Ecosystem 6

6.1 Overview

6.1.1 Geologic basis for biological diversity

The Laguna de Santa Rosa watershed is host to a wide variety of plant communities. The watershed's underlying geological formations provide the historical basis for this diversity, while its climate provides the mechanism for sustaining it. Understanding the interplay between functional ecosystems and clean water, requires a brief review of the patterns of physical and biological forces at work in the watershed.

An in-depth study of this is provided in Enhancing and Caring for the Laguna (Honton & Sears 2006). In brief summary: two great tectonic plates—the North Atlantic Plate and the Pacific Plate—are slipping past each other along the San Andreas Fault: in the past this movement triggered the Sonoma Volcanics that historically spread lava and ash over the Mayacama Range and Sonoma Mountain. This simple geologic activity was complicated when in former times a third plate—the Farallon Plate—subducted, forming the Coast Range. The highly diversified soils of the watershed are a direct result of these geological activities. In turn, this diversified substrate has given rise to a complex pattern of soils that have in turn supported a wide range of plant communities, supported by a climate characterized by an average annual rainfall ranging from 30 inches in the southern plain to 60 inches in the upper mountains. The watershed's diverse geology and wide climate range have together contributed toward the creation of an environment that supports many different types of plants, and an abundance of wildlife.

Today's expression of this geologic activity can be seen in the four distinct topographic zones that remain: mountains in the eastern half of the watershed, a level plain in the central watershed, the Laguna floodplain along the western edge of the plain, and a short line of hills along the far western edge of the watershed. This simplified view of the watershed's topography is useful when thinking in conceptual terms about ecosystem processes as they relate to water quality. In this part of the document we've chosen to model the watershed using this simplified view, and have developed two broad conceptual models of the relationship between water and biology: one for the upper watershed (which is a surrogate for the mountains in the east and the hills in the west) and one for the lower watershed (which is a surrogate for the central plain and floodplain.)

6.1.2 Biological diversity timeline

A conceptual model of biological diversity over time has been sketched out as a means to understand loss and gain of ecologic potential. (Figure 6-1). In this model the x-axis represents the two and one half century time period from 1800 to 2050, while the y-axis represents biodiversity gain or loss—as expressed through the impacts on upper trophic level species (e.g. slaughter of top predators) or direct habitat alterations (e.g., nutrient and sediment excesses). The estimate of biodiversity sketched out on this chart is conceptual rather than quantitative, and thus has no unit markers along the y-axis. The bases for the chart are the historical narrative accounts cataloged by the Laguna Foundation during the development of the restoration and management plan, *Enhancing and Caring for the Laguna*. References to these first hand accounts appear in Volume I of the plan on pages 338-343.

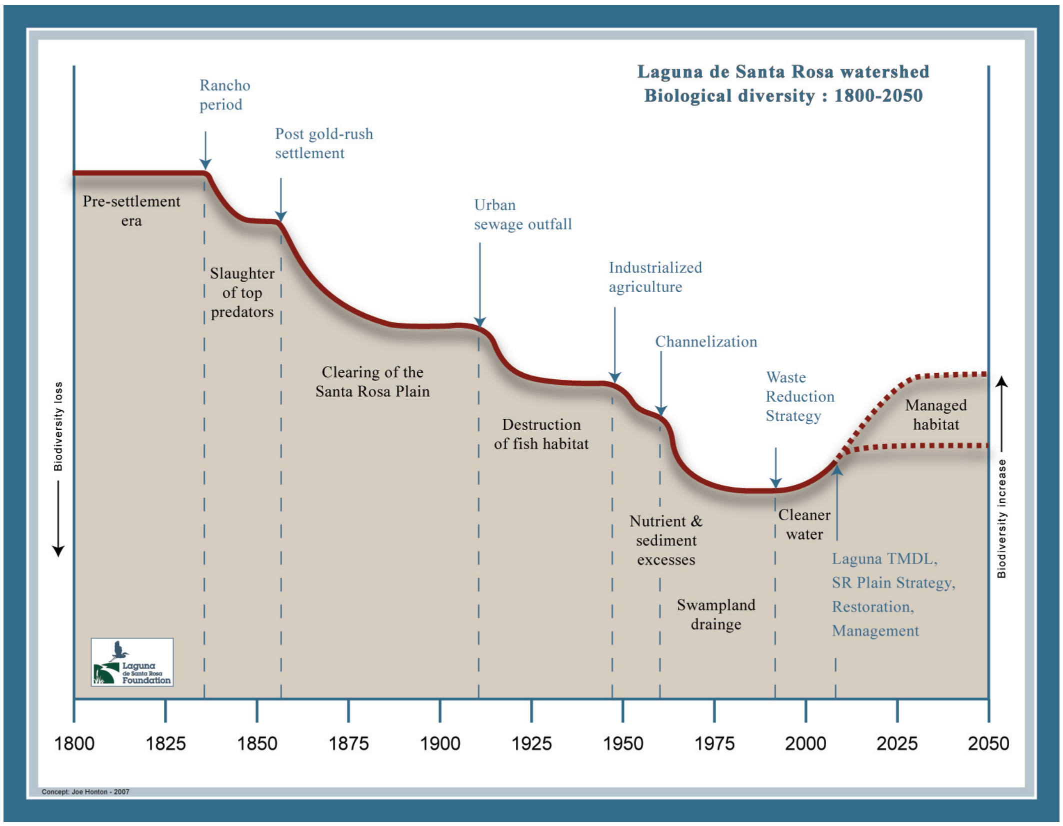

Figure 6-1
Biological diversity 1800-2050

As shown on the chart, biodiversity loss has occurred in stages, with rapid declines occurring in five stages, each stage followed by a period of new stability at a lower level. At the very end of the 20th century, a reversal of the downward trend is shown, with a hopeful upward trend beginning. Two projected trend-lines are plotted for the future, one at the existing plateau, the other at a slightly higher level. The lower trend line predicts a future based on the status quo; the upper trend line predicts a future based on the promulgation of a Laguna TMDL, implementation of the Santa Rosa Plain Strategy, and progress made towards the goals set forth in the Restoration and Management Plan.

Historical interpretation of events in the watershed as they relate to water quality are provided here to aid in reading the chart.

Pre-settlement

Very little documentation is available regarding the intentional tending of the landscape by the inhabitants of the eight Miwok- and Pomo-speaking villages known to have been situated along the Livantuyolomí (Tcétcewani, Butswáli, Kápten, Cakákmo, TciLeton, Kacíntui, Masikawáni, and Batíkletcawi) during the early decades of the 19th century. Human habitation in the watershed is commonly thought to have had some role in its active stewardship even prior to recorded history. Whether this pre-historic tending created an impaired system or an enhanced system is not known. For the purpose of this conceptual model, the pre-settlement era is regarded as a time of high biodiversity, where severe impairments and biological extinction were more likely due to natural phenomenon (fires, floods, earthquakes, landslides, etc.) than to human use.

Rancho period

Exploration by the Russians (1808-1841), the Spanish (1813-1820), the Mexicans (1820-1848), and later the Americans (1848-onward) revealed a landscape that supported grizzly bears, wolves, elk, pronghorn, beavers and condors, as well as other large predators and scavengers. Trapping by the Hudson's Bay Company and the Russian-American Company just prior to the Rancho period eliminated the beaver: it is curious—but speculative—to imagine what the absence of these ecosystem engineers has meant to the water bodies of the watershed.

The first Rancho period inhabitants, beginning in the early 1840s, brought with them cattle, sheep and horses which were free-ranged over the plains and foothills. In order to protect these domesticated livestock from predation, a concerted effort to eliminate the area's top carnivores was carried out. Simultaneous with the effort to eliminate the large carnivores, the hide and tallow trade capitalized on the rich fat obtainable from the Tule Elk, and through over-hunting, eliminated them from the watershed by 1851. Soon after, hunters supplying the dinner tables of the then-booming San Francisco market, wiped out the pronghorn. In terms of water quality, the presence of tens of thousands of free-range cattle, is thought to have resulted in localized patches of riparian vegetation thinning, possibly triggering the first artificially induced stream bank erosion.

