture is to control powdery mildew fungi on grape vines, which can damage or kill a vine.



2.1 - Fertilizing Grape Vineyards

Sulfur can be applied in a dust, granular, micronized, or liquid form. In its most popular form, dust, it is lightly shaken or sprayed from a container onto plants in the cool evening or early morning when the plants are moist with dew. In its micronized form, sulfur provides better coverage and is easier to handle. Pure sulfur is generally suspended in the air using heaters or vaporizing devices called sulfur pots (Dreistadt, 2001). However, the use of vaporized sulfur has been questioned due to its detrimental atmospheric and health effects. As a wetable powder or liquid, the sulfur is finely ground and mixed with a wetting agent so it can readily disperse in water, and is then applied directly to the vine. Sulfur in its micronized form is diluted with water and then spread on the vine. Micronized and wetable sulfurs often provide the best coverage and are easier to handle than sulfur dust for the control of powdery mildew and pathogens (Dreistadt, 1994). Thorough plant coverage is needed for the sulfur to be effective. Repeated applications are generally necessary to prevent infection of new growth and to renew deposits removed by rain or irrigation (Dreistadt, 1994).

Lime Sulfur

Lime Sulfur is also used as a protectant dormant spray on deciduous plants, grape vines included. It has curative actions against pathogens, such as powdery mildew, but is also very phytotoxic to leaves, and the residue left on foliage can be ugly (Rennenberg, 1984). A study on photosynthetic activity in ornamental plants found a **reduction in photosynthetic activity** after the plants were subjected to lime sulfur applications at higher temperatures. (Torgeson, 1969)

Toxicity of Sulfur

Sulfur is of low toxicity, and poses very little risk to human and animal health, however short-term studies have shown that sulfur can cause eye irritation, dermal toxicity, and inhalation of large amounts of the dust form can cause asthma and respiratory problems. (EPA, 1991) As a common atmospheric pollutant that is a by-product from the combustion of fossil fuels, it seems an excess of sulfur in the atmosphere would be detrimental to all living organisms. (Hawkesford, 2007) **Extended sulfur exposure to plants can be deadly.** Sulfur can be partially processed by plants via sulfate assimilation, but this causes oxidative stress and possible cell death. Cysteine content, which can be lethal in high doses, increases with sulfur dioxide fumigated plants. (Hawkesford, 2007) **Overall, sulfur has been found to effectively reduce the rate of photosynthesis in plants, and proves to be highly phytotoxic.**

Phytotoxicity

The incorporation of sulfur in vegetation occurs through microbial reduction both in and on the plant. (Kidd, 1991) Sulfur is a component of the environment, and there is a natural cycle of oxidation and reduction that transforms sulfur into both organic and inorganic products. But when there is an excess of sulfur, it can cause phytotoxicity in plants. This can lead to **discoloration of plant material, burning or browning of leaves, dead foliage, stunting of growth, or death** (Phytotoxicity, 2007). The damage can also appear as distorted leaves, fruit flowers, or stems.

Phytotoxicity can be influenced by many different external, environmental, and biological factors. If sulfur is mixed with oil, the combination can become extremely phytotoxic. (Kidd, 1991) Environmental conditions such as the temperature, humidity, and light can increase phytotoxicity. Soil properties such as texture, temperature, moisture, microbial activity, and pH also influence phytotoxicity. Higher pH soils are less binding and increase it; where as high microbial activity can reduce it (Phytotoxicity, 2007). The condition of the plant at the time of sulfur application can also affect the level of toxicity, increasing it if the plant is young or sensitive.

Plants with Sulfur Sensitivity

Plant sensitivity, which has been the most frequently observed phytotoxic damage, occurs because not all plants can coexist with all chemicals. For example, sulfur is toxic to viburnum, maples, and many species of fern. And when mixed or applied with horticultural oils, it can harm tender new growth and foliage of sensitive species such as mountain ash, beech and birch (Grounds Maintenance, 2008). Injury has also been reported on apricots, raspberries, cucurbits, and certain other "sulfur-shy" plants, particularly delicate ornamentals. (Thomson, 1993)

The effectiveness of all sulfur fungicides increases with an increase in temperature, but when applied to the vine in temperatures exceeding 83 degrees Fahrenheit, the toxic effects rise exponentially as temperature rises (Dreistadt, 1984). A study done on grape vines found that reduced photosynthetic activity resulting from lime sulfur application was much more marked at high temperatures (Torgeson, 1969). Although, some plants can be effected at lower temperatures as well, such as shade-loving plants. In a study conducted on oleanders, sulfur toxicity increase due to heat was shown by yellow to brown dying leaf margins, and more severe dieback and stunting of growth symptoms occurring in particular cultivars (Rennenberg, 1984).

Lichens absorb most of their mineral nutrients from the air and rainfall, so pollution in the atmosphere can be very dangerous to lichens because they can retain and accumulate deadly amounts of sulfur and ozone (Santis, 1999). **Sulfur dioxide is especially lethal to lichens because it lowers pH and deteriorates chlorophyll, which causes photosynthesis to stop**. In a study done by the American Bryological and Lichenological Society, four different kinds of lichens were subject to sulfur dioxide fumigation for four hours at a time at different levels to determine the effects on photosynthesis, respiration, and chlorophyll content. Respiratory rates dropped, and photosynthesis decreased after fumigation at the lower levels, but significantly decreased after fumigation at high levels (Beekley, 1981).

Mitigation for Detoxifying Plants

When a plant is suffering from phytotoxicity, there is a sudden change in the solute concentration around the cell. This change causes a lack of movement of water across the cell membrane, where high concentrations of salts or any solute accumulate, drawing water out of the cell and sending it into shock. (Ballbach, 2000) This is called osmotic shock, and can occur when a plant is subject to high amounts of sulfur toxicity. A plant can deal with this by increasing its amount of osmoprotectant molecules which help the organism survive osmotic stress. The molecules accumulate in cells and balance the osmotic (water) difference between the cells surroundings. (Ballbach, 2000)

There are a few mitigation practices that can be taken to reduce the toxic effects. For example, the application of a **proline solution** directly on the plant reduces the sulfur dioxide phytotoxicity. Proline is an amino acid, and osmoprotectant, and is used in many biotechnological applications. (Ballbach, 2000) The benefits of proline were proven in a study done on poplar leaves that were phytotoxic, and treated with proline solution. **The degradation of chlorophyll was smaller, and visible injury of the leaves was less apparent.** (Olson, 1992)

Plants also deal with excess amounts of sulfur pollution through the release of hydrogen sulfide through leaves when exposed to sunlight. (Olson, 1992) This explains why most shade-loving plants are succeptible to sulfur phytotoxicity because they are not exposed to enough light.

Alternatives for Sulfur

The protection sulfur provides from powdery mildew for grape vines is necessary for a healthy vineyard. But there are alternatives for sulfur in viticulture. There are pros and cons to each, but most importantly the detrimental effects of toxic exposure are less then those of sulfur.

2.2 - Low Angle of Farmer Fertilizing

Bordeaux mixture is one of the oldest copper formulas used as a fungicide. It is a combination of bluestone and lime that must be mixed in a particular way and used promptly after preparation. Bordeaux mixture can persist through extensive rain- making it an excellent choice for fungi control in California from fall through spring. (Rennenberg, 1984) It adheres well to plants, but can color sprayed plants blue and may discolor painted surfaces. If applied in hot weather or immediately before rainfall, it may cause leaves to yellow and drop prematurely. But if the mixture is diluted, risks of phytotoxicity greatly decrease.

Copper fungicides have been used instead of sulfur for the control of powdery mildew. They resist weather because they are only slightly soluble in water, have an ionic attraction to plant surfaces, and are ideal to use when tender plant parts are present. However, some particles must be dissolved to be effective, and this copper can damage plants, especially during cool, wet spring weather. (Rennenberg, 1984) Fixed coppers are formulated to minimize the amount of copper that dissolves in an application mixture, only releasing tiny amounts needed to prevent infection by fungi. (Rennenberg, 1984) This process reduces the risk of phytotoxicity from overexposing plants to copper.

