COUNTY OF SANTA CLARA
RIPARIAN CORRIDOR STUDY:

A Background Document for the Development of a Riparian Protection Ordinance for the County of Santa Clara

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1. INTRODUCTION

The purpose of this document is as follows:

1. Respond to issues raised at the Planning Commission workshop on February 6, 2003
2. Provide additional information regarding functions of riparian corridors based on review of current scientific literature and studies
3. Provide summary information on Santa Clara County unincorporated streams and property potentially affected by a riparian ordinance
4. Provide information regarding other jurisdictions' ordinances

This report is not intended to be an all-inclusive or exhaustive study addressing all possible aspects or issues attendent on the County's development of a riparian ordinance. Furthermore, the information provided is a basis of scientific understanding, and the comparison with other jurisdictions is not intended to suggest definitive recommendations at this time.

Staff believes that an appropriate and successful outcome for the riparian ordinance project is one that:

- Is based on scientific knowledge and local conditions;
- Is consistent with the County General Plan, and the efforts of other jurisdictions in the County;
- Balances riparian protection and the community interest with property owner interests;
- Is feasible and practical to implement; and
- Is effective in meeting the goals of riparian protection and enhancement, and doesn't promote unintended adverse consequences for riparian resources.

To those ends, staff intends to provide additional information and recommendations at a future PC workshop or hearing, the date of which is not yet determined.

2. FUNCTIONS OF RIPARIAN CORRIDORS

2. 1. Streambank Stability

Stream corridors are complex and dynamic environments that are strongly influenced by natural characteristics such as topography, soil type, bedrock material, groundwater discharge, overland flow, and climate (NRC 2002). Stream corridors are naturally evolving systems that change overtime, but the condition of these characteristics control the response of the streambed to natural and human induced changes to instream channel flows and sediment load.

The processes of erosion, transport, and deposition of materials continually disturb and reshape the stream corridor (NRC 2002). The term "stability" in this type of setting describes a condition in which the channel slopes, structure, and other characteristics are in balance with the sediment sizes, loads and water discharges (Riley 2002). This state of equilibrium allows for the appropriate energy and velocity required for the transportation and deposition of sediment load throughout the water basin (Riley 2002).

An unstable stream corridor environment can result in excessive widening and meandering of the stream channel leading to shallow or deep streambeds that deplete the diversity of habitats and species. On the other hand, unstable stream corridors can also result in the straightening of stream channels, accelerating instream flow velocity, which scours the streambed and banks leading to channel incision (Lowrance et al. 1995).

Vegetation along streambanks may have a significant affect in stabilizing stream channels (Hession 2001). Root systems in the streambank are likely to have the most significant affect by binding bank sediments and moderating erosion processes (FISRWG 1998, Castelle and Johnson 2000). Trees and other types of vegetation along the streambank anchor soils through dense root masses. Additionally, root systems and other large vegetative debris create "roughness" in the stream channel, which decreases flow velocity and increases the energy needed to dislodge materials from the streambank giving greater stability to the streambank (FISRWG 1998).

Over-saturated soils in the stream channel can lead to soil slumping into the streambed and channel instability. Vegetation in the stream corridor may also stabilize streambanks by reducing soil moisture content through plant uptake (Castelle and Johnson 2000). Vegetation may also provide organic material leading to more porous soil. These characteristics of soil aeration may reduce the saturation of soils in streambank corridors and the potential for streambanks to slump into the streambed.

Channelization or confining a natural stream channel into a defined area using hard surfaces and other mechanisms is a method used to reinforce streambanks. This procedure can be financially costly and can lead to significant adverse impacts to the physical and biological conditions of the stream system (Bolton and Shellberg 2001). Removal of vegetation and other disturbances along stream corridors has similar affects. There has been a substantial amount of literature and recent studies into the adverse affects of these disturbances and the need and process to restore stream corridors to their natural states (Palone and Todd 1997, FISRWG 1998, Bolton and Shellberg 2001, Riley 2002).

2. 2. Sediment Reduction

In addition to streambank instability, land adjacent to streams can release large amounts of sediments into streams over a long period of time (NRC 2002). During storm events there is an increase in volume, velocity, and energy of water flowing over land towards streams in a shorter amount of time. This can lead to higher rates of land erosion and erosion of larger sized sediments. Natural stream corridor processes accounts for erosion, transport of sedimentation, and deposition of sediment material, however, excessive sedimentation can have adverse impacts on these natural processes.

The increased quantity and size of sediments can decrease a stream's "competency" (ability to move larger sediments) and its "capacity" (ability to move greater amounts of these sediments) (Riley 2002). This results in streams dropping excessive amounts of sediment in the channel causing in-channel sediment bars, pools, and the formation of migrating channels. This in turn can induce extensive bank erosion and depositional instabilities downstream and possibly upstream of these sites. Long-term effects include the degradation of stream habitats and fish spawning areas, increases in turbidity, and accelerated filling of marshes and other wetlands (Riley 2002).

There are several articles discussing the ability of vegetation in the riparian area to reduce sedimentation and protect water quality (Lowrance et al. 1995, Correll 1997, Naiman and Decamps 1997, Wenger 1999, Castelle and Johnson 2000). Vegetation in the riparian area reduces sedimentation by maintaining soil structure and increasing soil strength, trapping sediment and debris, and slowing surface water flow rates.

As surface water flows over land, plant roots and litter create friction, mechanically trapping sediments and debris. This also reduces the surface water velocity, increasing the sedimentation of particulates in the vegetative corridor (Correll 1997). In addition to trapping sediments, vegetation in the riparian corridor can disperse the flow of water more evenly across the land in sheet flows, reducing the potential of channelization or concentrated, higher velocity flows into streams. These slower and less concentrated flows allow more time for the trapping and settling of sediments (Castelle and Johnson 2000).

Width and type of vegetation, and the type and condition of soil also have significant affects on sedimentation in the stream. Generally, areas with greater slopes have a higher potential of erosion conditions because among other things, surface flow is often channelized and steep slopes induce higher velocity flows. Wenger (1999) concluded that there is a positive correlation between the width of the vegetation along streams and its ability to trap sediments. However, Castelle and Johnson (2000) suggest the type and placement of vegetation may be equally significant. The type of soil being eroded, specifically the sediment size, is also a significant element because smaller particles are more likely to travel further than larger particles.

2. 3. Flood Protection

Most natural stream corridors have been described consisting of three components: the active stream channel, floodplain, and transitional upland fringe (Naiman and Decamps 1997, FISRWG 1998, Riley 2002). The floodplain consists of the relatively flatland adjacent to streams that forms by stream migration or natural meandering of the stream, erosion, and deposition of sediments (see Figure 1). The physical location of floodplains next to streams establishes a strong relationship between riparian corridors and floodplain areas. Many riparian corridors can partially consist of or be entirely floodplain areas.

Periodic flooding is a natural process in which the quantity of water cannot be contained by the active stream channel. When this occurs, water overflows the streambanks and discharges onto the adjacent land outside of the active stream channel. The frequency, duration, and magnitude of such events can vary depending on the amount of precipitation, discharge of overland flow, slope, soil type, and other physical characteristics.

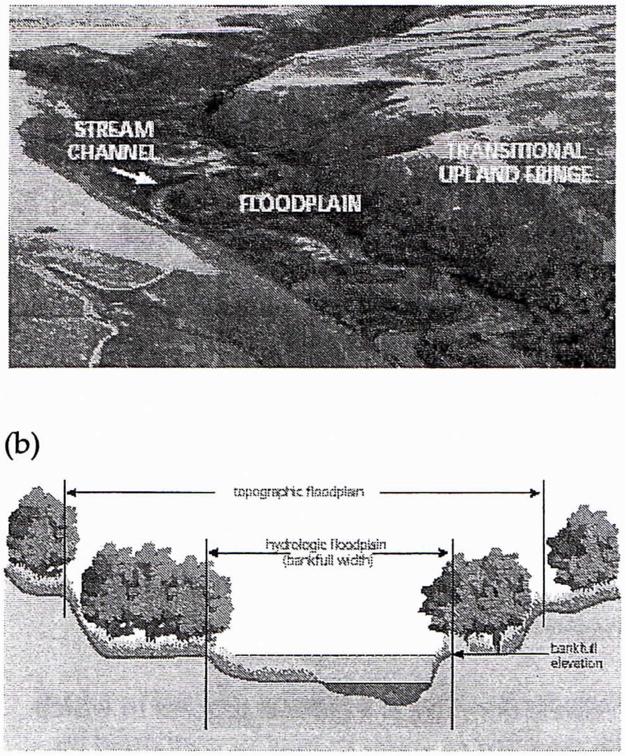
Maintaining riparian corridors reduces the adverse effects of flooding. Maintaining floodplain areas provides at least three benefits including:

- Disperse flow
- Flood storage
- Absorption of water

Figure 1 (a). The three components of the stream corridor. (b). A lateral view of a typical stream corridor with floodplain areas. (from FISRWG 1998)

(a)

(b)



During storm events, the floodplain area allows water to spread out over the land, reducing the velocity of the flow, the energy to erode or damage features on land and within the stream channel. The floodplain also provides temporary storage of floodwaters and sediment (FISRWG 1998). This is important during storm events because it increases the capacity of water within the stream corridor and the time for water to flow further downstream, while reducing the adverse affects downstream. While dispersing flow and providing storage of floodwaters, floodplains absorb water and allows for the infiltration of groundwater. Although the frequency and magnitude of disturbances within the floodplains can create unstable and sensitive environments, they are often valuable habitats for many species.