Post Gold Rush

Soon after the Gold Rush, a wave of settlement occurred in the watershed, with the newcomers seeking a new type of gold—wheat. The Santa Rosa Plain was cleared of its many valley oaks to make way for large fields of wheat. Oak wood from the cleared plain was turned into charcoal and sent by barge from Petaluma to San Francisco. In terms of water quality, this conversion of the plain to agriculture, meant that fields were seasonally plowed, sown, and reaped—a disturbance regime that almost certainly induced large sheet and rill erosion. This extended period—from the early 1850s through the late 1930s—was characterized by family farmers with 40-, 80-, or 160-acre farms. Agriculture in this period was diversified, with grapes, prunes, apples, wheat, potatoes, hops and livestock growing side-by-side. Fertilizers were home-grown mixtures of composted material and manure and would have been too highly-prized to waste: fertilizer run-off into nearby streams probably was not a problem.

Irrigation though was a limiting factor, and profitable farms had to be situated alongside nearby streams that flowed year-round. In the Laguna, this meant placing farms in the floodplains of Gravenstein Creek, lower Irwin Creek, Santa Rosa/Matanzas Creeks, Mark West Creek, and lower Windsor Creek. Pumping and diversion of water from these creeks would have reduced the quantity of summertime flow towards the Laguna and the Russian River somewhat, but no anecdotal stories have been uncovered to suggest that downstream water shortages were a problem in the watershed. In terms of water quality, farming in the floodplain certainly contributed to wintertime erosion from fields that had been cultivated the prior season, although no evidentiary record exists to suggest its magnitude.

Turn of the century

During this time the city of Santa Rosa had grown as new markets opened with the installation of the railroad. By the first decade of the 20th century, this new populace was complaining about the stench from too many poorly designed effluent ditches, which prompted the public works department to construct pipes whose outfall was Santa Rosa Creek downstream of the city (and upstream from the Laguna.) A similar, but smaller effort was conducted by Sebastopol. This direct discharge of wastewater into these waterways led to the watershed's third marked decrease in biodiversity (see chart) as fish were killed and their habitat was polluted. The impact to the waterway is believed to have also extended to the aquatic invertebrate, bird and mammal populations—a ripple effect in the food web.

Industrialized agriculture

Industrialized agriculture arrived immediately after the conclusion of World War II as munitions factories nationwide were converted to fertilizer factories and as diesel powered tractors became increasingly affordable. This new style of farming allowed the early adopters to effectively dominate the market, producing bumper-sized crops year after year. This new way to farm resulted in winners and losers and the eventual consolidation of some of the smaller farms. In terms of water quality, the affordability of fertilizer—and the predictability of increased yields—may have been inducement enough to apply excessive amounts of fertilizer to fields. The later 1940s probably marked the beginning of excess nutrients to the Laguna.

Channelization

The growing population within the county—coupled with the beginnings of the trend to seek alternatives to life in Santa Rosa—reached the point where it became politically desirable to convert the poorly drained areas north and west of Cotati. The areas just east and west of Stony Point Road were the subject of a roads project which was simultaneously designed for passage and drainage—even today the ditches that flank either side of each road act as a dendritic network for surface drainage.

By 1960 the conversion of the formerly marshy areas north of Cotati—which had been used for decades as a seed farm—was in full swing as the City of Rohnert Park sprang up. The growth of Rohnert Park west of Highway 101 was checked by the temporary enactment of urban growth boundaries, forestalling the complete conversion and development of the area. In terms of water quality, the loss of these former marshes represents a significant spatial shift in water and sediment transport. The large alluvial plain that fans out at the base of Sonoma Mountain was created over millennia as the waters of Copeland, Hinebaugh, Hunter, and Five Creeks hit the level plain, lost energy, and dropped their sediment loads. Periodic avulsions allowed these creeks to reposition themselves to low spots on the plain, thus creating a shifting zone of deposition.

Today's urban use of the area (east of Highway 101) makes it imperative to keep water in well defined channels: regular maintenance of these artificial channels are needed to keep them free of cobbles, gravel, sand, and silt. In terms of water quality this is a big issue: how can maintenance designed with an eye towards public safety and property protection be carried out in a way that safeguards fish habitat and protects riparian resources? This part of history is yet to be played out.

The historic trend in channel confining activities, both east and west of Cotati/Rohnert Park, using former design criteria, will continue to lead towards more water and more sediment reaching the Laguna west of Stony Point Road. Because of our need for public safety and property protection, the ultimate fate of sediment originating in the Sonoma Mountain foothills will either have to be east or west of the cities. Again, history will await the decisions made over the next decade, regarding management of this issue, to see if this becomes a water quality problem or a water quality solution.

Waste Reduction Strategy

In 1995 the North Coast Regional Water Quality Control Board promulgated the Waste Reduction Strategy for the Laguna de Santa Rosa in response to the seasonally high levels of ammonia and low amounts of dissolved oxygen levels caused by excessive nutrient loadings. By 1998, this phased TMDL had made enough of an impact that the Laguna was removed from the 303(d) list of impaired water bodies, but by 2002, the Laguna was again placed on the 303(d) list, this time for sediment, nitrogen, phosphorus, low dissolved oxygen, and temperature. In 2006 the listing for mercury was added. A new TMDL to address these impairments is expected in the 2008–2011 timeframe.

6.1.3 Endangered species

A chart of the rare (threatened or endangered) species found in the watershed is shown in Figure 6-2. The chart is laid out as a cross-sectional diagram slicing the watershed at approximately its midpoint, from east to west. Along the bottom of the chart, seven of the watershed's eighteen regions are listed (as the cross-section does not bisect all regions) together with key features seen in the landscape, such as named mountains, plains and hills. Above the elevation profile-line ten distinct habitat communities are listed and ten columns of species names are shown. For each habitat community, the rare species that are found in that community are listed under one of three headings: 1) federally listed species are at the top; 2) California species of concern are in the middle; and 3) species of local concern are at the bottom. Each of these are described in detail in the paragraphs below, with particular emphasis placed on species that are affected by water quality concerns.

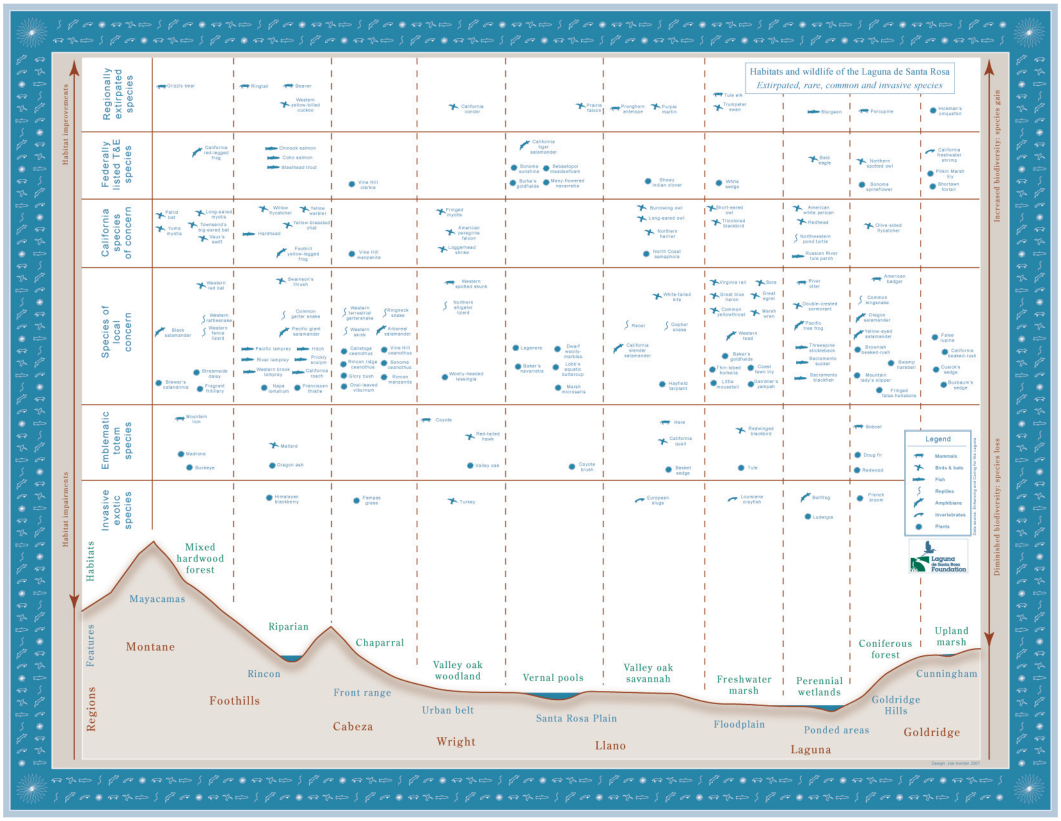

Figure 6-2
Habitats and wildlife
(see full-sized inset)

Figure 6-2 also lists species that have been extirpated from the watershed since 1850, although no further documentation of these are provided in this report. Emblematic species, which are common and occur ubiquitously, are listed on the chart for reference–these are subjective and are included to give flavor to the chart and to emphasize one of the RMP's goals which was to "keep common species common." Finally, invasive exotic species are shown on the chart because these are the targets of many of our management efforts.