Sustainable Sulfur Replacements

There are many fungicides now that are designed to meet integrated pest management as well as reduce environmental loading. Sulfur has highly toxic risks, while these new products significantly reduce the toxic effects reflected in plants. Emerald BioAgriculutre's AuxoGro WP[R] (wettable powder) was registered by the EPA in 1998. The product uses naturally occurring amino acids to boost growth by facilitating the uptake and utilization of nutrients. (Firstenfeld, 2003) Johnson calls the product, **"an environmentally responsible technology for increasing the growth, yield, quality and disease resistance"** of crops, with little or no toxicity. **Many of the sulfur replacements have a very low environmental impact.** Syngenta Crop Protection, in Greensboro, NC, has a variety of fungicides, including Abound[R] which when tested against sulfur, returned significantly lower toxicity levels.

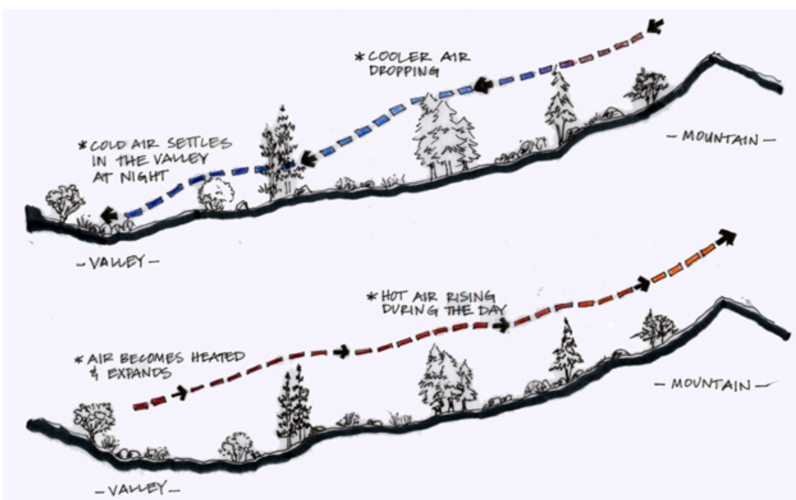
Other developers are using the concept of **preventing diseases in viticulture through nutrition.** Agro-K Coroporation in Minneapolis has two calcium-based products that have been shown to have disease management properties. "Vigor-Cal[TM] works well in managing powdery mildew" and has performed well in test plot trials at UC Davis, according to Agro-K vice president Chapman Mayo and UC Extension Farm Advisor, Roger Duncan. (Firstenfeld, 2003) Vigor-Cal-Phos[TM], a formulation of phosphite materials works to manage downy mildew. "Independent trial data compiled in South Africa showed that Vigor-Cal-Phos was as effective as the standard fungicide regime," states Mayo. These two products increase the calcium levels in the vine plant tissue and increase the thickness of the cell wall. These two improvements provide vines with a stronger defense against fungi, and also prevent the grapes from splitting, minimizing rot. (Firstenfeld, 2003)

The nutrient-based products that these companies are producing offer the **potential for better quality wine as well.** AuxiGro, which is registered for the control of powdery mildew, also increases Brix in grapes. An independent study done in South Africa treated plots with Agro-K and compared them to untreated plots. "Grapes were harvested and kept separate through the entire winemaking process." "The wines were analyzed for quality components and put through a blind taste panel. Agro-K-treated grapes were judged to produce better quality wines." (Firstenfeld, 2003)

1) Wind Circulation Patterns

General movement of wind through a space

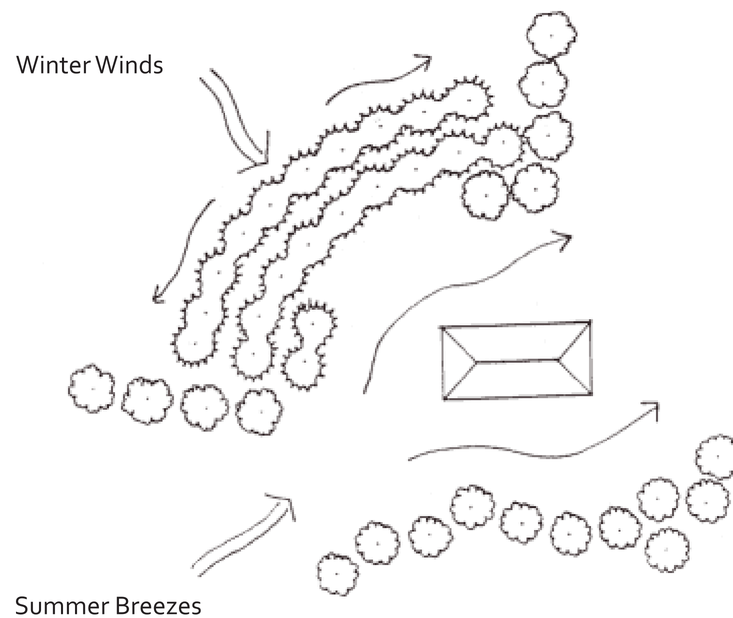
Wind patterns are influenced by many factors, including temperature, elevation, texture, seasons, and time of day, geography, and pollution. The diurnal heating and cooling of land near an ocean, for example causes air to blow toward the relatively warmer land during the day (sea breeze), and toward the relatively warmer water at night (land breeze). (Columbia, 2007) Similar diurnal changes can occur on mountain slopes, where the air in the valley becomes heated and expands so that it moves up the slope in the daytime, and at night the cold air settles into the warmer valley.



2.3 - Diurnal Wind Patterns

The location of the one-acre parcel is on a mountain, and during the early morning, breezes from the Napa Valley blow uphill (east) toward the property, and in the evening, breezes blow downhill (west) over and away from the property.

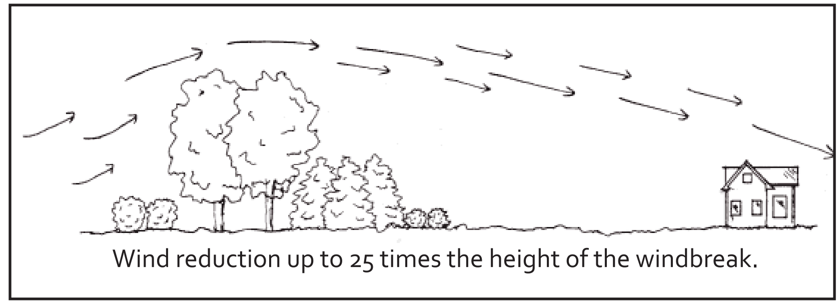
Inland areas are less susceptible to strong changes in gusts of winds, but if there are significant elevation changes, then the wind will tend to be pushed around faster. During the summer, lighter breezes tend to come from the southeast, and during the winter months stronger winds blow from the north. This is why most wind barriers are perpendicular to the north winds, and often times direct the summer breezes in.



2.4 - Directional Wind Barrier

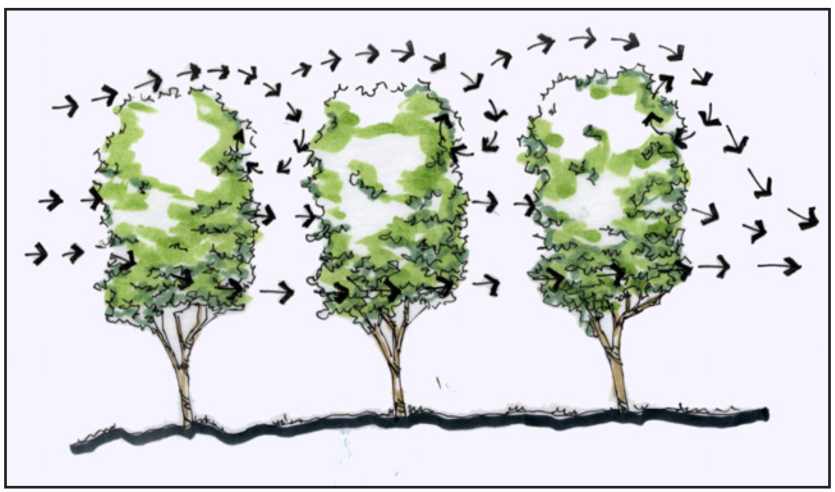
Wind Patterns Against Structures

When wind blows perpendicular to a row of buildings, for example, the windward side is exposed to strong gusts, while the leeward side is in an aerodynamic shadow. (Wypych, 2003) Local eddies are created on the leeward side of the rows, and the size of the eddy will increase with the height of the building. And by decreasing the distances between the blocks of buildings, the wind speed can be reduced up to 50%. (Wypych, 2003)