Riparian corridors are frequent areas of disturbance. Protecting these areas provides for the natural conveyance and attenuation of floodwaters. Developing within the riparian corridor and floodplain increases the need for costly flood management control measures, which may not be sustainable and may not provide the same level of benefits as natural ones (Bolton and Shellberg 2001, Riley 2002). Homes and other structures built within the riparian corridor and floodplain have a higher potential of being damaged by storm events and floodwaters. Providing an adequate protected stream corridor would reduce this likelihood.

2. 4. Additional Ecological Benefits of Riparian Vegetation

Vegetation within the stream corridor and adjacent upland areas play a vital role in the condition of the stream corridor (FISRWG 1998). Vegetation in the riparian area provides a variety of conditions and functions necessary for biological communities. Based on the literature reviewed for this report, the integrity of vegetation along stream corridors may be the most critical characteristic of a healthy ecological stream corridor. Vegetation is an important source of energy, provides essential habitat to aquatic and terrestrial organisms, and provides thermal protection and regulation of stream water temperature.

2. 4. 1. Vegetation As a Source of Energy

There are two main sources of food energy into streams. First, direct stream input of litterfall (leaves, twigs, seeds, etc.) and wind-blown and water-driven entry into the stream channel. This organic matter entering the stream through litterfall and by other means is a fundamental source of the food chain. (Lowrance, Altier, Newbold, et al. 1995, FISRWG 1998, Wenger 1999, Castelle and Johnson 2000, NRC 2002). Organic material entering the stream is the primary supply of coarse particulate organic matter (CPOM), fine particulate organic matter (FPOM), and dissolved organic matter (DOM), all more generally known as detritus material. Detritus is the basic source of nourishment for many aquatic organisms and in turn these organisms feed higher trophic levels in the food web such as macro-invertebrates, aquatic insects, and fish.

Therefore, a rich mixture of vegetation along stream corridors is necessary to support the abundance and diversity of organisms throughout the food chain within the stream corridor. A variety of animals that inhabit predominantly upland areas are also dependent on riparian vegetation because they forage on organisms that live in the riparian corridor.

The second source of food energy into streams is the production of aquatic plant life and algae within the stream. Similar to litterfall and other entry mechanisms of organic materials, aquatic plants and algae are primary food sources of many organisms. However, excessive growth of algal blooms and other aquatic plants may negatively impact stream water conditions by causing oxygen depletion and other functional and aesthetic problems (FISRWG 1998). Furthermore, excessive growth may cause some watersheds to become dominated by a few species that exclusively feed on algal materials (Lowrance et al. 1995) and may contribute to an adverse ecological imbalance of the food web and stream functions.

Riparian vegetation along the stream corridor functions to regulate the rate of photosynthesis of algae and aquatic plants. By shading the stream channel, vegetation can control the amount of light striking the surface of the water, thus controlling the productivity of algae and aquatic plants.

A mixture of food energies sustains a more diverse food web. The proper balance of both food energies is dependent on the quality and quantity of riparian vegetation. Therefore, the condition of riparian vegetation is crucial in determining the composition of the organisms that are able to survive in this habitat and the surrounding environment.

2. 4. 2. Riparian Areas Provide Habitat Conditions for Plants and Animals

Riparian areas are some of the most diverse, dynamic, and complex ecosystems (Naiman and Decamps 1997). Additionally, riparian vegetation has relatively high biomass productivity compared to other plant ecosystems within the same area (Stiles 1978). These characteristics are generally due to the availability of water, moist, rich and well drained soils, and the interactions between the stream corridor and upland ecosystems (Stiles 1978, Naiman and Decamps 1997, Nilsson and Svedmark 2002). Furthermore, disturbance regimes along stream corridors, such as intense flooding and draught conditions and impacts of upland ecosystems such as fires, mudslides, and landslides can regenerate a mosaic of vegetation types in various successional stages of development (Nilsson and Svedmark 2002). Vegetation in the riparian area also has a distinctive capacity to migrate longitudinally along the stream corridor, thereby restoring disturbed areas.

The unique characteristics of riparian areas provides essential habitat for a diverse community of terrestrial species. In the Pacific Coast ecoregion, 60 percent of amphibian species, 16 percent of reptiles, 34 percent of birds, and 12 percent of mammals can be classified as riparian (Kelsey and West 1998 in Naiman and Decamps 1997). Knopf and Samson (1994) reported that although only 1% of the land in the western United States is considered to be riparian, more species of breeding birds use riparian areas than any other habitat.

There have been many studies examining how the characteristics of riparian vegetation directly influence the establishment and sustainability of terrestrial species. While not all of the characteristics are known, there are many generally accepted theories and observations.

The vegetation structure in riparian areas is different from surrounding areas and attracts a variety of wildlife. Disturbance regimes and successional patterns along stream corridors maintains a variety of plant types including low growing plants, shrubby plants, and trees. This mixture of plants produces a variety of vertical levels of vegetation, which provides a complex habitat structure and a greater opportunity of suitable habitat for wildlife. Some species require this complexity for survival because it affords a variety of shelter and foraging opportunities.

The linear characteristic of riparian corridors creates a natural"edge effect" that can increase the diversity of the species in this environment. Because the riparian corridor serves as the transition zone between the aquatic, riparian, and upland habitats, wildlife in this environment are able to simultaneously access more than one cover type and exploit the resources of both for reproduction, escape, nesting, and foraging (Palone and Todd 1997, FISRWG 1998). While such edges provide the potential for a variety of habitats and available resources, the linear characteristic of the riparian corridor may be too narrow to provide adequate habitat for a number of species that prefer forest-interior conditions (Fischer et al 1999).

Riparian corridors can also serve as important connectors between fragmented islands of habitats. Wildlife may use these habitats during different life stages and travel along these corridors at different times of the year (Palone and Todd 1997, Fischer et al 1999). Without these corridors, fragmentation of ecosystems may occur with an adverse impact to the geographic distribution of species that are dependent on these corridors for movement. Avian species might be the most dependent on riparian areas because of the vegetative structure and available resources (Knopf and Samson 1994). There is a growing level of interest in the dependence of neotropical birds on riparian areas, especially those that utilize riparian areas during winter months. Reduction in the quantity and quality of riparian areas may reduce the population and geographic distribution of neotropical birds.

Vegetation along stream channels is also the source of large woody debris (LWD), which provides necessary habitat and functions for in-stream organisms. LWD is the accumulation of trees, branches, and root wads in the stream channel and can also include overhanging logs protruding from the stream bank. LWD serves to: (1) create and maintain pools (causing local reductions in stream velocities) that serve as foraging sites for fish feeding on drifting food items; (2) form eddies where food organisms are concentrated; (3) supply protection from predators; (4) provide shelter during winter high flows; and (5) trap and store organic inputs from streamside forests, enabling them to be processed biologically (Sedell and Beschta 1991 in Castelle and Johnson 2000). LWD is one of the major factors in habitat diversity and there is a strong relationship between the supply of LWD and the populations, growth, and diversity of aquatic organisms, especially fish (Stiles 1978, Lowrance et al. 1995, Palone and Todd 1997, Wenger 1999, Castelle and Johnson 2000).

2. 4. 3. Regulation of Water Temperature

Although direct sunlight and increases in stream temperature can generate increased aquatic plant production, the lack of shade and elevated stream temperature can have a serious effect on populations and diversity of particular aquatic invertebrates and fish species (Palone and Todd 1997, Robins 2002). For some aquatic organisms, the increase in water temperature is detrimental to physiological and biochemical functions because many aquatic organisms can only survive within a relative narrow range of temperatures (Lowrance et al. 1995). In addition, increased water temperature can be a catalyst for oxygen depletion from the stream, eliminating crucial support for a healthy stream ecosystem (Palone and Todd 1997, FISRWG 1998).