Federally listed species

At a different scale, we also looked at species and communities as they relate to water quality. The Federal Endangered Species Act of 1973 (FESA) provides special protection to species when they become officially listed as threatened or endangered, with greater emphasis being placed on animals than plants. Many species that are listed as threatened or endangered (T&E) are known to inhabit the watershed. While developing the watershed-scale conceptual models, it became apparent that special models needed to be considered to provide an understanding of how water quality issues relate to the survival and revival of these T&E species (Table 6-1). Official consultations regarding the disturbance of species or their habitats are under the jurisdiction of the US Fish and Wildlife Service, with the exception that migratory fish that spend part of their life cycle in marine water are under the jurisdiction of NOAA's National Marine Fisheries Service.

Not all of the species listed in Table 6-1 have an easily discernable connection to water quality. In the notes below, the T&E species that have a strong connection to water pollution are discussed.

Of particular note are Coho *(Oncorhynchus kisutch),* Chinook *(Oncorhynchus tshawytscha),* and Steelhead *(Oncorhynchus mykiss)* and their need for passage, spawning habitat, and rearing habitat. These anadromous fish need unobstructed passageways from the Pacific Ocean to spawning areas in the upper Mark West Creek and Santa Rosa Creek tributaries. The peak of this migration occurs between January and March for Steelhead and between November through January for Coho. Chinook, which have not been found in recent years in the Laguna watershed, have an upstream migration season—in the main stem of the Russian River—between September and November, and a downstream emigration between February to June. Downstream emigration for Coho occurs between February and mid-May. In contrast to Coho and Chinook, Steelhead juveniles remain year round in fresh water and are more impacted by the warmer temperatures of the Laguna than by fish passage concerns (USACE 2004). For successful breeding these anadramous species require:

- upstream gravel beds with properly-sized cobles,
- adequate water depth,
- appropriate water temperatures (e.g., 13-17°C),
- a tolerable stream velocity, and
- a lack of excessive siltation, which smothers eggs and hampers gill function.

California freshwater shrimp *(Syncaris pacifica),* which occur within the Laguna watershed only in Blucher Creek, deserve special consideration in terms of water quality. Pollution in the form of high algal production and high ammonia from nearby dairies is implicated in their recovery plan as being of key concern. Loss of riparian cover and encroachment from rural residential neighbors is also of concern (USFWS 1998). The possibility of a link between poorly designed or failing septic systems—suspected to occur in the area—and shrimp decline, is a question which deserves further research.

California red-legged frogs *(Rana aurora draytonii),* known to occur on Taylor and Sonoma Mountains, require dense, shrubby or emergent riparian vegetation located near still or slow moving water. Pools that are deep, fringed by cattails and surrounded by overhanging willows are ideal. A nearby well-vegetated riparian corridor provides the best habitat for wintertime aestivation (USFWS 1996).

Among the plants listed in Table 6-1, White sedge *(Carex albida)* is one of the rarest and has a direct connection to waterway impairment: the marsh which was the type locality for the plant—at the confluence of Santa Rosa Creek and the Laguna—was destroyed in the 1960s by channelization. A second marsh where it was known to occur, on the City of Sebastopol's Meadowlark Field, was destroyed through the repeated application of cannery waste from 1971 to 2001, causing the loss of the population (USFWS 1997). Other threats to this plant include the possibility of habitat loss from hydrological alterations.

The remaining species in Table 6-1 are not directly impacted by poor in-stream water quality. Nevertheless, summer irrigation using reclaimed wastewater, and increased atmospheric nitrogen deposition near major roads (Gluesenkamp and Wirka 2006, Fenn et al 2003) may impact several listed T&E plants (e.g., Sonoma sunshine, Burke's goldfields, Sebastopol meadowfoam); these are plants that are adapted to low nitrogen conditions in vernal pool systems on the Santa Rosa Plain. This deserves further research.

Table 6-1
FESA-protected species occurring in the watershed

Species	Common name	Taxonomy	Federal status
*Rana aurora draytonii**	California red-legged frog	Amphibian	Threatened
*Oncorhynchus mykiss**	Steelhead trout	Fish	Threatened
*Oncorhynchus kisutch**	Coho salmon	Fish	Endangered
*Oncorhynchu tshawytscha**	Chinook salmon	Fish	Threatened
*Syncaris pacifica**	California freshwater shrimp	Invertebrate	Endangered
*Carex albida**	White sedge	Plant	Endangered
Ambystoma californiense	California tiger salamander	Amphibian	Threatened
Lilium pardalinum	Pitkin Marsh lily	Plant	Endangered
Alopecurus aequalis	Sonoma alopecurus	Plant	Endangered
Strix occidentalis caurina	Northern Spotted Owl	Bird	Threatened
Chorizanthe valida	Sonoma spineflower	Plant	Endangered
Clarkia imbricata	Vine Hill clarkia	Plant	Endangered
*Lasthenia burkei***	Burke's goldfields	Plant	Endangered
*Blennosperma bakeri***	Sonoma sunshine	Plant	Endangered
*Limnanthes vinculans***	Sebastopol meadowfoam	Plant	Endangered
Navarretia leucocephala	Many-flowered navarretia	Plant	Endangered
Potentilla hickmanii	Hickman's cinquefoil	Plant	Endangered
Trifolium amoenum	Showy Indian clover	Plant	Endangered

* *Species significantly impacted by poor water quality.*
***Species potentially impacted by summer irrigation with reclaimed waste water or atmospheric N deposition from major roads on the Santa Rosa Plain.*

California listed species

The California Endangered Species Act of 1984 (CESA) provides additional protection to rare species that are not listed under FESA. In some cases species listed under the federal law have received less protection than needed—in the opinion of California state experts—and have accordingly been given a higher status under California law. Bald eagles, for example, are listed by the California Department of Fish and Game as endangered, a higher level of protection than afforded by the federal threatened classification. The species known to occur within the watershed that are listed as threatened or endangered under California law, but not under federal law (or to a lesser status under federal law), are listed in Table 4-2. Official consultations regarding the disturbance of these species or their habitats are under the jurisdiction of the California Department of Fish and Game.

Bald eagles *(Haliaeetus leucocephalus)*, which beginning in 2005 were observed regularly in the CDFG Laguna Wildlife Area along the Laguna (J. Honton, pers. obs.), have a strong connection to open water habitat and fish abundance. As generalist raptors Bald eagles, eat fish, small mammals, and waterfowl. Cloudy water has been implicated by researchers in the Everglades as an impediment to successful hunting by osprey and other raptors (Regan 1996). Nearby perching and nesting sites on strong limbed mature trees, such as pines or Douglas firs, are also needed for a viable habitat.

The American Peregrine Falcon *(Falco peregrinus anatum),* which was listed federally as endangered until delisting in 1999, is still listed as endangered under CESA. Peregrine Falcons likely target blackbirds, ducks, and pigeons in the Laguna. It is well known that falcons can adapt urban environments into suitable nesting and feeding habitat; nevertheless, the more traditional open-water and emergent marsh habitats—which have diminished in size in the watershed—are thought to support falcons better. A reversal of the declining trend in perennial ponds and emergent marshes should favor the revival of falcons as well as other more common raptors.

Table 6-2
CESA-protected species occurring in the watershed

Species	Common name	Taxonomy	California status
Haliaeetus leucocephalus	Bald Eagle	Bird	Endangered*
Falco peregrinus anatum	American peregrine falcon	Bird	Endangered
Coccyzus americanus occidentalis	Western yellow-billed cuckoo	Bird	Endangered
Empidonax traillii	Willow Flycatcher	Bird	Endangered
Arctostaphylos densiflora	Vine Hill manzanita	Plant	Endangered
Pleuropogon hooverianus	North Coast semaphore	Plant	Rare

** The Federal Eagle Protection Act of 1940 provides special protections to Bald Eagles and Golden Eagles (both of which are known to occur in the watershed) preventing the taking of eagles. Significantly in this context, disturbance of their nests and their immediate habitat during nesting season is subject to regulatory permits.*

The Western yellow-billed cuckoo *(Coccyzus americanus occidentalis),* which has not been observed in the Laguna in the past decade, is associated with large contiguous stands of riparian habitat comprised of cottonwoods and willows—a dense understory also appears to be an important factor in their habitat selection. In general, declines throughout their range have been attributed to degradation and fragmentation of riparian habitat, overgrazing, and a shift in native riparian woodland species to non-natives species. Also implicated in their decline are altered stream flow and sediment regimes, channelization, bank protection measures and similar flood control management practices (USFWS 2001).