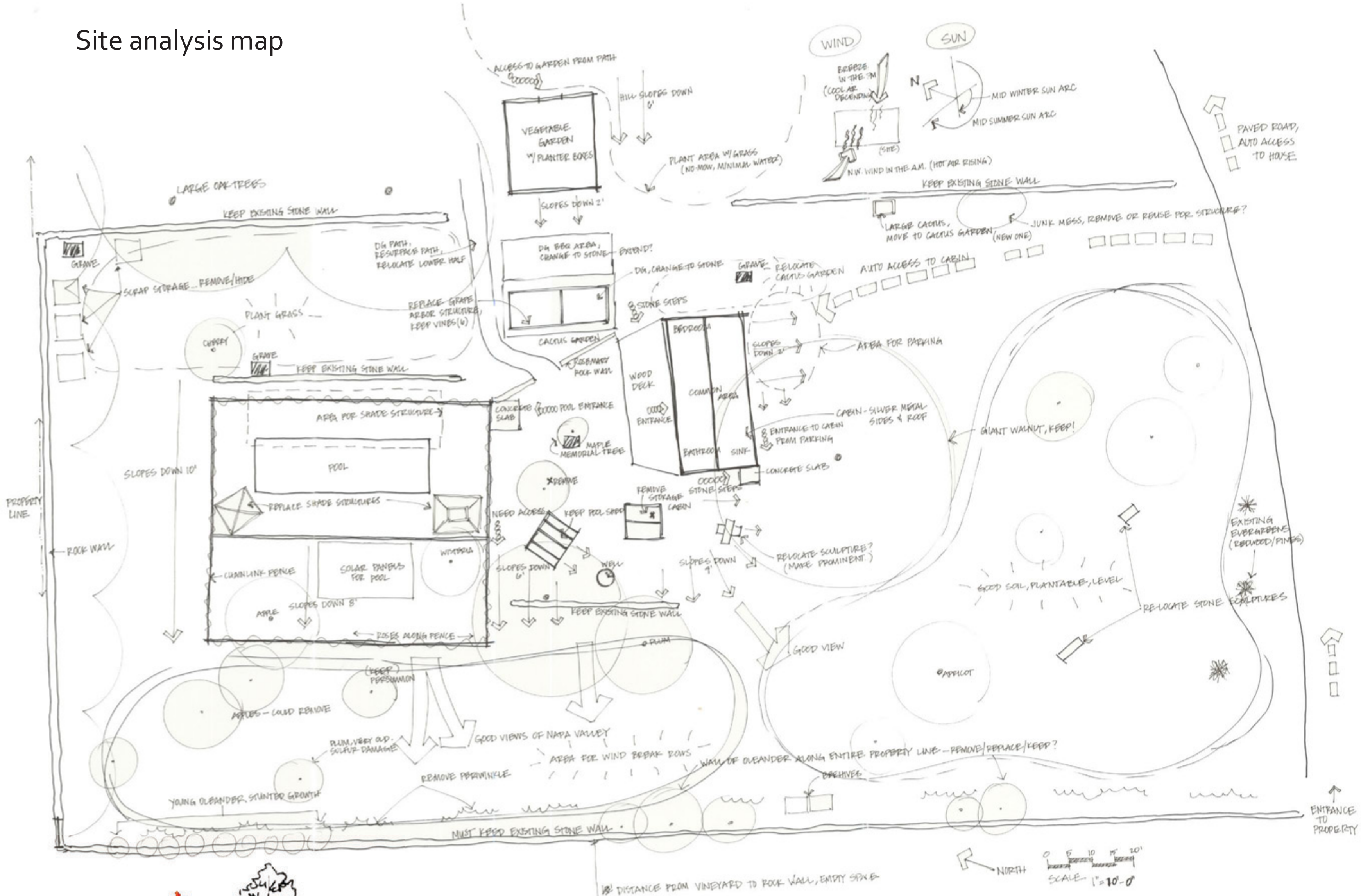
2.6 - Wind Reduction Wind Break

So wind moves up and around buildings, but a windbreak that allows 50-60% of the wind to penetrate, such as evergreen trees, is a much better solution than a solid barrier because it creates a larger area of protection on the downwind side. (Slusher, 1997) As far as vegetative wind barriers, the most efficient should consist of at least one row of dense evergreen trees whose branches reach the ground. The rows should be planted perpendicular to the wind direction, in most cases running to the north and west of the area to be sheltered.



2.5 - Air Streams around Trees

Site analysis map



3.1 - Site Analysis Map

Existing Conditions

The southwest parts of the site are relatively flat, while at the center it begins to gradually slope up to the northeast about ten feet. The building on site is under renovation to become a pool house.

There are seven old rock walls on the site that used to define property lines and orchards. The three rock walls near the center of the site will be removed or replaced. There are four resting places on the site: one memorial tree dedicated to the grandmother, two pet cat graves, and one recent pet dog grave, all of which will remain. There are three stone sculptures that can be moved to new locations within the site.

The current irrigation system is rigged for drip lines, which can be used for the fruit trees and wind barrier vegetation. There are also septic lines running along the western border and east through the site towards the house.

Vegetation

Identifying Damaged Plants

Determining the cause, pathogen, or disease on a landscape ornamental can be baffling. The first thing that must be done is to determine the general cause of the symptoms. If symptoms are present, such as pathogens, environmental factors, phytotoxicity, nematodes or insect pests, then it is relatively easy to determine the source. (Grounds Maintenance, 2008)

For this particular site, the most obvious causes are the pollutants used on the adjacent vineyard, in particular sulfur, which is most commonly used and causes phytotoxicity. Moving from the vineyard onto the property, the oleanders, which currently provide a low vegetative barrier, have signs of phytotoxicity, especially on specific cultivars. There is yellowing of leaf margins, and many of the oleanders seem to have stunted growth, considering they were all planted at the same time, and all receive the same care and water. Moving further into the property, a few of the much older apricot trees show distortion of fruits and leaves, which according to the Ministry of Agriculture is an effect of phytotoxic damage. There are a few shade-loving ornamentals beneath larger trees that show browning of the leaf margins, and even have a thin, grimy layer coating the leaves. Vegetables too are also very sensitive to sulfur phytotoxicity. And as noted by the residents, along the outside of the lower, westward-vineyard facing chain link fence surrounding the pool, there was an attempt to grow vegetables, in particular beans, which survived for the first couple years, but quickly began to dieback and did not produce beans.

What to keep and what to take out

The oleanders will be removed, and replaced with a larger, more effective vegetated barrier. The affected apricots are old and still fairly beautiful, and the residents would prefer they remain. They will be treated with a phototoxic mitigation application, possibly proline solution, and routinely checked for improvements. The vegetables have already been relocated to the large vegetable garden further up the slope behind the pool, much further from the vineyard, and will remain there. The damaged ornamentals were mainly shade loving plants, and will be removed and replaced with hardy, drought tolerant, sun-loving perennials.

Wind and Time

Currently, the wind blows up hill during the morning, and downhill in the evening. And strong winter winds blow from the north, and softer spring and summer breezes blow from the southeast. After interviewing the vineyard manager in charge of the grapes bordering the site, he stated that they spray at dawn or dusk sulfur application, it just depends on the weather. A few of the vineyard workers mentioned that they prefer spraying in the morning when it is cool and damp, instead of having to stay up past midnight. Spraying in the morning allows the sulfur to drift on the wind, which is rising uphill. At dusk the wind is blowing downhill, away from the site, and would be the ideal time to spray, but the manager doesn't send his crew out to spray until 10pm or later, when most of the wind has cooled and dropped into the valley already, allowing the sulfur to drift with no dominating wind movement.