Riparian vegetation along the stream corridor that shields water from direct sunlight and moderates temperature from extreme fluctuations (Budd, Cohen, and Saunders 1987, Palone and Todd 1997). Canopy cover over streams protects against increased temperatures during summer months and heat loss during winter months. However, factors other than shading affect stream temperature. There is considerable evidence that evapotranspiration (the process of water loss due to liquid water turning into vapors), inflow of cool surface and groundwater, stream depth, and other factors can have significant effect on stream water temperature. It is likely that stream temperature moderation by vegetation has the greatest impact on small order streams because they have the greatest potential of being shaded (FISRWG 1998, Wenger 1999).

2. 5. Other Functions of Riparian Corridors

In addition to physical, chemical, or biological functions, riparian corridors enhance scenic value, open space, and intrinsic values. Many people appreciate riparian corridors for the personal enjoyment of observing wildlife, birds, and plants in their natural habitats. Even if the public does not directly benefit from a particular landowner's riparian corridor, they might have an intrinsic value just knowing that it is there. Riparian corridors are components of a larger watershed system at work, so the manner in which riparian corridors are protected has a direct impact on other parts of the watershed.

3. CONSIDERATIONS IN THE PROTECTION OF RIPARIAN CORRIDORS

The concepts that follow are basic elements that should be considered when designing a system or procedures to protect riparian corridors.

3. 1. What types of protective systems could be adopted?

3. 1. 1. Fixed vs. Variable Buffer Widths

Generally, there are two methods to establish buffer widths: variable width, which is dependent on site conditions or fixed width for all streams. Each of these methods has its advantages and disadvantages. Variable width buffers enable land managers to determine a buffer width based on a set of criteria and make practical determinations of a width that will effectively protect riparian habitat. Such widths can be tailored to include many abiotic (soil texture, soil depth, topography, in-stream water volume, frequency of flow, condition of stream channel, land use, etc.) and biotic factors (type of vegetation, % of ground cover, plant height, root abundance, number and diversity of flora and fauna, etc.).

Some of the key advantages of using a variable buffer width are they may be more sensitive to specific stream corridor conditions and functions and the goals of protecting the resource (Palone and Todd 1997). However, establishing variable buffer widths can be a very extensive process that requires an in-depth site investigation to collect detailed information, an evaluation of the data, and ultimately a decision making process to determine an acceptable buffer width (Castelle and Johnson 2000). This approach is likely to be difficult in monitoring and administering as well as time consuming and financially costly.

Another approach is a fixed width buffer, which is uniform for all streams in the County's jurisdiction. Fixed width buffers are generally simpler to implement and administer than variable width buffers (Palone and Todd 1997). A fixed width buffer can be established by considering the common objectives and goals of protecting stream resources throughout the County by determining a minimum width that will protect a majority of the desired functions of riparian areas. However, it is likely that fixed width buffers may provide adequate protection in some areas and too little protection in other areas.

3. 2. What is the extent of the streams that should be protected?

Whether fixed or variable buffers are used to protect riparian corridors, it is necessary to determine which streams should be protected and in the case of variable buffers, the level of protection. Classification of streams using the level of water flow or other characteristics can be used to make these determinations. The following classification schemes are accepted methods in classifying streams.

3. 2. 1. Water Flow: Perennial vs. Intermittent vs. Ephemeral

Streams can be classified based on the balance and timing of stormflow and baseflow components (FISRWG 1998). Streams can be classified into three categories, generally defined as follows:

Perennial: A stream that normally continues to flow throughout the year through wet and dry seasons. Perennial streams have been designated by a solid line symbol on the U.S. Geological Survey Topographic map most recently published or verified by field investigation.

Intermittent: A stream that flows only certain times of the year. Intermittent streams should usually have flow at least 30 days after a storm event or throughout seasonal periods. Intermittent streams should have a defined stream channel and evidence of sediment transport. Intermittent streams have been designated by a dash-and-dots symbol on the U.S. Geological Survey Topographic map most recently published, or when it has been field determined.

Ephemeral: A stream that flows only in direct response to precipitation, storm events, or seasonally, but normally lasts no longer than 30 days following the event.

It is important to consider protecting as many stream reaches as possible because stream systems are interrelated and the conditions of one stream reach can have a significant impact on others. While the perception that perennial streams are the most important waterways in watershed systems, intermittent streams comprise nearly 80% of the streams in the unincorporated area of Santa Clara County and provide necessary functions of the watershed. Intermittent streams along with ephemeral streams are likely to carry a substantial amount of water and sediments during storm events and other periods throughout the year. Intermittent streams are also important sources of groundwater and aquifer recharge and the recharge of reservoirs in the County. Additionally, these streams are likely to support unique habitats that are important to many wildlife species.

Nevertheless, protecting all types of streams, particularly ephemeral streams, in Santa Clara County may not be feasible or practical. First, a comprehensive dataset of all the waterways including ephemeral streams in the County does not exist. Secondly, it is possible that not every ephemeral stream satisfies conditions that are worth protecting. Finally, the delineation and designation of ephemeral streams would likely be a process racked with problems and it is questionable whether the practicality of designating and protecting every ephemeral stream in the County is sensible.

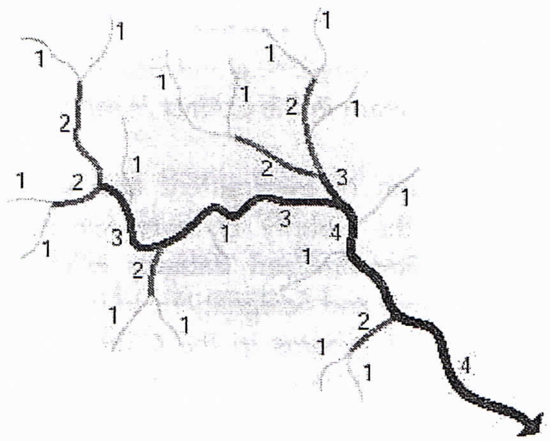
The protection of intermittent and perennial streams in the County is more feasible and practical. Standardized datasets exist which map the extent and designations of intermittent and perennial streams in the County. When examining these datasets, most of the stream reaches in the County are designated intermittent (80%). Even reaches of streams that are perceived as major waterways such as the upper reaches of the Llagas, Thompson, and Uvas Carnadero Creeks are intermittent.

To reiterate, intermittent streams perform critical functions in the watershed and should be considered important resources in the overall watershed.

3. 2. 2. Stream Order: Protection of Headwaters

Another method of classifying streams in an order of hierarchy was developed by scientists in the 1940's and later modified in the 1950's (FISRWG 1998). This classification scheme starts with first-order streams, which are comprised of headwater streams with no upstream tributaries. In Santa Clara County, many first-order streams are likely to be located in the Santa Cruz Mountains, the Diablo Range, and associated foothills. Second-order streams are formed below the intersection two first-order tributaries. Likewise, third-order streams form when two second-order streams intersect, and so on. Figure 2 is a general illustration of this classification scheme.

Figure 2. Stream order diagram (from FISRWG 1998)

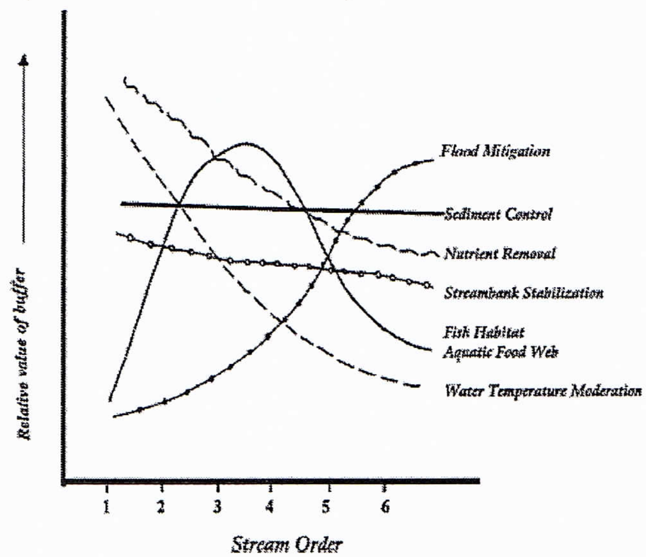


It may be questioned whether it is practical and/or feasible to protect low-order types of streams. In general, buffered riparian areas have the greatest potential for control over water quality when adjacent to low-order streams because there is the greatest potential for interactions between water and riparian area (Lowrance et al. 1995, Palone and Todd 1997). For instance, riparian vegetation has the greatest impact to the regulation of stream temperature in lower-order streams because lower-order streams are generally narrower than higher order streams, thus vegetation over the stream is more likely to shade surface water. In addition, headwater streams are more likely to occur in steeper sloped areas and the protection of riparian areas may have the most impact on reducing erosion and sedimentation. These small streams are the most vulnerable to human disturbance because they respond dramatically and rapidly to alterations on adjacent lands and are the most sensitive to changes in riparian vegetation in the surrounding watershed.