The Willow flycatcher *(Empidonax traillii)*, is an insectivorous bird inhabiting dense riparian stands of willows. In the spring it migrates north from Mexico searching for suitable breeding and nesting sites; in the autumn it returns south. Suitable summertime foraging habitat includes moist brushy thickets, open second-growth, and riparian willow and buttonbush, with even linear narrow riparian strips providing suitable food supply. Breeding habitat is typically moist meadows with perennial streams; tree-formed willows, cottonwoods, alders, and small spring-fed areas. (Craig 1998) Areas in the watershed that approach this description are found in the Occidental Rd. to River Rd. reach of the Laguna: this is the area most heavily impacted by sediment deposition which in turn has caused the demise of the mature willow forest.

The two plants species in Table 6-2 are not directly impacted by poor water quality.

The California Department of Fish and Game also provides another type of protection to species which do not fit the criteria for being listed as threatened or endangered; this protection is to list a species as being of special concern. A species of special concern is so listed due to declining population levels, limited ranges, or continuing threats that have made the species vulnerable to extinction. These are listed in Table 6-3.

Foothill yellow-legged frogs *(Rana boylii)* inhabit partially shaded riffle patches of shallow perennial streams containing cobble-sized rocks occurring in chaparral, open woodland and forested areas. They attach their eggs to cobbles and boulders in low-velocity streams and wide shallow reaches near tributary confluences. This species responds well to stream channels that have been restored through "bank feathering" (NatureServe 2006). Suitable habits are in the upper watershed where localized sediment deposits may impact its persistence.

Northwestern pond turtles *(Emys marmorata)* inhabit perennial ponds that have islands of vegetation where they can bask. In the Laguna they are frequently observed near Sebastopol. Additional suitable habitat include the creeks and man-made channels in the watershed that have in-stream logs or other anthropogenic refuge areas where predators cannot reach adults or their eggs. Straight, heavily maintained channels, such as found throughout the Santa Rosa Plain, are poor habitats.

Redheads *(Aythya americana)* inhabit seasonally flooded wetlands with persistent emergent vegetation. They forage on the rhizomes and tubers of aquatic vegetation, as well as on aquatic invertebrates including crustaceans, mollusks and insects. (Mitchell 1993) In the Laguna, cattails and tules are a likely habitat for Redheads, with mature tule seeds providing food. The intentional removal of cattails and tules for mosquito and flood control may be a limiting factor in their local abundance.

American white pelican *(Pelecanus erythrorhynchos)* are fish feeders and need large open water bodies for feeding habitat. A recent restoration project in the Laguna—the Hummock and Swale project in the CDFG Laguna Wildlife Area—was very successful at attracting a squadron of these birds immediately after its completion in 2003. The area's large population of introduced Louisiana crayfish *(Procambarus clarkii)* is also thought to be an important part of their local diet. The Laguna is at the far northern edge of their winter range.

Olive-sided flycatchers *(Contopus cooperi)* are nearctic-neotropical migrants, with the Laguna at the southern edge of their summertime range: they typically arrive in May. Their preferred habitat consists of montane and coniferous forests, often associated with forest openings and edges, especially those with snags or live trees that provide foraging and singing perches. They are frequently found along streams, lakes and wetlands where natural edge habitat and standing dead trees occur. Their prey is almost exclusively flying insects, including bees, wasps, beetles, flies, moths and dragonflies (Kotliar 2007). The most likely habitats for Olive-sided flycatchers in the Laguna watershed are the eastern edge of the

Goldridge hills adjacent to the standing water of the Laguna. Lack of natural fire-created openings in the forest has been cited in other areas as being a limiting factor, but the lack of regular insect foraging habitat may be more limiting in the Laguna, especially in otherwise suitable habitats that are adjacent to orchards and vineyards which employ insecticides.

Table 6-3
California species of special concern occurring in the watershed

Species	Common name	Taxonomy	California status
*Rana boylii**	Foothill yellow-legged frog	Amphibian	Special concern
Emys marmorata *	Northwestern pond turtle	Reptile	Special concern
*Aythya Americana**	Redhead	Bird	2nd level concern
*Pelecanus erythrorhynchos**	American white pelican	Bird	1st level concern
Circus cyaneus	Northern harrier	Bird	2nd level concern
Athene cunicularia hypugea	Burrowing owl	Bird	1st level concern
Asio otus	Long-eared owl	Bird	2nd level concern
Asio flammeus	Short-eared owl	Bird	2nd level concern
Chaetura vauxi	Vaux's swift	Bird	3rd level concern
Contopus cooperi	Olive-sided flycatcher	Bird	2nd level concern
Progne subis	Purple martin	Bird	1st level concern
Lanius ludovicianus	Loggerheaded shrike	Bird	2nd level concern
Dendroica petechia	Yellow warbler	Bird	2nd level concern
Icteria virens	Yellow-breasted chat	Bird	3rd level concern
*Agelaius tricolor**	Tricolored blackbird	Bird	1st level concern
Myotis evotis	Long-eared myotis	Mammal	Special concern
Myotis thysanodes	Fringed myotis	Mammal	Special concern
Myotis yumanensis	Yuma myotis	Mammal	Special concern
Corynorhinus townsendii	Townsend's big-eared bat	Mammal	Special concern
Antrozous pallidus	Pallid bat	Mammal	Special concern
Bassaricus astutus	Ringtail	Mammal	Special concern
*Mylopharodon conocephalus**	Hardhead	Fish	Special concern
Hysterocarpus traskii spp. *pomo**	Russian River tule perch	Fish	Special concern

* *Species significantly impacted by poor water quality.*

Tricolored blackbirds *(Contopus cooperi)* nest in cattails, tules, and a variety of other species found in flooded areas that are defensible against mammalian predators. Tricolors will not roost/nest without access to open water, and will avoid narrow strips of emergent vegetation along channels. Tricolors favor agriculturally productive habitats such as irrigated pasture, maturing grain crops and dairies. Foraging tricolors are particularly attracted to ephemeral pools. As an endemic North American bird species with a narrow habitat range, Tricolored Blackbirds are at a far greater risk than other widely distributed endangered species such as Swainson's Hawks and Burrowing Owls, but because they are a flocking species, and are in some places abundant, they often fail to command much conservation attention. (Hamilton 2004) In the Laguna the encroachment of hayfields in the floodplain and the loss of cattail and tule stands are likely limiting factors.

Hardhead *(Mylopharodon conocephalus)* are bottom feeders that forage for benthic invertebrates and aquatic plant material in quiet water. Hardhead require large to medium-sized, cool to warm-water streams with natural flow regimes for their long-term survival. Younger fish feed primarily on mayfly larvae, caddisfly larvae, and small snails; while adults feed more on aquatic plants, crayfish, and other large invertebrates. Hardhead prefer clear, deep pools with sand-gravel-boulder substrates and slow water velocities. Low oxygen levels are implicated as an impairment to their natural habitat. The specialized habitat requirements of Hardhead, combined with alteration of downstream habitats makes them vulnerable to local extirpation (CDFG 1995a). The most likely habitat for Hardhead in the Laguna watershed are the local stream pools of the upper Mark West and Santa Rosa Creek.

Russian River tule perch *(Hysterocarpus traskii spp. pomo)* are specially adapted to the unpredictable flow conditions of the Russian River system. These Tule perch require clear, flowing water and deep pools together with abundant cover, such as beds of aquatic macrophytes, submerged tree branches, and overhanging plants which are used by the young as a refuge from predators. Tule perch feed on benthic and plant-dwelling aquatic invertebrates. In the Laguna, a population of Tule perch survived for a number of years in a deep water pond near Cotati / Rohnert Park, but this population is now gone. They are usually absent from polluted water with reduced flows, high turbidity and lack of cover; alterations to these habitat conditions are the most significant threats to their survival (CDFG 1995b).

Townsend's Big-eared bats *(Plecotus townsendii)* live in a variety of communities, including coastal conifer and broadleaf forests, oak and conifer woodlands, arid grasslands and deserts, and high-elevation forests and meadows. Throughout most of its geographic range, it is most common in mesic sites (Kunz and Martin, 1982).