Mitigation Practices

Sulfur phytotoxicity affects many aspects of design. The placement of vegetation, the application of products, pruning, and the plant palette are all decided by the level of sulfur phytotoxicity mitigation. In this case, most of the plants effected will be either removed or replaced, with a few undergoing treatment.

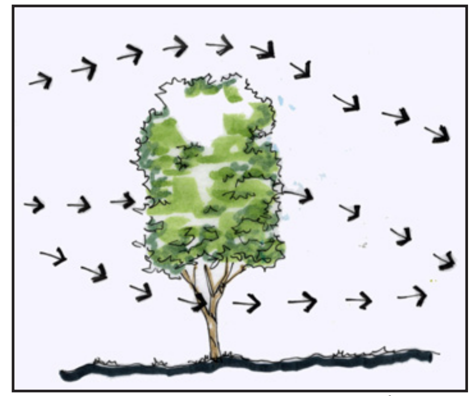
A safe distance from other plants must be maintained around plants that will be **treated for sulfur phytotoxicity**, such as existing apricots, to ensure no adverse effects on healthy plants. When seasonally pruning, **safe pruning practices** must be followed to ensure no further spread of toxins. These include cleaning the pruning tools before and after use, and clearing all pruned waste away.

In order to avoid phytotoxicity, the majority of new **plants will be in full sun** for the release of excess sulfur dioxide. The plant palette must consist of plants able to cope with excess sulfur exposure. The plants must also be deer resistant, drought tolerant, low maintenance, meet the wind formation needs of the site, and of course be aesthetically pleasing.

How wind will determine vegetation

Building size and arrangement in cities provides a similar environment for the types of wind patterns that would benefit the site, and therefore was a model for determining the types of species necessary to provide similar wind patterns.

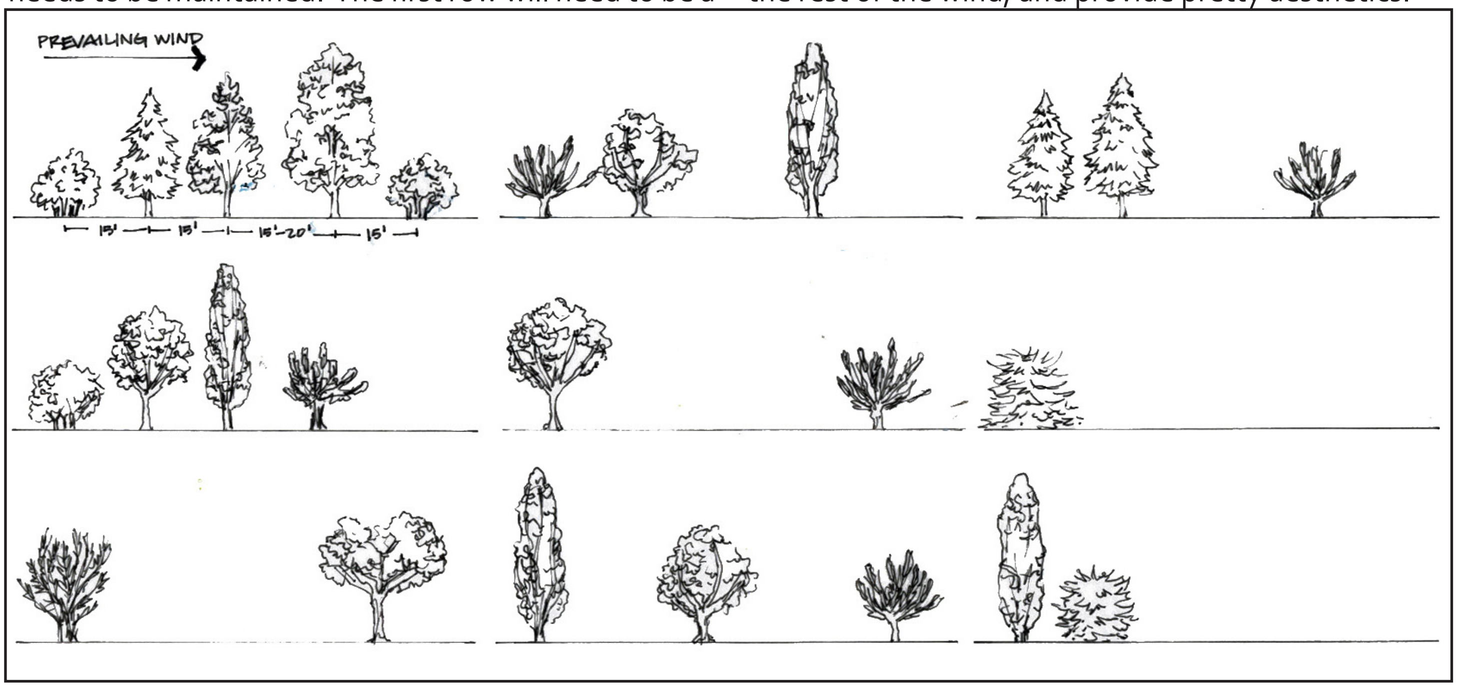
When wind hits a high building, the air stream divides. A part moves upward and the rest goes around. This causes an increase in the wind speed at the corners of the building. Lower buildings in the area are hit with higher wind speeds.



3.2 - Air Stream around a Tree

The wind barrier will need rows of high vegetation to keep the wind moving to particular areas of the site, and rows of low vegetation to slow down the wind upfront.

The ability of a tree planting to provide protection depends on the sum of all tree and shrub foliage making up windbreak height, density, and longevity. (Slusher, 1997) It is best to have about five rows of vegetation to create the optimal barrier, but with this site, there is not enough space. Rows have about 15 feet between themselves for optimal wind circulation movement. (Slusher, 1997) In this particular site, there is room for barely four rows, but to maintain functional space, three rows will suffice. Ideally, the first row would be a tall, dense evergreen stacked close together. But for this site, the view needs to be maintained. The first row will need to be a medium to large evergreen. The next row should have lower, more densely packed shrubs to catch the intensified winds blow down and around the larger trees. A medium deciduous tree or evergreen shrub will suffice. The third row allows for an eddy and room for the wind to settle. The wind that 'hops' over the larger front row will drop into an eddy, where it will then drop even lower. It will then hit the third row, which will be higher than the second, but lower than the first, less dense, and more widely spaced. A tall to medium deciduous tree works best. The optional fourth row can be a flowering shrub that will slow the rest of the wind, and provide pretty aesthetics.



3.3 - Twelve Vegetative Wind Barrier Possibilities

How wind will determine vegetation patterns

In cities, wind tunnels are created when there are two rows of high buildings on either side of the street. (Wypych, 2003) This type of wind movement is something I aim to create, but direct towards areas of minimal gathering. Wide roads can also act as wind arteries, similarly would wide rows of large trees. **I plan to direct some of the wind along a row of trees and settle in the fruit orchard where the sulfur is actually beneficial for most of the trees.**

If there are rows of buildings, wind will 'hop' over each building, gaining speed as it rises, and loosing some speed when dropping into an eddy behind each building. Strong wind against an object can be detrimental, but having ventilation through the building helps airflow; as would a semi-pervious tree. As mentioned earlier, **a windbreak that permits at least half of the wind to penetrate is better than a solid barrier.**

3.4 - Air Stream Sketch

How wind will determine forms and materials

Wind damage, and in particular particulate sulfur damage to materials and people can ruin the design of a site. Types of sulfur used on vineyards can discolor and deteriorate certain materials such as precious metals, woods, and paint. Copper sulfide in particular leaves behind a bluish-green tinge on vegetation and materials, and if not cleaned, can stain. Ideally, and as requested by the client, all structures created will consist of types of metal. And all other structures not of metal should be stone. The only wood on site will be the existing new deck recently installed out front the pool house. The pool house is already made of glavanized steel, and will not be renovated.

The location of gathering spaces is also defined by wind. Ideally, gathering spaces should be located in the wind-shadows created by vegetation barriers. But these areas will be at a low elevation in relation to the wind barriers, and the views outward from the site will not be visible. **Gathering spaces will need to be elevated to preserve the amazing views, as well as protected from the stronger winds.** The casual paths should be protected from the wind as well. The places for quicker passage can be subject to wind, and can double as wind tunnels.