Protection of only high-order streams would not necessarily provide adequate water quality protection (Lowrance et al 1995, Palone and Todd 1997, Fischer and Fischenich 2000, USACE 2002). Streams below headwater tributaries have two primary water sources (Lowrance et al 1995, Palone and Todd 1997). The first is surface flow from areas adjacent to the stream. The second is from tributaries higher up in the watershed. As water flows from low-order streams to higher-order streams, their impacts are cumulative. This is evident in Santa Clara County with the erosion of the upper watersheds transporting excessive sediments to lower reaches.

Figure 3 illustrates the relative value of riparian buffers for various purposes, depending on stream order. As an example, a buffer in higher-order streams may have a greater impact on flood attenuation, while moderation of water temperature may be more effective on lower- order streams.

Figure 3. Effect of stream order on functions of buffers (From Palone and Todd 1997)



In relationship to the delineation of streams (perennial, intermittent, or ephemeral), many first-order streams are intermittent or ephemeral.

3. 2. 3. Other Factors

In addition to these factors, there are additional variables that may be important in deciding where appropriate riparian corridors should be protected, the level of protection, and the extent of mitigation for future development. Some of these include (Wenger 1999):

- Slope of banks and areas contributing flow to the stream segment
- Soil infiltration rate and other soil factors
- Soil moisture content
- Floodplain width
- Catchment size
- Land use
- Impervious surface coverage and proximity to streambank
- Type of vegetation, amount of biological litter, and other materials

3. 3. Where Should Buffer Widths Be Measured?

Another issue is where to measure riparian buffer zones. The goal in making this determination is to establish procedures that adequately protect the riparian corridor and their associated affects on water quality, while establishing procedures that are understandable, consistent, and are practical for measurement in the field.

Based on the physical characteristics of the stream, the location from which to measure can be established. There are three general approaches to determine the inner edge of the buffer:

- Ordinary High Water Mark (OHWM) - generally means the line on the stream channel where sustained high water levels typically occur. OHWM have physical characteristics such as clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other distinctive physical characteristics.

- Centerline of the Stream – generally defined as the median between the average or low water marks of a streambed. USGS "blue-lines" are considered to be centerline designations

- Top of Streambank – generally defined as the break in slope at the top of a streambank, where the streambank meets the floodplain. The streambanks are the slopes of the active channel, between which streamflow is normally confined.

Of these three methods, measuring from the top of the streambank is likely to be the most practical and accepted method of delineating the edge of the stream and the beginning of the riparian corridor. Measurements from the top of the streambank provide the necessary protection to land adjacent to the active stream channel and are less susceptible to change during variable flow periods and streambed alignment. It is unfeasible to make accurate measurements from the centerline of wider streams.

In a survey of counties in the Bay Area and throughout California, eight out of ten counties use the top of the streambank as their setback measurement point. Consistency with other agencies within Santa Clara County is also important. The Santa Clara Valley Water District uses the top of streambank to delineate their jurisdictional boundaries. The Department of Environmental Health along with other agencies within Santa Clara County also use the top of streambanks to delineate the edges of streams.

4. RECOMMENDED WIDTHS FOR RIPARIAN CORRIDORS

4. 1. Recommendations from Regulatory Agencies

The following recommendations or guidelines are intended to demonstrate design considerations at the state or national level. Generally, there are very few regulatory agencies having adopted specific dimensions of riparian corridors because a "one-size-fits-all" standard is not well established and may not adequately address site conditions of individual watersheds (Fischer and Fischenich 2000).

4. 1. 1. U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers has recently changed and reissued permits under the Nationwide Permit System (NWP). As stated in the Federal Register (FR 67(10): 2019-2095, Jan. 15, 2002) the Corps has the statutory authority to require vegetated buffers next to streams and other open waters where there are discharges of dredged or fill material into "waters of the United States", which the Corps regulates under Section 404 of the Clean Water Act. The goal of the Clean Water Act is to restore and maintain the chemical, physical and biological integrity of the Nation's waters. This goal is stated in Section 101 of the Clean Water Act and is applicable to all sections of the Clean Water Act, including Section 404. Vegetated buffers next to streams and other open waters help maintain the chemical, physical, and biological integrity of these waters.

When determining the appropriate width of vegetated buffers, district engineers are to consider the degree of the adverse effects on the aquatic environment caused by the authorized work and require compensatory mitigation to the extent necessary to ensure that the adverse effects are minimal (FR 67(10): 2019-2095). Under the conditions of the reissued permits, the vegetated buffer are normally designed to be minimally 25 to 50 feet wide on each side of the stream, but District Engineers may require slightly wider vegetated buffers to address documented water quality or habitat loss concerns.

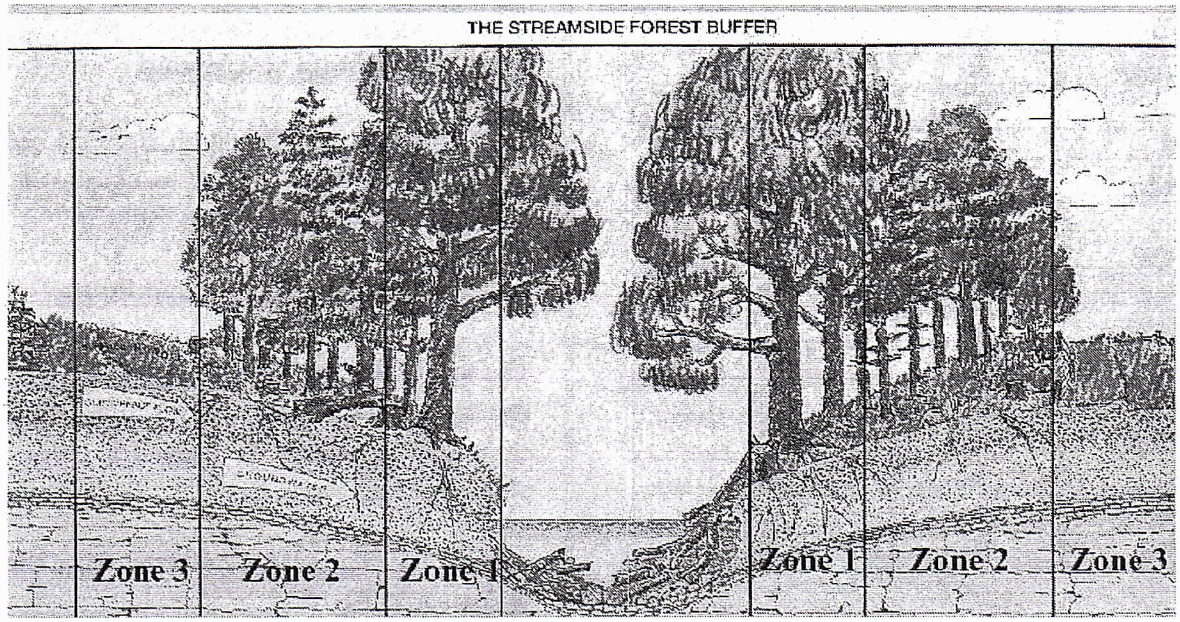
Other regulatory assistance documents produced by the U.S. Army Corps of Engineers, provide additional recommendations for designing riparian corridors and vegetated buffer strips based on scientific studies of a variety of streams and ecosystem types (Fischer and Fischenich 2000, ERDC 2002). The general minimum recommendations for buffers on each side of the stream for the noted functions are as follows (from Fischer and Fischenich 2000):

Water Quality Protection	16 – 98 ft
Flood Attenuation	65 – 490 ft
Input of Organic Materials	10 – 33 ft
Riparian Habitat	98 – 1,640+ ft
Stream Stabilization	33 – 65 ft

4. 1. 2. U.S. Department of Agriculture

In 1991, the U.S. Department of Agriculture (USDA), with the assistance of other federal and state agencies, developed guidelines for establishing riparian forest buffers (Welsch 1991). This initiative developed a riparian buffer system consisting of three zones. Zone 1 is described as permanent woody vegetation