6.2 Available data for analysis

Efforts at compiling existing data focused on the recently published reference sources within *Enhancing and Caring for the Laguna* (Honton and Sears 2006) and available GIS layers in the Laguna Foundation geo-database. Additional information was obtained via the Russian River Interactive Information System (RRIIS), from the Sonoma County Water Agency Website, and was made available to us by City of Santa Rosa staff and USDA/ARS researchers.

6.2.1 Laguna de Santa Rosa watershed fish and aquatic habitat surveys

Sonoma County Water Agency

As part of a Fisheries Enhancement Program, the Sonoma County Water Agency (SCWA) conducts wildlife and habitat studies aimed at endangered Salmonid species within the Russian River watershed. The fish and habitat monitoring program contains several Russian River tributaries, including Mark West Creek, Santa Rosa Creek and Millington Creek within the Laguna de Santa Rosa watershed.

The aim of the salmonid monitoring program was to detect trends in salmonid populations and identify possible fisheries management and enhancement opportunities (Cook & Manning 2002). The program began in fall 1999 with a pilot study to collect detailed distribution, habitat use and juvenile abundance data in streams of the Russian River basin, sampling five of its tributaries via electrofishing and snorkel surveys for three years (Cook & Manning 2002).

Table 6-4 (a)
Fish species composition and relative abundance by channel type in Mark West Creek in 2000

Species	F4 Channel	Lower B2 channel	C4 Channel	Upper B2 channel
CA Roach	70%	61%	33%	0%
Green sunfish	<1%	0%	0%	0%
Lamprey Amnoceoete	7%	14%	3%	0%
Three-spined Stickleback	1%	0%	0%	0%
Sculpin	14%	3%	52%	0%
Steelhead	<1%	19%	52%	100%
Tule Perch	1%	0%	0%	0%
Sacramento Sucker	7%	3%	0%	0%

Table 6-4 (b)
Fish species composition and relative abundance by channel type in Santa Rosa Creek in 1999-2001

Species	F4 Channel*			C4 Channel			B2 channel		
	1999	2000	2001	1999	2000	2001	1999	2000	2001
CA Roach	50%	25%	-	35%	26%	33%	<1%	0%	0%
Pikeminnow	<1%	0%	-	<1%	0%	0%	0%	0%	0%
Hardhead	<1%	0%	-	0%	0%	0%	0%	0%	0%
Bluegill	1%	<1%	-	1%	<1%	<1%	0%	0%	0%
Lamprey Amnocoete	5%	8%	-	5%	5%	11%	1%	<1%	0%
Three-spined Stickleback	1%	2%	-	5%	3%	<1%	0%	0%	0%
Sculpin	9%	54%	-	29%	52%	47%	26%	32%	33%
Steelhead	2%	10%	-	14%	11%	8%	73%	68%	67%
Sacramento Sucker	32%	1%	-	6%	3%	1%	0%	0%	0%
Green sunfish	0%	<1%	-	5%	<1%	<1%	0%	0%	0%
Redear Sunfish	0%	<1%	-	0%	0%	0%	0%	0%	0%
Mosquitofish	0%	0%	-	0%	<1%	0%	0%	0%	0%
Brown bullhead	0%	0%		0%	<1%	0%	0%	0%	0%

** Channel type F4 is closest to the Laguna de Santa Rosa confluence, and channel type B2 represents the extreme upper reach of the creek.*
** F4b channel in 2000. (adapted from Cook & Manning 2002).*

The three year study assessed both salmonid demographic data, and fish community species composition and abundance along a longitudinal creek profile from e.g. the confluence of Mark West creek with the Laguna de Santa Rosa to the creek headwaters in the mountains. Table 6-4 (a) shows fish species composition and relative abundance by channel type in Mark West Creek in 2000.

At present, the SCWA is no longer surveying Mark West, Santa Rosa, and Millington creeks (D. Cook pers. comm.). Extensive long-term datasets that incorporate fish demography, species composition and abundance along the creek profile are crucial in elucidating the natural variations in fish population abundance and community composition, and so are well suited to serve as reliable indicators for environmental changes affecting water quality. For example, Table 6-4 (b) shows a slight shift in species composition in Santa Rosa Creek from 1999 to 2001, showing an increased relative abundance of Sculpin, accompanied by a decrease in the relative abundance of Steelhead. It becomes apparent that three years are not long enough to get a comprehensive picture of the dynamics of the system. Long-term fish-survey programs are critically needed in order to determine whether observed fluctuations in Salmonid or other fish indicator species populations are due to natural or anthropogenic causes.

In addition, SCWA has prepared the Copeland Creek Restoration Project Monitoring Plan (Cook & Lamb 2001) to restore fish and wildlife habitat along this upper Laguna de Santa Rosa tributary. The plan outlines extensive surveys of stream profile, vegetation, stream habitat, fish, reptiles, amphibians, birds, and small mammals. As part of these annual surveys this effort will identify habitat used by steelhead, quantify aquatic habitats, and characterize streambed composition to evaluate salmonid spawning and habitat value. Data from this program will be very valuable to assess the habitat and water quality along this tributary creek. Data collections have been ongoing, and a monitoring report is forthcoming (D. Cook pers. comm.)

California Department of Fish and Game

Stream inventory reports from California Department of Fish and Game (CDFG) are available for several tributaries of the Laguna de Santa Rosa: Santa Rosa Creek, North Fork Santa Rosa creek, Blucher creek, and Copeland creek The latest inventories were conducted during the summer of 1998 for Santa Rosa Creek and North Fork Santa Rosa Creek, and in July & August of 2001 for Copeland and Blucher creeks. All inventories followed the methodology presented in the California Salmonid Stream Habitat Restoration Manual (Flosi et al. 1998), sampling approximately 10% of habitat units within the survey reach. Due to inadequate staffing levels, no biological surveys were conducted for Copeland, Blutcher and North Fork Santa Rosa creeks as part of these most recent inventories. In the North Fork Santa Rosa Creek, Steelhead trout and Sculpin were observed and noted during the habitat inventory (CDFG 2000a). A biological inventory of Santa Rosa Creek is available, and Table 6-5 shows aquatic fauna observed in historical and recent CDFG/SCWA surveys.

Table 6-5
Aquatic fauna observed in historical and recent CDFG/SCWA surveys

Years	Species	Source	Native/ Introduced
1954, 1957, 1958, 1973, 1975, 1991, 1998, 1999	Steelhead	CDFG/SCWA	N
1998	Brown Bullhead	SCWA	I
1973, 1975, 1977, 1991, 1999	Sculpin	CDFG/SCWA	N
1954, 1957, 1973, 1975, 1977, 1991, 1999	Roach	CDFG/SCWA	N
1954, 1957, 1991, 1999	Sacramento Sucker	CDFG/SCWA	N
1977, 1991, 1999	Stickleback	CDFG/SCWA	N
1999	Blue Gill	SCWA	I
1954, 1957, 1991, 1999	Green Sunfish	CDFG/SCWA	I
1999	Hardhead	SCWA	N
1954, 1999	Pike Minnow	CDFG/SCWA	N
1973, 1991, 1999	Lamprey Amnocoetes	CDFG/SCWA	N
1977	Crayfish	CDFG	N/I
1954	Carp	CDFG	I
1957	Largemouth Bass	CDFG	I
1957	Catfish	CDFG	I
1998	Tree Frog	SCWA	N
1998	Bull Frog	SCWA	I

** Historical records reflect fish transfer operations in 1974 (CDFG 2000b).*

City of Santa Rosa

Macroinvertebrate Surveys

The City of Santa Rosa stormwater monitoring program includes a professional benthic community survey for six creeks within the Santa Rosa urban boundary. Benthic macroinvertebrate (BMI) sampling has been conducted at set monitoring sites along Brush, Colgan, Matanzas, Paulin, Piner, and Peterson creeks by City of Santa Rosa staff from 1998-2005. BMI samples are sent to a certified laboratory (SLSI in Chico, CA) each year and processed and evaluated according to the appropriate regional Index of Biotic Integrity (norCal IBI, Rehn and Ode, in press).