Merging Art and Science

There exists a disconnect between science and the creative process. Even though they are thought of as two separate entities –and are often discussed as such –they have so much in common, and it is essential to consider the science behind the design when developing a space.

For this project, **wind is the connection between science and design**. The wind is what carries the sulfur across boundaries and distributes it onto the landscape. Without it, the problem at hand would not exist. Considering wind will not go away, the only choice is to work with the elements, and create a design that uses the wind in a functional, beautiful way.

The wind can be represented in more ways then just feeling it. The wind can be seen, heard, and imagined. The movement of wind is commonly represented with curves, twirls, spirals, and waves. These forms can be used to create pleasant and functional wind patterns and spaces. To represent the beautiful, irregular movement of wind, the integration of forms with irregular patterns will not only provide the foundation for directional movement of sulfur pollution along the wind, but will also represent the invisible forms of wind directly onto the landscape.

Design Content

In order to represent the wind, I have created beautiful forms through patterns of vegetation that move wind, move with the wind, and depict wind movement on the landscape. The spiral fruit orchard and the curving line of the almond trees represents the movement of wind when it hits an eddy, or the swirling power of a tornado.

More indirect representations of wind are found in the materials chosen for the site. The metal wine barrel rings that make up the ceilings to the grape arbors not only cast a beautiful shadow on the ground, but also represent the slicing of wind into different shapes and directions as it passes through the rings. There are also metal wind chimes hanging in the grape arbor, which alert the wind's presence.

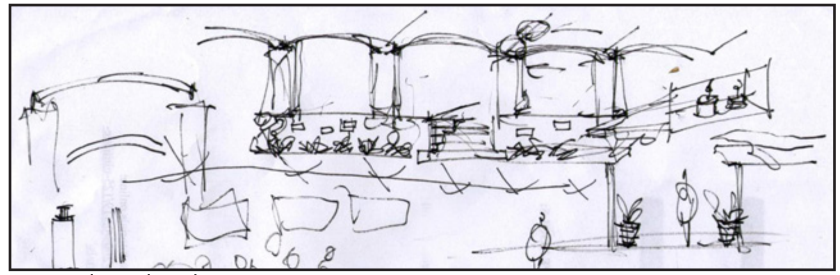
The gathering areas are determined by wind movement and views. The terraced patios above the pool are wind-sheltered because of their elevation, and have to be higher to preserve the views over the vegetative barrier. Versus the areas for passing through are located at lower levels, and often double as wind tunnels and intersections with eddies.

Materials

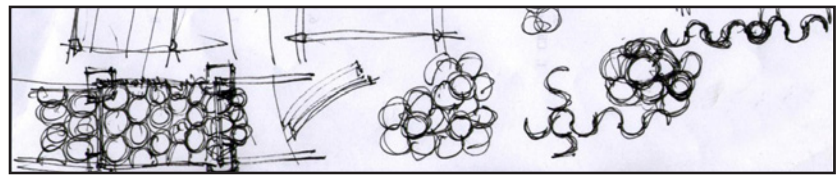
Stone is the most common material used in the design. A few of the existing, informal stonewalls remain, along with new formal stonewalls. There are also large boulders scattered throughout the site to maintain a rustic atmosphere. All of the rock and stone used on the site was collected from the site, or from surrounding acreage.

Metal will replace any wood structures, and will be used as the primary material. The client not only declined the use of wood, but it is also higher maintenance and subject to harsh weathering and rot. Metal wine barrel rings are to be collected from neighboring vineyards in the Napa Valley, and recycled into structural forms.

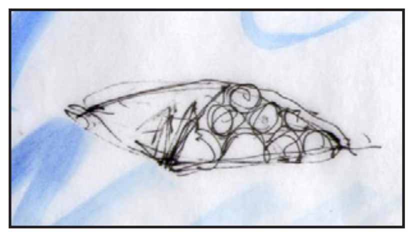
4.1 - Sone Column with Incorporated Metal Wine Barrel Rings



4.2 - Arbor Sketch



4.3 - Arbor Ring Sketch



4.4 - Arbor Metal Wine Barrel Ring

The rings will be in both the arbor ceilings and the stone columns supporting the arbor. The metal will not be treated, and will rust naturally.

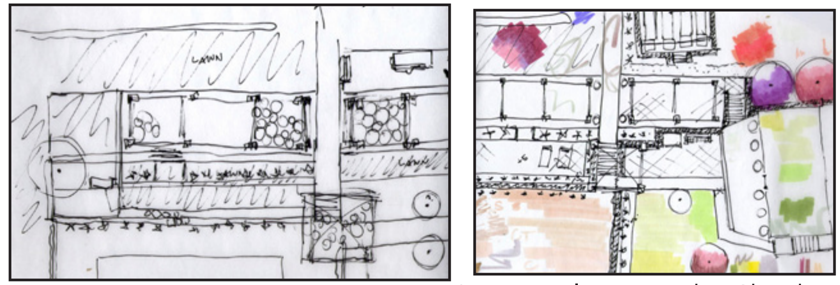
The pool house on site currently is sheathed in galvanized steel, and will remain untouched. No paint will be used on the building or at the site because paint can be easily damaged by sulfur.

Sketches

For increased shade and weather protection, thick canvas canopies in the shape of triangles can be erected over the arbors. The advantages of canvas include reduced light transmittance, heat absorption, and transfer of heat which ideal for the California Mediterranean climate.

The informal paths in the orchard will remain dirt instead of gravel. There is no need to formalize the paths being that they will not be highly utilized except during the harvest.

4.5 - Spiral Fruit Orchard Sketch



4.6 / 4.7 - Preliminary Arbor Sketches


4.8 / 4.9 - Conceptual Arbor Sketches

Plant List

Most of the plants chosen for the site are native to California, in particular Sunset Zone 14, and are non-invasive. They were primarily chosen for their resistance to sulfur toxicity and functionality. The plants compliment the existing vegetation, and provide vibrant colors throughout the year. Plants were chosen to be tolerant of both moist and dry conditions, and require little water during the hot summer months. Plants that are also deer resistant, low maintenance, and provide aesthetic intrigue were also chosen.

Note: Scientific names not noted unless specific species distinction is necessary.

Larger Trees:
- American Sweet Gum
- Cedar
- Douglas Fir
- Italian Cypress

Medium Trees:
- Almond
- Apple
- Apricot
- Nectarine
- Olive, Olea europaea
- Peach
- Plum
- Sweet Mazzard Cherry

Smaller Trees and Shrubs:
- Butterfly Bush
- Flowering Pomegranate
- Lavender
- Persimmon (Japanese)
- Plume Cryptomeria, 'Elegans'
- Pride of Madeira

Small plants and Grasses:
- Agapanthus
- Autumn Sage, Salvia greggii 'Alba'
- Blue Fescue, 'Elijah Blue'
- Breath of Heaven, 'Sunset Gold'
- California Poppy
- Calla
- Century Plant
- Chinese Wisteria
- Coreopsis grandiflora
- Deer Grass
- Fortnight lily
- New Zealand Flax

Master Plan Context

The master plan draws from the surrounding context as well as the artistic nature of the residents.