Figure 4. The three-zone buffer strip design (from Fischer and Fischer and Fischenich 2000, modified from Welsch 1991)



immediately adjacent to the stream bank. Zone 2 is described as a managed forest occupying a strip upslope from zone 1. Zone 3 is described as an herbaceous filter strip upslope from zone 2. (See Figure 4 for a diagram of these zone designations)

These guidelines have been refined into National Conservation Practice Standards (NCPS) by the Natural Resources Conservation Service (NRCS) of USDA. The NCPS contains information on why and where riparian buffer systems should be applied, and sets forth the minimum quality criteria that must be met during the establishment of a riparian buffer system in order for it to achieve its intended purpose. The NRCS has adopted the following minimal standards with additional criteria for the State of California (NRCS 2000, NRCS 2002):

Zone	Dominant Vegetation	Width
1	Naturally regenerated, or planted trees and shrubs	15 ft (minimum)
2	Native trees and shrubs (usually taller)	20 ft (minimum)
3	Stiff, multi-stemmed grasses	10-300 ft depending on function of filter strip

4. 2. Other Counties' Ordinances

In November 2002, Planning staff sent questionnaires to 14 counties in the Bay Area and throughout California regarding their County regulations for riparian protection. Based on the responses, 10 (71%) of the counties surveyed had some type of riparian ordinance. Of the counties surveyed that already had a riparian ordinance, 50% were in the process of revising their ordinance. Since then, the County of Napa has adopted a new ordinance

Table 1. Counties surveyed for riparian ordinances

County	Current Riparian Ordinance	Revising or Developing a Riparian Ordinance
Alameda	Yes	Yes
Contra Costa	No	No
Marin	Yes	Yes
Merced	No	No
Monterey	Yes	No
Napa	Yes	Yes
San Benito	Yes	No
San Bernardino	Yes	No
San Francisco	N/A	N/A
San Luis Obispo	Yes	No
San Mateo	Yes	Yes
Santa Cruz	Yes	No
Solano	No	No
Sonoma	Yes	Yes
Stanislaus	No	No

Table 2. County definition of a stream subject to their riparian protection ordinance

County	Definition of Protected Streams
Alameda	USGS blue-line creeks, 50 acre drainage area, & designation by use
Marin	USGS blue-line creeks
Monterey	USGS blue-line creeks or through field verification.
Napa	USGS blue-line creeks and streams at least 3 ft deep. Proposed to be changed to biological classified system as defined by CA Dept. of Forestry and CA Dept. of Fish & Game
San Benito	USGS blue-line creeks or through field verification.
San Bernardino	USGS blue-line creeks or through field verification.
San Luis Obispo	Coastal Zone Map - USGS blue-line creeks
San Mateo	Coastal Zone Map based on local coastal plan. Proposed to be changed to include all Non-Coastal Zone Mapped creeks.
Santa Cruz	USGS blue-line creeks
Sonoma	Mapped creeks based on field research previously conducted in the 1980s. Proposed to be changed to include all USGS blue-line creeks.

(adopted on April 7, 2003). Table 1 shows a summary of the counties in our survey with riparian protections ordinances.

4. 2. 1. Definition of a Stream

8 (80%) of the counties with riparian ordinances use USGS blue-line creeks to define the subject streams to be protected. (see Table 2)

4. 2. 2. Setback Measurement Point

The top of the streambank is used by 8 (80%) of the counties to delineate the inner edge of the riparian corridor to measure the setback distance. (see Table 3)

Table 3. County delineation of the inner edge of the riparian corridor

County	Setback Measurement Point
Alameda	1:2 daylight point from top of bank
Marin	Top of bank (Marin anywhere besides West) or Edge of riparian vegetation (West Marin)
Monterey	Top of bank
Napa	Top of bank
San Benito	Top of bank
San Bernardino	Top of bank
San Luis Obispo	Top of bank
San Mateo	Edge of riparian vegetation on both sides of stream.
Santa Cruz	Edge of riparian vegetation
Sonoma	Top of bank

4. 2. 3. Distance and Basis of Riparian Corridor Setback

All counties surveyed have unique riparian protection ordinances. Each county has established distinctive setback distances based on particular criteria important to their jurisdiction including: the goals of adopting the ordinance, the political and economic feasibility, the resource being protected, and local stream and riparian conditions. Counties that responded to the survey have established ordinances with setback distances of 20 – 200ft. The median setback distance is approximately 75ft. The setback distances are based on a variety of characteristics including: type of stream, slope variability, type and condition of riparian habitat, and location within the county. Many jurisdictions have developed variable buffer widths based on established criteria. (For more details about specific county setback distances and the basis for the distance see Appendix A.)

4. 3. Scientific Recommendations

County staff reviewed scientific literature to determine a technical basis for an appropriate riparian corridor width. Criteria for determining proper corridor widths are not well established, however, scientific research indicates recommended widths that are based on experimental and natural conditions in a variety of stream types. Site specific conditions play a critical role in determining appropriate riparian corridors. There are no known studies that have been conducted in Santa Clara County to determine adequate riparian corridor buffers for streams in this county. However, it is likely that the information provided by the scientific literature can be adapted to local conditions.

Based on the scientific literature reviewed, it is possible to develop conservative estimates of minimum riparian corridor widths. These estimates should be based on the functions or goals of protecting riparian corridors, water quality, and other stream resources. The following data offers a starting point for establishing appropriate practices that contributes to water quality and stream resource protection.

These reviews and our understanding of these reviews should be viewed as our best understanding and professional judgment about the scientific information available. It is reasonable that additional studies exist, but it is likely that they will not conflict greatly with the information reported.

Three literature reviews were found that comprehensively examined published studies on recommended widths from the scientific community. They include:

Robins 2002 – Jones and Stokes, Environmental Consulting Firm. Provided a written memorandum to the Napa County Development and Planning Department regarding scientific justifications for proposed stream setbacks.

Fischer and Fischenich 2000 – Environmental Laboratory, U.S. Army Corps of Engineers Ecosystem Management and Restoration Research Program. Provide design recommendations for riparian corridors and vegetated buffer strips for Corps civil works and military projects, other federal agencies, and state and municipal authorities.

Wenger 1999 – Institute of Ecology, an extension of the University of Georgia. Purpose was to provide a scientific foundation for riparian buffer ordinances for local governments.

Many of the same studies were reviewed in each of these literature reviews. Recommended minimum riparian widths, as reported in scientific studies, for specific riparian functions were reported in all three literature reviews. For all three literature reviews, the buffer width reported applies to each side of the stream channel.

A comparison between Robins (2002) and Fischer and Fischenich (2000) reviews, found they identified nearly the same studies. The minimum riparian widths, as reported in these reviews, were combined. (A summary of this data is provided in Appendix B.)

Figure 5 is a summary of the recommended minimum riparian widths of the scientific studies as reported in the combined literature reviews (Robins 2002 and Fischer and Fischenich 2000) for specific riparian functions.

In addition to the literature review, Fischer and Fischenich (2000), identified minimum general riparian buffer strip recommendations. These recommendations are illustrated in Figure 6. It should be noted that they describe their recommendations as a "synopsis of values reported in the literature review." They also

Figure 5. Summary of scientific recommendations for stream buffers from Robins (2002) and Fischer and Fischenich (2000)