Results indicate that each of the six monitoring reaches are in very poor biological condition and that conditions are similarly poor for most years (Sustainable Land Stewardship Institute 2005). In 2005, the total number of benthic taxa at all sites only ranged from 8 to 15, very low when compared to the average 37 for reference conditions in Northern California. Most of the invertebrates collected in 2005 (chironomids, oligochaeta, and beatids) tolerate sedimented streams and have no need for complex habitats (Sustainable Land Stewardship Institute 2005). Further, a high percentage of collector and filterers and the presence of Oligocheata worms indicated organic enrichment at all six sites in 2005.

Overall, none of the sites was in better condition compared to the other sites (Sustainable Land Stewardship Institute 2005). Physical habitat condition at all six sampling reaches has been rated good to fair throughout the four years of determining scores, suggesting that improved biological condition would be expected with improved water quality (Sustainable Land Stewardship Institute 2005).

Creek bioassays

The City of Santa Rosa conducts bioassay tests to determine whether storm water runoff is impacting the water quality in creeks that support fish populations (City of Santa Rosa 2005). Toxicity is measured by exposing twenty rainbow trout fry (15-30 days of age) under controlled conditions to 100% sample water for 96 hours, noting percent survival. Bioassay samples were collected from eight sampling sites within the Santa Rosa urban boundary during the 2004-2005 rainy season (City of Santa Rosa 2005). Table 6-6 shows the results for two samples per site, overall showing no significant effects on trout survival at most sites.

Table 6-6
Bioassay results 2004-2005 - City of Santa Rosa 2005

Sampling Location	First Flush October 19, 2004	Representative Storm May 4, 2005
Peterson Creek @ Fulton Road	100%	100%
Matanzas Creek @ Hoen Frontage Rd	100%	95%
Paulin Creek @ Mendocino Avenue	100%	100%
Brush Creek @ Hwy 12	100%	90%
Colgan Creek @ Bellevue Road	100%	80% (65%)
Piner Creek @ Marlow Road	100%	100%
Santa Rosa Creek @ Melita Road	100%	100%
Santa Rosa Creek @ Piner Creek	100% (100%)	100%
Controls	90% (100%)	100% (100%)

* *Duplicates shown in parentheses.*

Environmental field data accompanied results from each sampling location, indicating conditions that meet basin plan objectives for pH, and odors for all sites. Elevated turbidity levels were observed in Santa Rosa and Peterson creeks. The representative storm at Santa Rosa creek exceeded basin plan objectives for temperature with a difference of 5.4 degrees F (City of Santa Rosa 2005).

Invasive *Ludwigia* sp. research

Exotic Uruguayan primrose-willow (*Ludwigia* sp.) has aggressively spread in recent years and has impacted sensitive wetlands of the Laguna de Santa Rosa and greater Russian River watershed. While non-invasive members of the same genus (*Ludwigia peploides* spp. *peploides* and *L. palustris*) are extant in the watershed aquatic plant community, the invasive *Ludwigia* sp. is a fast-spreading, perennial, creeping emergent weed. The invasive *Ludwigia* sp can rapidly form extensive dense floating mats that displace native vegetation and open water habitat, degrade water quality, increase flood risk, and inhibit effective mosquito control. Definitive species identification and management recommendations throughout California have been complicated by variable growth responses of this invasive to environmental conditions.

Dr. Brenda Grewell, a research ecologist with the USDA-Agricultural Research Service has initiated ecological, cytological and genetic studies in 2005 to confirm species identity in California and to assess factors influencing invasion success and so address a number of key uncertainties with regard to the *Ludwigia* sp. invasion. The overall goal of her research program is to understand the mechanisms that control the dynamics of aquatic and riparian plant communities and promote the invasion of exotic species, and to identify key factors that must be overcome for successful integrated weed management and wetland restoration.

The development of effective management strategies for invasive *Ludwigia* sp. control requires information regarding weed tolerance and response to a range of environmental conditions.

The current experimental invasive *Ludwigia* sp. research program includes:

- Identification of invasive *Ludwigia* sp. growth responses to biotic and abiotic factors
- Investigating life cycle vulnerability
- Study of the effects of invasive *Ludwigia* sp. growth and control strategies on native plant community restoration
- Invasive *Ludwigia* sp. establishment, growth, nutrient allocation, and decomposition dynamics across environmental gradients in field and mesocosm experiments
- Assessing sediment seed bank dynamics, plant and animal species interactions with invasive *Ludwigia* sp., ecological attributes and biogeochemical functions of reference and invaded wetlands
- Assessing the potential for directed succession of plant communities to inhibit invasive *Ludwigia* sp. establishment
- Investigation of the ecology and population controls of *Ludwigia* in its native range in South America (Uruguay and Argentina).

Ludwigia control project

The Laguna de Santa Rosa Foundation (LdSRF) is currently engaged in a three-year active invasive *Ludwigia* sp. control and removal program at two large invaded areas in the Laguna de Santa Rosa watershed: the Bellevue-Wilfred Channel, a Sonoma County Water Agency (SCWA) site near Rohnert Park, and the Laguna Wildlife Area, a California Department of Fish and Game (CDFG) site near Sebastopol. Vegetation monitoring completed prior to year two (2006) herbicide application and mechanical removal showed variable responses of *Ludwigia* depending on site conditions. Deeper and wider channels, present at the CDFG site and the SCWA site near Rohnert Park, showed very little re-growth after the prior year's removal. Invasive *Ludwigia* sp. must root in sediment and is therefore forced to begin at the bank and "creep" across the channel. In shallower channels where rooting is possible across the entire channel base, invasive *Ludwigia* sp re-growth was estimated at 54%. In the flooded wetlands of the CDFG site where vegetation could not be removed in year one, re-growth was widespread. However, the density of *Ludwigia* within this area was significantly reduced. Where 80% of the monitored plots had greater than 95% cover prior to year one, only 6% had the same cover in year 2. Greater species richness and open water were also observed following year one control activities (LSRF 2007).

Year two control acreages were expanded at both sites. Control methods employed in year two again included application of herbicide followed by mechanical removal where necessary and where feasible. The herbicide triclopyr (Renovate®) appeared to have greater efficacy than glyphosate in controlling *Ludwigia* and was applied at one-third the rate of glyphosate. Mechanical removal was limited to expanded control areas and to the Bellevue Wilfred Channel near Rohnert Park. Post-season monitoring at the CDFG flooded wetland site indicated that re-growth did occur after the herbicide application but that in the drier areas there was a marked increase in species richness. Dense patches of non-*Ludwigia* species occupied significant areas. True evaluation of the effect of year two will only be possible after monitoring in late spring 2007 (LSRF 2007).

The LSRF has initiated a yearly invasive *Ludwigia* sp. mapping and monitoring program in 2006, covering a subset of creeks in the Laguna de Santa Rosa watershed. This effort has yet to incorporate the distinction between the native *Ludwigia peploides* ssp. *peploides* and the invasive *Ludwigia* sp., the taxonomy of which is still unclear. Planned field training sessions with Dr. Brenda Grewell will allow Laguna de Santa Rosa Foundation staff to indicate these two species in future monitoring.

6.3 Ecosystem conceptual models

6.3.1 Model extent

In *Enhancing and Caring for the Laguna* (Honton & Sears 2006, Volume II, Appendix E), the Laguna was divided into eighteen distinct geophysical regions through a detailed analysis of surficial geology, topography and precipitation. For the purposes of this study, the boundaries to these eighteen regions are used, in aggregate form, to define the boundaries to the two conceptual models: six regions correspond to the lower watershed model; twelve regions correspond to the upper watershed model.

Table 6-7
Watershed regions as they correspond to the two conceptual models

Geophysical Region	Topographic zone	Conceptual Model
Taylor	Mountains	Upper watershed
Bennett	Mountains	Upper watershed
Matanzas	Mountains	Upper watershed
Los Guilicos	Mountains	Upper watershed
Cabeza	Mountains	Upper watershed
Montane	Mountains	Upper watershed

Foothills	Mountains	Upper watershed
Gossage	Goldridge Hills	Upper watershed
Blucher	Goldridge Hills	Upper watershed
Goldridge	Goldridge Hills	Upper watershed
Forestville	Goldridge Hills	Upper watershed
River	Goldridge Hills	Upper watershed
Cotate	Santa Rosa Plain	Lower watershed
Llano	Santa Rosa Plain	Lower watershed
Wright	Santa Rosa Plain	Lower watershed
Piner	Santa Rosa Plain	Lower watershed
San Miguel	Santa Rosa Plain	Lower watershed
Laguna	Floodplain	Lower watershed

6.3.2 Upland, riparian and stream knowledge bases

The draft Russian River Watershed Management Plan Synthesis Report for Baseline Watershed Assessment (Smith 2006) outlines logic networks for the Russian River watershed upland, riparian, and stream knowledge bases. These logic networks represent the key conceptual elements used to evaluate the upland, riparian and stream systems in the Russian River watershed, of which the Laguna de Santa Rosa is a small part. These networks contain the conceptual relationships that exist in the Laguna de Santa Rosa watershed at certain scales with respect to upland, riparian and stream conditions, as well as to the potential anthropogenic influences on these systems, and anadromous fish dynamics. Smith also incorporates networks of indicators of hydrologic alterations, upland, riparian and stream vulnerability.