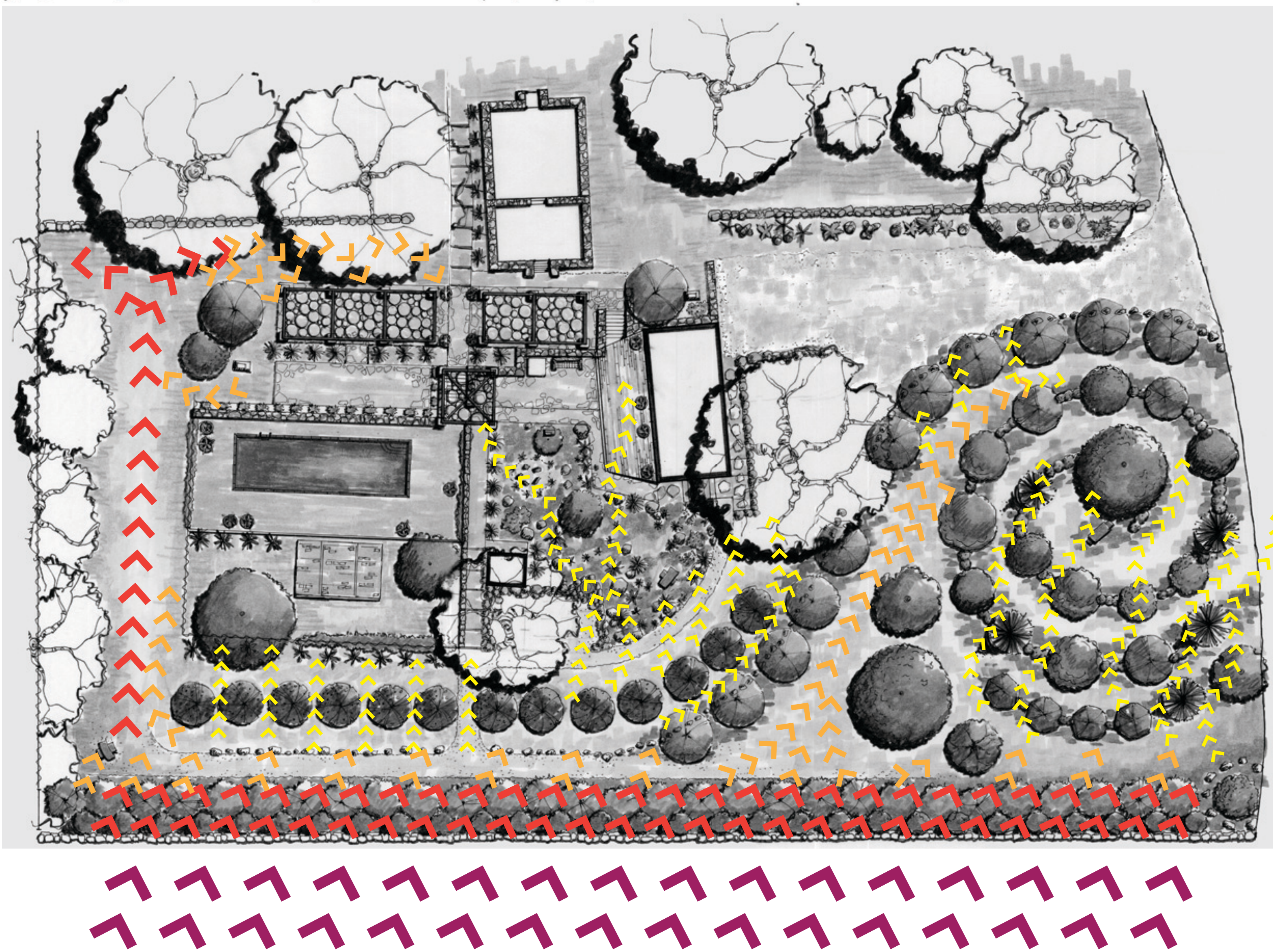
5.1 - Master Plan Context

Master Plan

The following images represent the product of my extensive research of art-meets-science design approach.

From left: pool and grape arbor, stone patio, vegetable garden, terraced informal planting on slope, pool house, cactus garden, almond curve, spiral fruit orchard. Vegetative barrier: cypress, cryptomeria, almond, olive, flowering shrubs. Original at: 1″=10′-0″

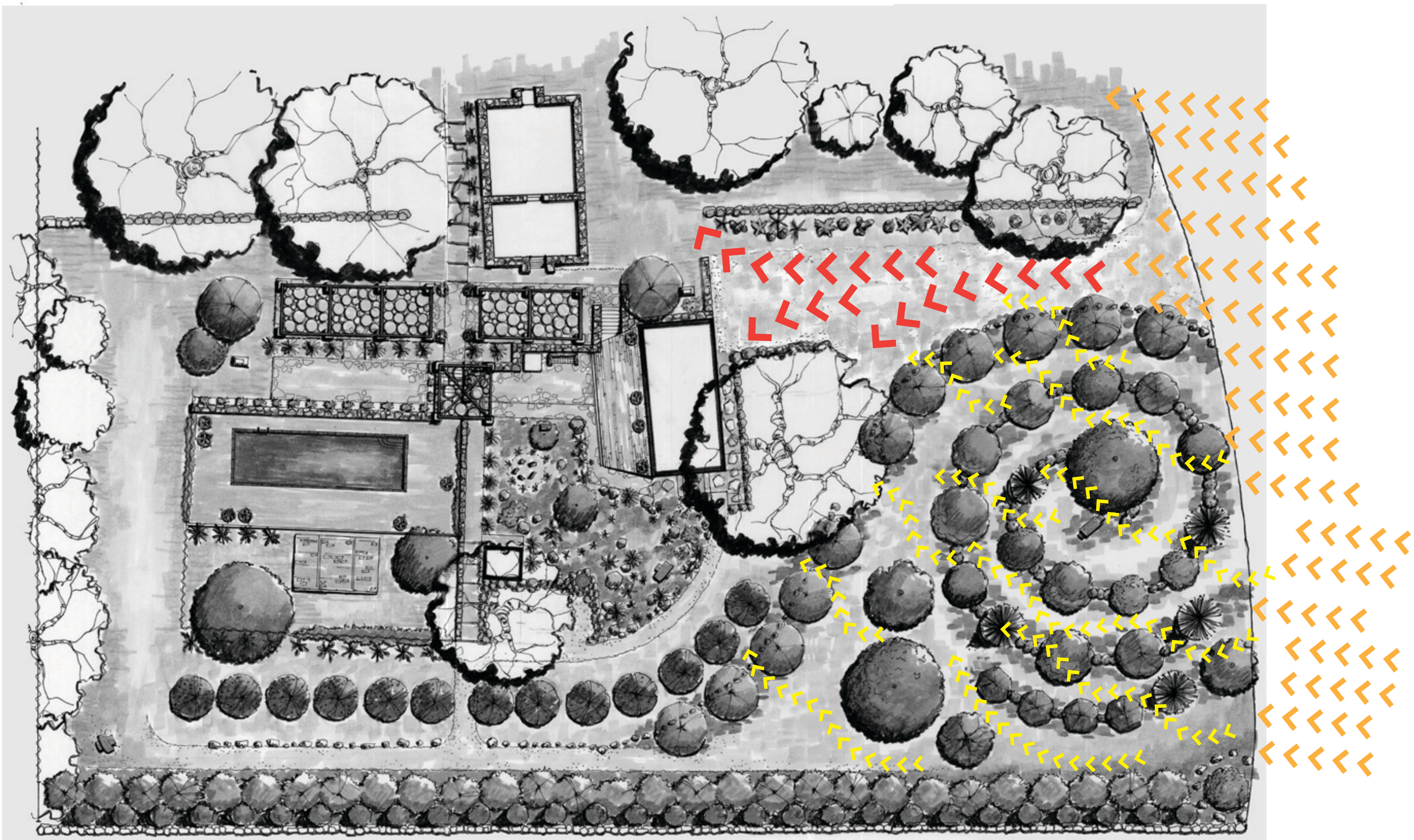
Master Plan -Wind Patterns- Sulfur Drift



The strong winds from the southwest blow the excess sulfur through the vegetative barrier, dissipating both the volume of pollutant as well as the wind speed. As the wind moves further through the site, it is filtered through many different areas of vegetation.