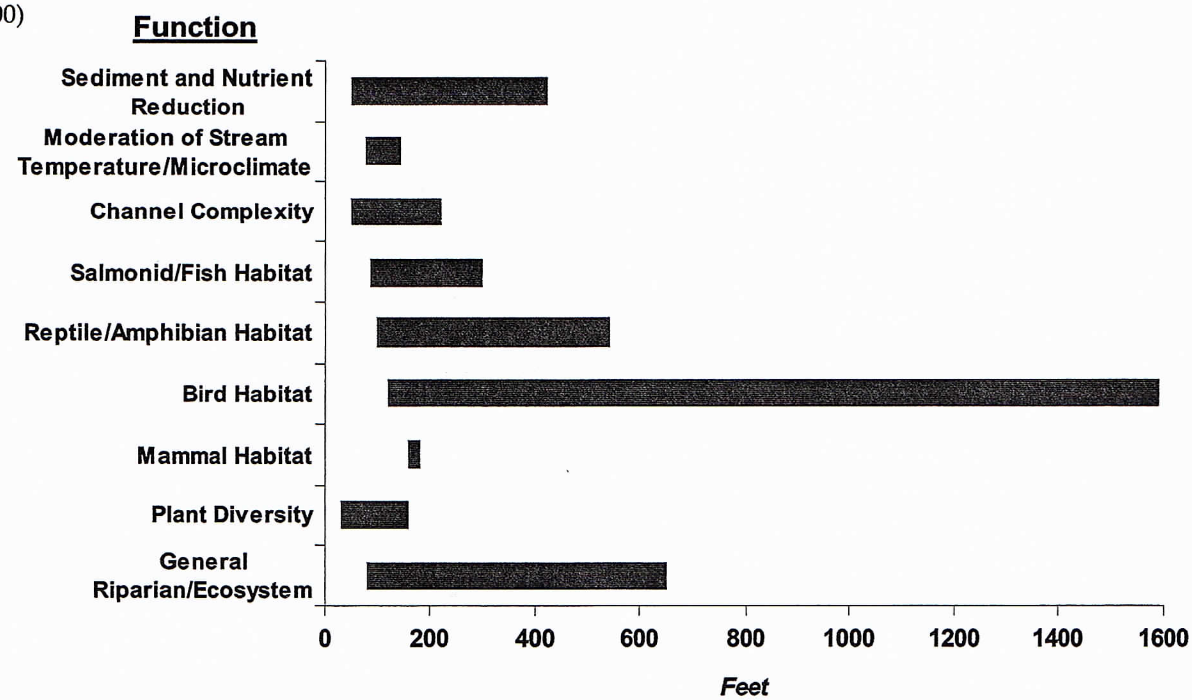


Figure 6. Summary of Fischer and Fischenich's (2000) minimum general recommendations for stream buffers based on a review of scientific literature.

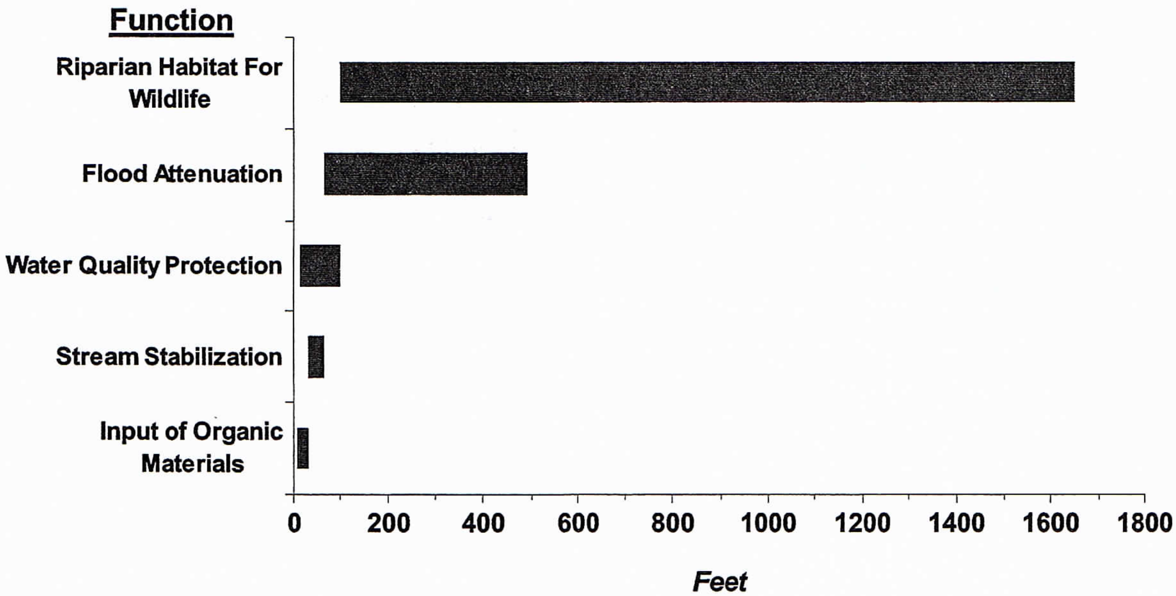
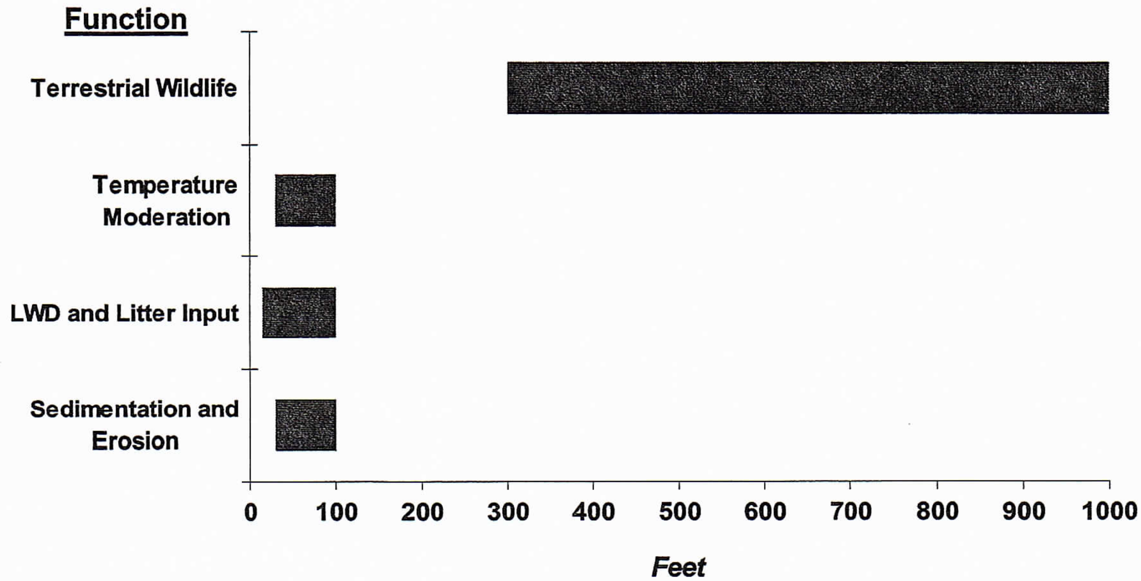


Figure 7. Summary of Wenger's (1999) minimum recommendations for stream buffers based on a review of scientific literature.



state that "recommended widths for ecological concerns in buffer strips typically are much wider than those recommended for water quality concerns" and "a few wildlife species require much wider riparian corridors" than recommended in the guidelines.

Wenger (1999) similarly reviewed relevant studies pertaining to recommended riparian corridor widths. For each riparian function discussed in this report, Wenger also formulated minimum recommendations based on the scientific literature. A summary of Wenger's (1999) recommendations is illustrated in Figure 7.

5. SANTA CLARA COUNTY CONDITIONS: ANALYSIS OF STREAMS, STREAM BUFFERS, AND AFFECTED PARCELS

Staff conducted a preliminary study to examine the extent of stream resources in the unincorporated areas, the number of potentially affected parcels, and other related information. The reported data was collected and analyzed using geographical information systems (GIS) to provide estimates of the data at a countywide scale. The buffer widths used in this analysis were for hypothetical purposes only and should not be considered as staff's proposed recommendations.

5. 1. Length of Streams

The unincorporated area of Santa Clara County contains approximately 574 miles of natural streams selected from United States Geological Survey (USGS) blue-line streams. This nationally standardized data set identifies streams through field conducted surveys, remotely sensed data (aerial, satellite, and other types of imagery), and historical maps. Of the USGS identified streams in the unincorporated area, approximately 80% of the stream length has been delineated as intermittent streams and 20% as perennial (see Table 4). Ephemeral streams are not identified in this dataset.

Approximately 555 miles (97%) of the USGS blue-line streams in the unincorporated area are found outside of the Urban Service Areas (USAs). Outside of USAs, approximately 441 miles (79%) of streams are intermittent and the remaining 114 miles (21%) perennial. Approximately 19 miles (3%) of the USGS blue-line streams in the unincorporated area are found inside USAs. Intermittent streams comprise 18 (94%) miles of streams in the unincorporated areas within the USAs and 1 mile (6%) is perennial. (see Table 4)

Table 4. Length of identified natural USGS blue-line streams in the unincorporated areas.*

	Intermittent	Perennial	Total
Inside USA	18.2	1.2	19.4
Outside USA	440.9	113.8	554.7
Total	459.1	115.0	*574*

**All values in Miles*

5. 2. Parcels Containing Streams

Staff analyzed the number of privately owned parcels in the unincorporated area that have identified USGS blue-line streams crossing them.

5. 2. 1. Outside Urban Service Areas

The analysis found 15,107 privately owned parcels in the unincorporated area outside of USAs. Approximately 3,457 (23%) privately owned parcels contain a USGS blue-line stream. The median size of all privately owned parcels in the unincorporated area outside of the USAs is approximately 2.4 acres, while the median parcel size of those parcels containing a USGS blue-line stream is approximately 20.1 acres.