We feel that these networks are directly applicable to the Laguna de Santa Rosa system and we therefore saw no need to repeat this portion of conceptual work. In addition, we will present specific models for the Laguna de Santa Rosa in the next section that show the more detailed dynamics of the upper and lower watershed, and the invasion of an exotic aquatic Primrose species (invasive *Ludwigia* sp.) into parts of the lower watershed. The next sections describe in more detail the Russian River knowledge bases and logic networks presented by Smith.

Upland knowledge base

The upland knowledge base reflects the proposition that upland areas of an assessment unit exhibit conditions within the range of natural variability regarding vegetation, fauna landscape patches, human disturbance, and fire regime. The upland knowledge base consists of three primary logic networks related to condition of habitat, human disturbance, and fire regime (Figure 6-3).

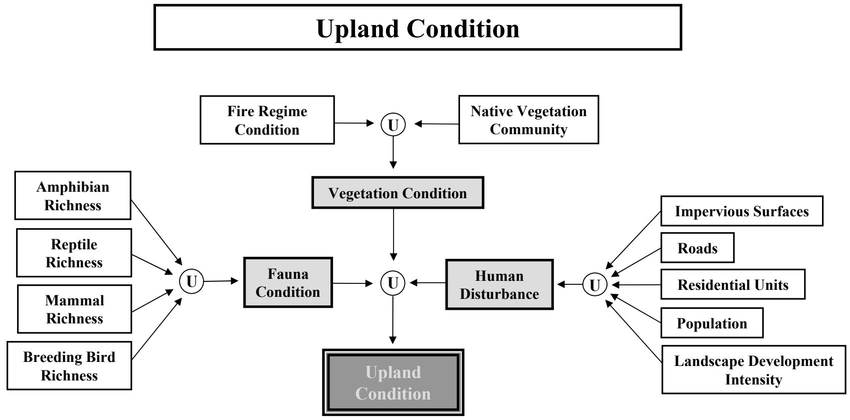

Figure 6-3 Upland condition knowledge base schematic (Smith 2006)

Riparian condition knowledge base

The Riparian condition knowledge base reflects the proposition that riparian areas along the main stem of each assessment unit show conditions within the range of natural variability with respect to vegetation, fauna, corridor structure, and hydrologic regime (Smith 2006). The knowledge base consists of four primary logic networks related to vegetation condition, fauna condition, corridor condition, and hydrologic condition (Figure 6-4).

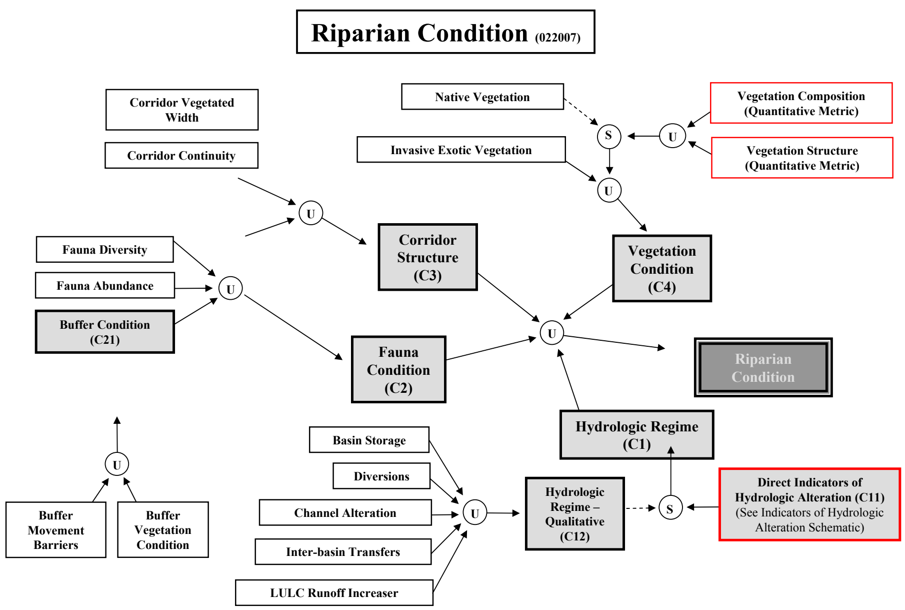

Figure 6-4 Riparian condition knowledge base schematic (Smith 2006)

Physical and chemical stream condition knowledge base

The physical and chemical conditions in the main stem stream channel of an assessment unit are, (1) within the range of natural variability, or (2) not subject to anthropogenic disturbances with the potential to alter physiochemical stream conditions, or (3) within the range of current water quality, flow, or other standards, objectives, or recommendations (Smith 2006).

The Physical and Chemical Stream Condition knowledge base includes logic networks for four key factors that influence physical and chemical conditions of a stream including: hydrologic regime, sediment regime, geomorphic condition, and water quality Figure 6-5. The Anthropogenic Sediment Erosion Potential knowledge base schematic is shown in Figure 6-6. Each logic network incorporates direct indicators that quantitatively represent important characteristics or processes related to physicochemical stream condition and indirect indicators that quantitatively, or qualitatively, represent anthropogenic disturbances with the potential to alter physicochemical stream conditions (Smith 2006). Switch nodes dictate that direct indicator data is used when available and indirect data when direct data is not available (Smith 2006). The Physical and Chemical Stream Condition truth value is the union of the truth values resulting from the hydrologic regime, water quality, geomorphic condition, and sediment regime logic networks.

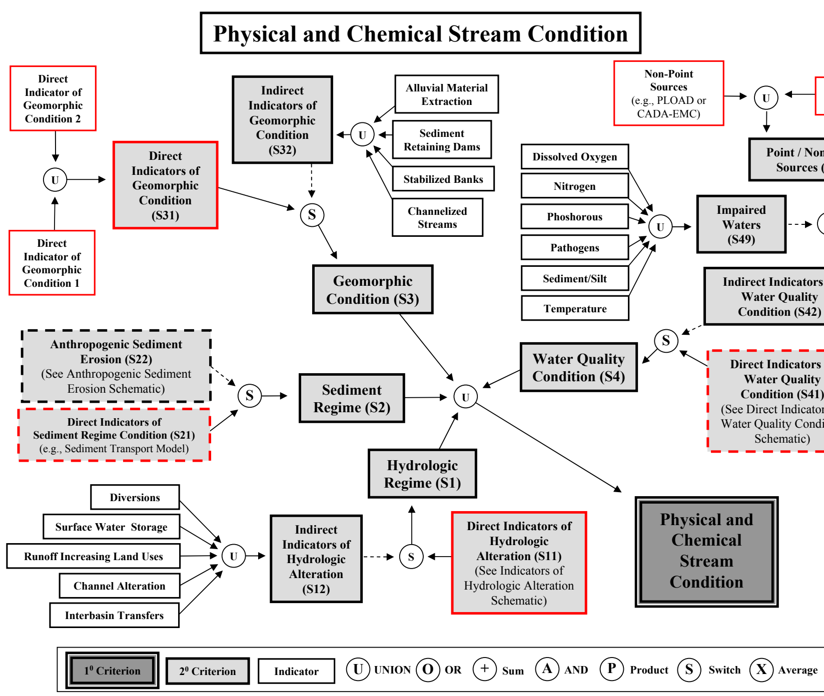

Figure 6-5 Physical and chemical stream condition knowledge base schematic (Smith 2006)