5.3 - Master Plan -Sulfur Drift

Master Plan -Wind Patterns- Summer breezes

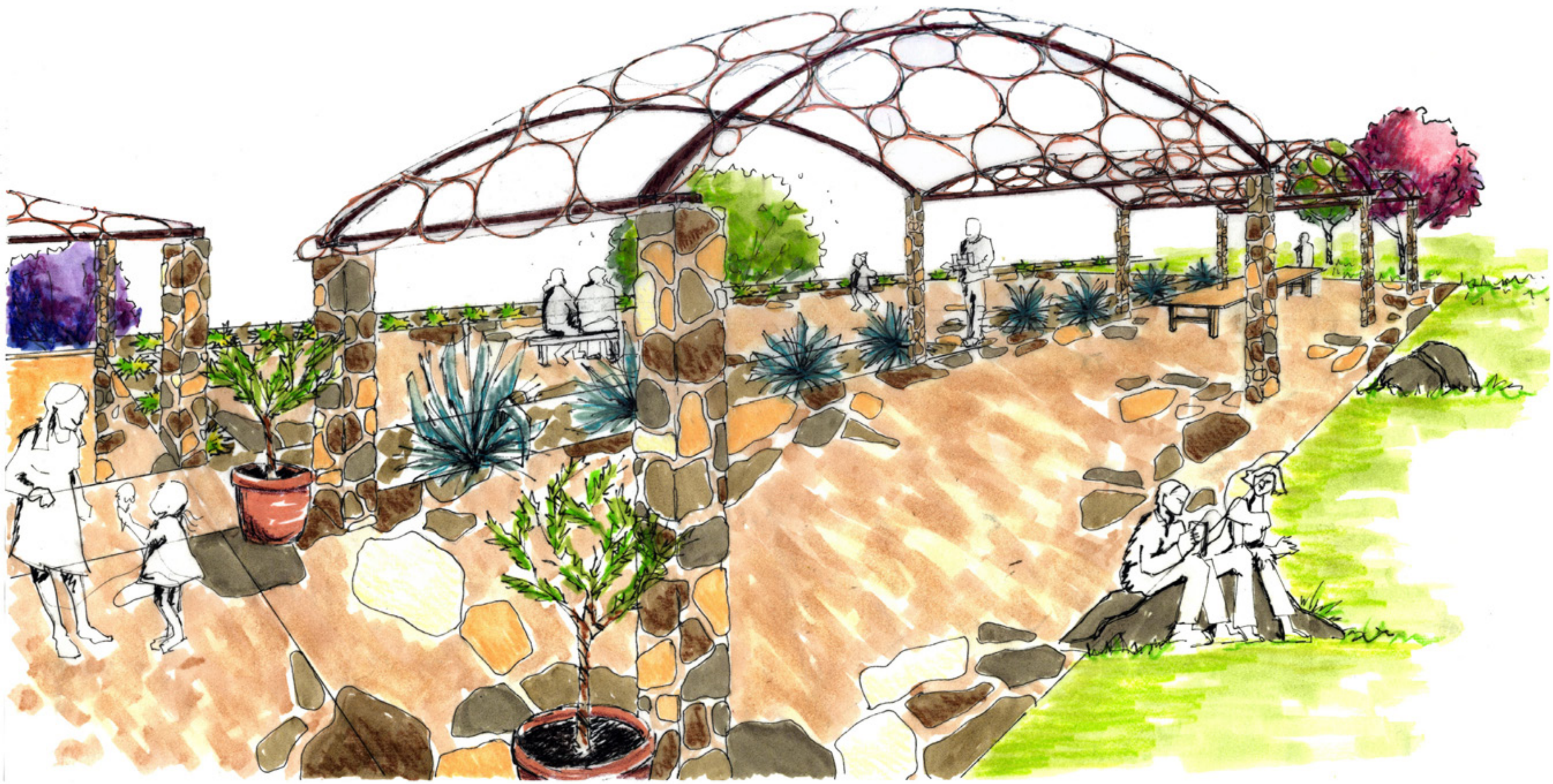


The softer summer breezes blowing from the south are not met with a barrier. Instead they are funneled into the site, toward the pool house and gathering areas.

Pool House Drive Way Perspective

From the driveway, the main entrance to the pool house is from the top southeastern corner. This is a view looking northwest from the corner. On the right is the relocated cactus garden, and on the left is the top of the spiral fruit orchard lined with almond trees.

Grape Arbor and Picnic Area Perspective



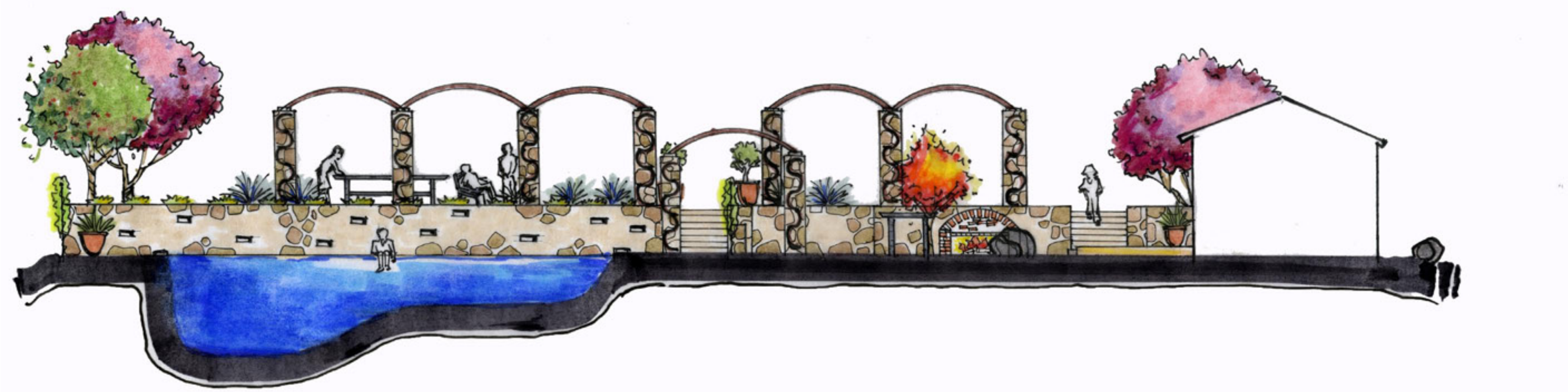
The grape arbor is built from recycled wine barrel rings, welded together and held up by stone columns. This lounge area is a stone patio, five feet above the pool deck, with stairs leading down to the entrance. The patio faces west toward the pool with a gorgeous view of the acre site and the Napa Valley.

5.6 - Grape Arbor Perspective

Pool Entrance Perspective

This solo arbor is the destination point that can be seen from the house. It too is made of recycled wine barrel rings. There is a stone patio connecting the pool house to the pool and a barbeque area. A chain link fence is required around the perimeter of the pool, but is partially hidden by a stone seat wall.

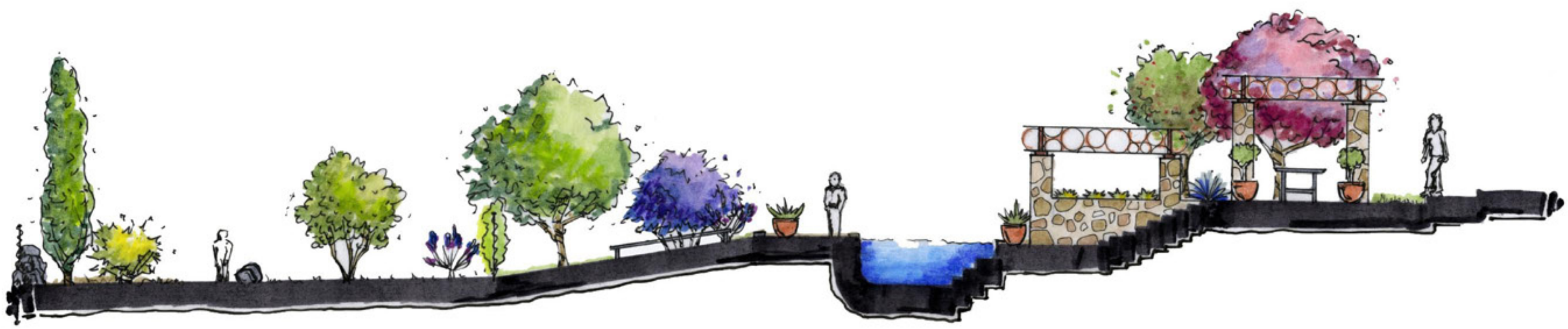
Grape Arbor



Section looking north from the pool deck toward the grape arbor. The stone wall bordering the pool contains inlets for candles, and between the pool and poolhouse is a barbeque firepit and outdoor cooking area.