Table 5 and Figure 8 include data on privately owned parcels outside of USAs that are potentially affected by USGS streams.

Figure 8. Analysis of privately owned parcels outside USAs potentially affected by identified natural USGS streams and stream buffers.

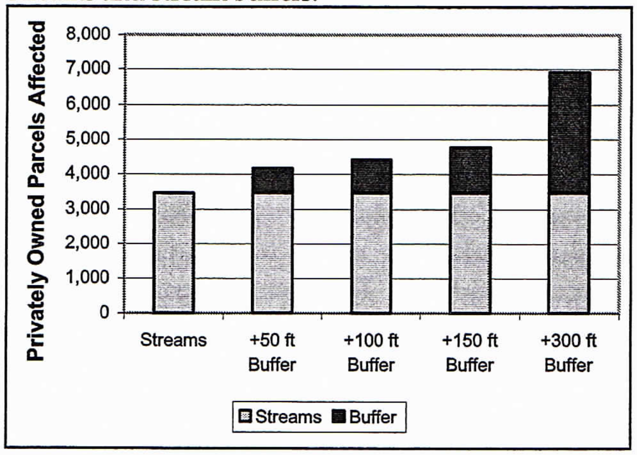


Table 5. Analysis of privately owned parcels outside USAs and analysis of those potentially affected by identified natural USGS streams and stream buffers.

	Parcels			% of Total Parcels	Median Parcel Size (Acres)	# of Unique Parcel Owners
Total Parcels Outside USA*	15,107			--	2.4	11,651
Parcels Affected By:	**Streams**	**Buffer**	**Stream + Buffer**			
Streams	3,457	--	3,457	23%	20.1	2,374
50 ft Buffer	3,457	704	4,161	28%	14.9	2,840
100 ft Buffer	3,457	954	4,411	29%	12.1	3,069
150 ft Buffer	3,457	1,310	4,767	32%	10.3	3,331
300 ft Buffer	3,457	3,458	6,915	46%	4.4	5,189

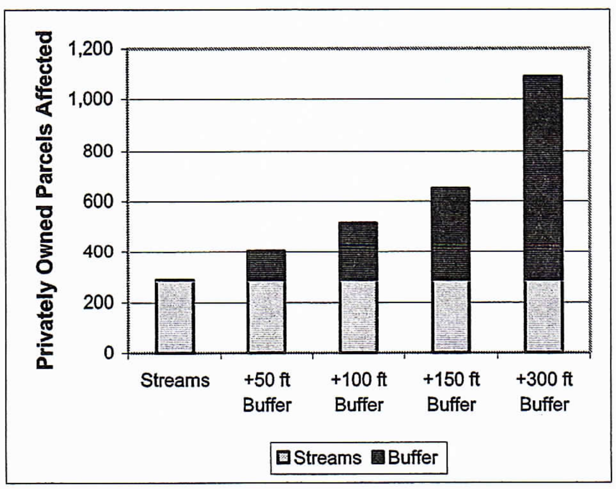
*This is not a total of the parcels affected. It includes all parcels outside USAs.

Table 6. Analysis of privately owned parcels inside USAs and analysis of those potentially affected by identified natural USGS streams and stream buffers.

	Parcels			% of Total Parcels	Median Parcel Size (Acres)	# of Unique Parcel Owners
Total Parcels Inside USA*	16,518			--	0.2	15,568
Parcels Affected By:	**Streams**	**Buffer**	**Stream + Buffer**			
Streams	285	--	285	2%	0.9	271
50 ft Buffer	285	117	402	2%	0.7	383
100 ft Buffer	285	232	517	3%	0.6	494
150 ft Buffer	285	363	648	4%	0.5	621
300 ft Buffer	285	804	1,089	7%	0.3	1,045

*This is not a total of the parcels affected. It includes all unincorporated parcels inside the USAs.

Figure 9. Analysis of privately owned parcels inside USAs potentially affected by identified natural USGS streams and stream buffers.



5. 2. 2. Inside Urban Service Areas

The analysis found 16,518 privately owned parcels in the unincorporated areas inside the USA. Approximately 285 (2%) privately owned parcels contain a USGS blue-line stream. The median size of all privately owned parcels in the unincorporated area inside the USA is approximately 0.2 acres, while the median parcel size of those parcels containing a USGS blue-line stream is approximately 0.9 acres.

Table 6 and Figure 9 include data on privately owned unincorporated parcels inside USAs that are potentially affected by USGS streams.

5. 3. Stream Buffers

Staff analyzed stream buffers of 50, 100, 150, and 300-feet widths to gain a better understanding of how many private parcels would be affected by varying buffer widths. The buffer widths were used for hypothetical purposes and are not necessarily widths recommended by staff.

5. 3. 1. Outside Urban Service Areas

Outside the USAs, 4,161 private parcels would be affected by a 50-foot buffer width or nearly 28% of the 15,107 total privately owned unincorporated parcels. Likewise, a 100-foot buffer would affect 4,411 parcels or 29% of the total private parcels. The data from these analyses as well as 150 and 300-foot buffer widths can be found in Table 5 and Figure 8.

Another analysis was completed to determine the total land area the buffers would cover.

Based on the analysis, a 50-foot buffer would cover approximately 27,916 acres or 4% of the total land area outside of the USA. Data for the other buffers analyzed are contained in Table 7.

Table 7. Analysis of the area outside of USAs and portion of area potentially covered by stream buffers.

	Acres	% of Area Outside USAs
Total Area Outside USAs	641,285	--
50ft Buffer	27,916	4.4%
100ft Buffer	47,203	7.4%
150ft Buffer	72,503	11.3%

5. 3. 2. Within Urban Service Areas

Within the USAs, 402 private parcels would be affected by a 50-foot buffer width or nearly 2% of the 16,518 total privately owned unincorporated parcels. Likewise, a 100-foot buffer would affect 517 parcels or 3% of the total privately owned parcels. The data from these analyses as well as 150 and 300-foot buffer widths can be found in Table 6 and Figure 9.

Staff determined it was not appropriate to determine the total area buffers cover inside the USAs. Although streams have been identified on unincorporated parcels, the extent of their buffers cover land that is not exclusively unincorporated land within USAs and would therefore not accurately represent the situation.

5. 4. Building Permits Issued

Staff examined how many building permits would be affected by hypothetical stream buffer widths using a geographical information system (GIS). However, staff did not examine whether the building site on these parcels would have actually encroached within the buffered area. Data for this type of analysis is not readily available to determine this at a countywide level.

For this investigation, staff examined building permits issued for new residential units that received final approval over a 2-year period. During the 2-year period between the 2000-2001 calendar years there were 552 building permits issued for new residential units that received final approval. The total number of building permits for new residential housing units receiving final approval was 330 in 2000 and 222 in 2001. The building permits in this analysis are a sample of the total issued. Updates to the database used to record parcel information has been modified since then enabling an information match for 237 (72%) of the 330 permits for 2000 and 179 (81%) of the 222 permits for 2001.

5. 4. 1. Outside Urban Service Areas

This analysis found 55 parcels outside of the USAs that were issued building permits receiving final approval and were affected by identified USGS blue-line streams between the 2-year (2000-2001) period. If a 50-foot stream buffer were created, 65 of the building permits receiving final approval issued during the 2-year period would occur on a parcel within the 50-foot buffer and would possibly be subject to a riparian impact review. Similar analyses were completed for 100-foot, 150-foot, and 300-foot buffers. Table 8 contains the data related to these analyses.

Table 8. Parcels where building permits were issued for new residential units that received final approval and potentially affected by streams or stream buffers.

	Building Permits Issued					
	2000		2001		Total (2000-2001)	
	Within USA	Outside USA	Within USA	Outside USA	Within USA	Outside USA
Total Parcels Issued Building Permits[A, B]	69	168	69	110	138	278
Parcels Issued Building Permits[A] Affected By:						
Streams	5	33	3	22	8	55
50 ft Buffer	6	39	4	26	10	65
100 ft Buffer	7	44	4	29	11	73
150 ft Buffer	7	50	4	33	11	83
300 ft Buffer	12	66	6	41	18	107

A. Only includes building permits for new residential housing units that received final approval.

B. The total number of building permits for new residential housing units receiving final approval was 330 in 2000 and 222 in 2001. The building permits presented here are a sample of the total issued. Updates to the database used to record parcel information has been modified since then enabling an information match for 237 (72%) of the 330 permits for 2000 and 179 (81%) of the 222 permits for 2001.