5.8 - Grape Arbor Section

Property Width through Pool



Section looking northwest through the width of the site. From left, a stone wall, cypress trees, cryptomeria shrubs, informal pathway, olive trees, flowering shrubs, and pool perimeter fence. From right, terraces stone patios with arbors and stairs leading to pool.

5.9 - Property Width Section

Verification of Results

When the design process of this project progresses, and the project is implemented, I plan to follow the development of the site, and hopefully verify my conclusions about wind patterns, sulfur drift, and sulfur toxicity mitigation.

Conclusion

Even though there is no set plan to implement this project, the progression of my design process will continue throughout my professional career. This project has created a solid base for the creative action between science and design that I will be able to build from to continue creating sustainable, beautiful designs.

My intent for this project was to uncover a deeper meaning behind the way I move through the design process. I sincerely believe that I have strengthened this meaning, and brought my approach to landscape architecture to a new collaborative level.

References

Abelli-Amen, Bruce, and Eric Parfrey. "Survey of Land Use Conflicts Associated with Vineyards and Pesticide Use." *Environmental Monitor* (2002): 11-14. Print.

Adedipe, N. O., and R. F. Barrett. "Phytotoxicity and Growth Responses of Ornamental Bedding Plants to Ozone and Sulfur Dioxide." *Ti:Journal of the American Society for Horticultural Science* 97.3 (1972): 341-45. Print.

Beekley, Pamela K., and George R. Hoffman. "Effects of Sulfur Dioxide Fumigation on Photosynthesis, Respiration, and Chlorophyll Content of Selected Lichens." *The Bryologist* 84.3 (1981): 379-89. Print.

Costello, Laurence R. *Abiotic Disorders of Landscape Plants: A Diagnostic Guide*. Regents of the University California, 2003. Print.

"Diseases of Ornamentals & Turf | With Luck, You Can Diagnose the Cause Using Plant Symptoms, Site History and Reference Material." *Grounds Maintenance | How to Care for Your Lawn, Landscape, Turf, Grass*. 2010. Web. 03 May 2010. <http://grounds-mag.com/mag/chapter_14_disease_ornamentals_turf/index.html>.

Dreistadt, Steve H. "Diseases." *Integrated Pest Management for Floriculture and Nurseries*. Oakland, Calif.: University of California, Statewide Integrated Pest Management Project, Division of Agriculture and Natural Resources, 2001. 92-93. Print.

Dreistadt, Steve H., Jack Kelly. Clark, and Mary Louise Flint. "Diseases." *Pests of Landscape Trees and Shrubs: an Integrated Pest Management Guide*. Oakland, Calif.: University of California, Division of Agriculture and Natural Resources, 1994. 218-20. Print.

Firstenfeld, Jane. "Which cide are you on? Vineyard pesticide update". Wines & Vines. FindArticles.com. 04 Mar, 2010. http://findarticles.com/p/articles/mi_m3488/is_4_84/ai_1005420

Fertilizing Grapes. Tech. Spectrum Analytic Inc. Web. 2010. <http://www.spectrumanalytic.com/support/library/pdf/fertilizing_grapes.pdf>.

Gove, B., et al. "Effects of herbicide spray drift and fertilizer overspread on selected species of woodland ground flora: comparison between short-term and long-term impact assessments and field surveys." *Journal of Applied Ecology* 44.2 (2007): 374-384. *Academic Search Premier*. EBSCO. Web. 12 Feb. 2010.

Hawkesford, Malcolm J., and Kok Luit J. De. *Sulfur in Plants an Ecological Perspective*. Dordrecht, The Netherlands: Springer, 2007. 154. Print.

Harris, Paula. "New Report Claims Pesticide Overuse on Local Vineyards." *Sonoma County Independent*. MetroActive, 13 Nov. 1997. Web. Feb. 2010. <http://www.metroactive.com/papers/sonoma/11.13.97/news-9746.html>.

Hilderbrandt, Alain, and Miriam Guillamon. "Impact of Pesticides Used in Agriculture and Vineyards to Surface and Groundwater Quality (North Spain)." *Water Research* 32.13 (2008): 3315-326. Print.

Igbedioh, S.O. "Effects of Agricultural Pesticides on Humans, Animals, and Higher Plants in Developing Countries." *Archives of Environmental Health* 46.4 (1991): *Health Source: Nursing/Academic Edition*. EBSCO. Web. 12 Feb. 2010.

"Localized Influences on Wind Patterns." *The Columbia Electronic Encyclopedia*. 2007. Web. 2010.

Olson, Richard K., Dan Binkley, M. Böhm, and M. Arbaugh. *The Response of Western Forests to Air Pollution*. New York: Springer-Verlag, 1992. 193-216. Print.

Pesticide Mitigation. *Central Coast Vineyard Team-Promoting Sustainable Winegrowing*. 2008. Web. 2010. <http://www.vineyardteam.org/projects/pesticide.php>.

Probst, Björn, Christian Schuler, and Rainer Georg Joergensen. "Vineyard soils under organic and conventional management-microbial biomass and activity indices and their relation to soil chemical properties." *Biology and Fertility of Soils* 44.3 (2008): 417-545. *Earth and Environmental Science*. SpringerLink. Web. 12 Feb 2010.

"Phytotoxicity - Pesticides." *BC Ministry of Agriculture, Food and Fisheries*. 2007. Web. 03 May 2010. <http://www.agf.gov.bc.ca/pesticides/e_10.htm>.

Rull, Rudolph P., and Beate Ritz. "Historical Pesticide Exposure in California Using Pesticide Use Reports and Land-Use Surveys: An Assessment of Misclassification Error and Bias." *Environmental Health Perspectives* 111.13 (2003): 1582. *Health Source: Nursing/Academic Edition*. EBSCO. Web. 12 Feb. 2010.

Santis, Salvadore D. "An Introduction to Lichens." *New York Botanical Garden*. National Science Foundation, 1999. Web. 03 May 2010. <http://www.nybg.org/bsci/lichens/>.

Slusher, John P., and Doug Wallace. "G5900 Planning Tree Windbreaks in Missouri | University of Missouri Extension." *University of Missouri Extension Home*. Natural Resources Conservation Service, USDA, Dec. 1997. Web. 03 May 2010. <http://extension.missouri.edu/publications/DisplayPub.aspx?P=G5900>.

Solberg, Richard A., and Donald F. Adams. "Histological Responses of Some Plant Leaves to Hydrogen Fluoride and Sulfur Dioxide." *American Journal of Botany* 43.10 (1956): 755-60. Print.

Sparks, Beverly. "Phytotoxicity: The Unexpected Danger." *Grounds Maintenance | How to Care for Your Lawn, Landscape, Turf, Grass*. 1997. Web. 03 May 2010. <http://www.grounds-mag.com/mag/grounds_maintenance_phytotoxicity_unexpected_danger/>.

Torgeson, Dewayne C. *Fungicides -An Advanced Treatise*. New York: Academic, 1969. 123-24. Print.

Toxic-Free Organic Vineyards. Advertisement. *Frey Vineyards Mendocino America's First Organic Winery*. Frey Vineyards LTD, 2009. Web. 2010. <http://www.freywine.com/toxic-free-vineyards.html>.

USA. Environmental Protection Agency. *Ecological Risk Assessments*. EPA, 13 Aug. 2008. Web. 2010. <http://www.epa.gov/oppoooo1/ecosystem/ecorisk.htm>.

USA. Napa County Resource Conservation District. *Napa Country RCD*. 2010. Web. Feb. 2010. <http://www.naparcd.org/index.html>.

USA. United States Department of Agriculture. National Resources Conservation Service. *Soil Survey of Napa County, California*. By G. Lambert and K. Kashiwagi. USDA Soil Conservation Service, 1978. Web. Feb. 2010. <http://www.ca.nrcs.usda.gov/mlra02/napa/>.

Wypych, Sebastian, and Anita Bokwa. "Air Circulation." *Atmospheric Chemistry*. Aug. 2003. Web. 03 May 2010. <http://www.atmosphere.mpg.de/enid/3rm.html>.