5. 4. 2. Inside Urban Service Areas

This analysis found 8 parcels inside USAs that were issued building permits receiving final approval and were affected by identified USGS blue-line streams between the 2-year (2000-2001) period. If a 50-foot stream buffer were created, 10 of the building permits receiving final approval issued during the 2-year period would occur on a parcel within the 50-foot buffer and would possibly be subject to a riparian impact review. Similar analyses were completed for 100-foot, 150-foot, and 300-foot buffers. Table 8 contains the data related to these analyses.

5. 5. Notes

All information regarding unincorporated parcels potentially affected by streams and stream buffers of varying widths are dependent on the data and type of analysis performed. Given the variable mapping accuracy of the various data layers involved, staff cannot ascertain with absolute precision the exact number of parcels affected. While staff deems this information to be reliable, its accuracy cannot be guaranteed.

6. CONCLUSIONS AND NEXT STEPS

The purpose of this report has been to provide essential, but not exhaustive, information and analysis that will form part of the basis for the County's evaluation of a riparian protection ordinance. It purposely does not draw conclusions at this time or contain staff recommendations for the content or applicability of such an ordinance.

The process to date has been to preview with the Planning Commission and the public potential approaches to adopting a riparian protection ordinance and to conduct research requested by the Planning Commission and the public.

The next steps in the process will be for staff to conduct additional mapping research and evaluation of streams and stream buffer widths. Staff will also develop scenarios illustrating how a potential riparian ordinance would apply to various types of development and lot sizes, which will be used to further inform the Commission and the public the effects of various approaches or types of ordinances for private property.

No firm date has been set for the next Planning Commission hearing regarding these issues. Staff intends to keep the Commission and the public informed through the Planning Office's website, www.sccplanning.org, and reports to the Commission.

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APPENDICES

APPENDIX A

County Riparian Ordinance Questionnaire (November 2002) Results

County	Setback Distance	Basis for Distance
Alameda	20 ft. with possible extension to cover riparian habitat.	Flood protection, bank stability
Marin	50 ft. - East Marin 100 ft. - Central and West Marin	Location, Local Coastal Plan & General Plan findings
Monterey	100 to 200 ft.	Land/coastal policy
Napa	Less than 1% slope - 25 ft. More than 60% slope - 150 ft.	Slope variability Propose to change setbacks- biological classification of creeks. Class I - 150 ft., Class II - 75 to 125 ft., Class III - 25 ft.
San Benito	30 ft. - intermittent streams 50 ft. - perennial streams 100 ft. lake, wetland, estuary, lagoon or natural body of standing water	Grading Ordinance, type of stream
San Bernadino	200 ft.	Biologist expertise
San Luis Obispo	50 ft. - urban streams 100 ft. -wetland & rural streams	Type of waterway
San Mateo	20 ft. for existing structures. 30 ft. intermittent streams 50 ft. - perrenial streams 100 ft. lakes, ponds, and other wet areas. Where no riparian vegetation exists: 30 ft. from center of stream for intermittent streams 50 ft. from the high water point of stream for perennial streams	Type of stream
Santa Cruz	20 ft. -other woody vegetation habitat not considered to be riparian woodland 50 ft. - riparian woodland habitat	Type of habitat
Sonoma	50 ft. - urban & upland riparian corridor 100 ft. - flatland riparian corridor 200 ft. - Russian River riparian corridor Agricultural projects: 25 ft. - upland riparian corridor, 50 ft. -flatland riparian corridor, 100 ft. - Russian River corridor	Environmental factors such as slope density Propose to eliminate 50 ft. setback.- urban & upland riparian corridors would use 100 ft. setback instead.

APPENDIX B

Scientific Recommendations for Riparian Corridors Widths

This table was constructed by combining the literature review summaries in Fischer and Fischenich (2000) and Robins (2002). Irrelevant summaries were excluded.

Citation	Recommended Width/Range	Notes
	Sediment and Nutrient Reduction	
Corley et. al. 1999	>33 ft	
Nichols et. al. 1998	>60 ft	
Woodward and Rock 1995	>50 ft	The effectiveness of natural buffer strips is highly variable, but in most cases, a 15m natural, undisturbed buffer was effective in reducing phosphorus concentrations adjacent to single family homes
Desbonnet et. al. 1994	80 ft	
Peterson et. al. 1992	>33 ft	
Castelle et. al. 1992	>50 ft	
Schellinger and Clausen 1992	75 ft	
Welsch 1991	>85 ft	
Dillaha et. al. 1989	>30 ft	Removed an average of 84% of suspended solids
Gilliam and Skaggs 1988	290 ft	50% sediment deposition
Budd et. al. 1987	50 ft	
Jacobs and Gilliam 1985	50 ft	
Lynch et. al. 1985	98 ft	98ft buffer between logging activity and wetlands and streams removed an average of 75 to 80% of suspended sediments
Erman et. al. 1983	98 ft	
Lowrance 1984	60-120 ft	
Moring 1982	98 ft	
Young et. al. 1980	80 ft	
Erman et. al. 1977	98 ft	
Karr and Scholosser 1977	98-125 ft	75% removal
Broderson 1973	50-200 ft	One tree height
Wilson 1967	49 ft or 400 ft	49 ft for sand and 400 ft for clay
Horner and Mar 1982	>200 ft	Removed 80% of suspended sediments in stormwater
Ghaffarzadeh, Robinson, and Cruse 1992	>30 ft	Removed 85% of sediment on 7 and 12% slopes
	Moderation of Stream Temperature/Microclimate	
Lynch and Corbett 1990	100 ft	
Jones et. al. 1988	100-140 ft	
Lynch et. al. 1985	98 ft	

APPENDIX B

Citation	Recommended Width/Range	Notes
Steinblums et. al. 1984	75-125 ft	60-80% shade
Brosofske et. al. 1997	>145 ft	Buffers at least 145 ft wide are needed to maintain an unaltered microclimatic gradient near streams (could extend up to 984 ft in some situations)
	Channel Complexity	
Hewlet and Fortson 1982	50-100 ft	
Marcus 2002	4X bankfull width	
Chapel et. al. 1992	135-220 ft	
Lynch et. al. 1985	65-100 ft	
	Salmonid/Fish Habitat	
Ligon et. al. 1999	>150 ft	
USFS/BLM 1994	300 ft	
Welsch 1991	>85ft	
Moring 1982	>98	Increased sedimentation from logged, unbuffered streambanks clogged gravel streambeds and interfered with salmonid egg development. Buffer strips at least 98 ft wide allowed eggs to develop normally
	Reptile/Amphibian Habitat	
Burbink, Phillips, and Heske 1998	>325 ft	Wide areas (>3,250 ft) of riparian habitat did not support greater numbers of species of reptiles and amphibians than narrow areas (325 ft)
Semlitsch 1998	540 ft	
Buhlmann 1998	440 ft	Aquatic turtles may spend a greater proportion of a year in terrestrial habitat than in wetlands where they would have predicted to occur
Rudolph and Dickson 1990	98 ft	Recommend retaining riparian areas with mature trees at least 98 ft wide and preferably wider when forest stands are harvested.
	Bird Habitat	
RHJV 2000	250 ft	
Whitaker and Montevechi 1999	>160 ft	
Hagar 1999	>130 ft	Riparian buffers along forested streams are likely to provide the most benefit for forest-associated bird species if they are >130 ft wide
Kilgo et. al. 1998	>1600 ft	Buffer zones at least 1600 ft wide are necessary to maintain the complete avian community
Richardson and Miller 1997	>160	
Mitchell 1996	>325 ft	Need >325 ft buffers to provide sufficient breeding habitat for area sensitive forest birds and nesting sites for re-shouldered hawks

APPENDIX B

Citation	Recommended Width/Range	Notes
Hodges and Krementz 1996	>325 ft	Riparian strips >325 ft were sufficient to maintain functional assemblages of the six most common species of breeding Neotropical migratory birds
Spackman and Hughes 1995	450 ft	90% of species diversity
Keller, Robins, and Hatfield 1993	>325 ft	Riparian forests should be at least 325 ft wide to provide some nesting habitat for area-sensitive species
Gaines 1974	>325 ft	Provide riparian breeding habitat for California yellow-billed cuckoo populations
Tassone 1981	>160 ft	Many Neotropical migrants will not inhabit strips narrower than 160 ft
Mammal Habitat		
Dickson 1989	>160 ft	The minimum width of streamside management zones that will maintain gray squirrel populations is about 160 ft
Plant Diversity		
Spackman and Hughes 1995	30-100 ft	90% species diversity of vascular plants
General Riparian/Ecosystem Functions		
Levey et. al. 2002	>80 ft	
Spence et. al. 1996	98-145 ft	
Chapel et. al. 1992	160-650 ft	
Welsch 1991	>85ft	