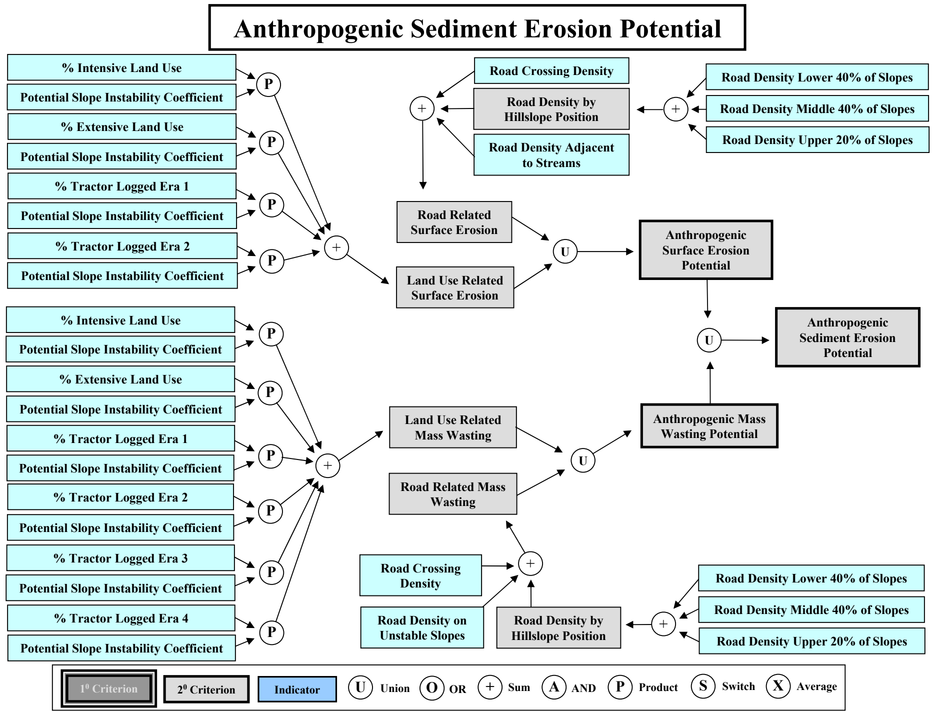

Figure 6-6 Anthropogenic sediment erosion potential schematic (Smith 2006)

Anadromous fish suitability

The main stem stream channel of an assessment area exhibits physical conditions that are either: (1) within the range of natural variability, or (2) within the range of existing regulatory standards (e.g., TMDL or other water quality standards) (Smith 2006). Also, the main stem stream channel of an assessment area, (1) meets the target habitat objectives for embeddedness, riparian canopy, primary pools, and upper water temperature established for North Coast salmonid bearing streams (tributary level) in the CDFG Russian River Basin Fisheries Restoration Plan (Coey et al. 2002), (2) meets the desired salmonid freshwater habitat condition established for sediments by the North Coast Regional Water Quality Board (NCRWQB), and (3) is not affected by downstream anadromous fish migration barriers (Figure 6-7). Coey developed four reach level variables to explain the state of salmonid habitat condition. These variables included riparian canopy, primary pools, upper water temperature, and embeddedness. The Anadromous Fish Suitability truth value is the union of Anadromous Fish Habitat Condition, the Physical Stream Condition, and the access barriers indicator truth values. Habitat Condition, the Physical Stream Condition, and the access barriers indicator truth values.

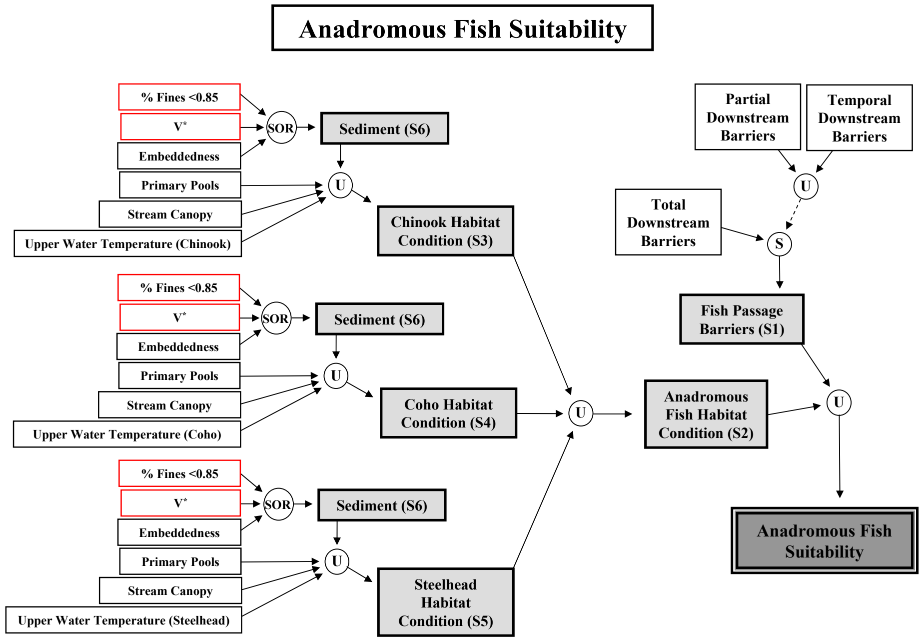

Figure 6-7 Schematic of the anadromous fish suitability knowledge base (Smith 2006)

Riparian vulnerability

Riparian areas along the main stem of an assessment area exhibit current conditions, or predicted future conditions, with the potential to reduce the truth value of the Riparian Condition criterion. The Riparian Vulnerability criterion schematic is shown in Figure 6-8 and the Indicators of Hydrologic Alteration is shown in Figure 6-9.

Riparian Vulnerability criterion is the union of the Hydrologic Regime, Proximity of Invasive Species, Human Stressors, and Development Potential criteria truth values, and the Land Ownership and Riparian Buffer Land Use / Land Cover indicator truth values (Smith 2006).

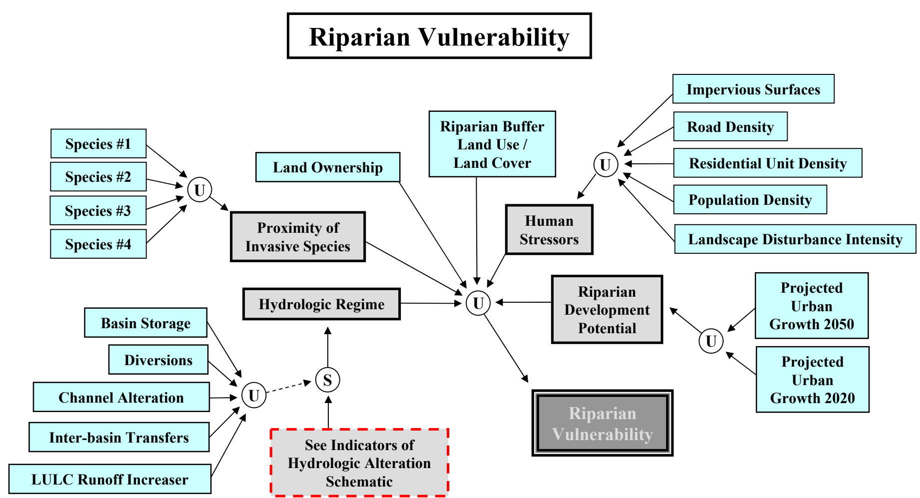

Figure 6-8 Riparian vulnerability knowledge base schematic (Smith 2006)

Indicators of hydrologic alteration

The main stem stream channel in an assessment area exhibits a hydrologic regime within the range of natural variability with respect to flow duration, frequency, and timing. Inter-annual and intra-annual variation such as seasonal flow patterns; frequency, duration, and predictability of floods, droughts, and intermittent flows, timing of extreme flows; daily, seasonal, and annual flow variability; and rates of change play a critical role in maintaining biodiversity and the evolutionary potential of aquatic, riparian, and wetland ecosystems (Poff and Ward 1989, Richter et. al. 1996, Olden and Poff 2003, and Nature Conservancy 2005). The indicators of hydrologic alteration truth values is the union of the magnitude of monthly conditions, magnitude and duration of annual extremes, timing of annual extremes, frequency and duration of high and low pulses, and rate and frequency of change truth values (Smith 2006).

Smith proposes further networks addressing restoration and conservation potential with respect to all three knowledge bases, and non-point sources, organic and inorganic chemicals, nutrients, dissolved oxygen, specific conductance with regard to the stream knowledge base (Smith 2006). With regard to integrating data nd information, Smith suggests Ecosystem Management Decision Support 3.1 (EMDS) as the most fitting data and information integration framework (Reynolds et al 1996, Reynolds et al 2000, Reynolds 2002, Reynolds and Hessburg 2005). As a mature ArcGIS extension, EMDS incorporates knowledge based model development with GIS, allowing the display of results, evaluation of the influence of missing data, scenario simulation, and priority analysis (Smith 2006). This type of modeling may prove fruitful with specific focus on the Laguna de Santa Rosa watershed.

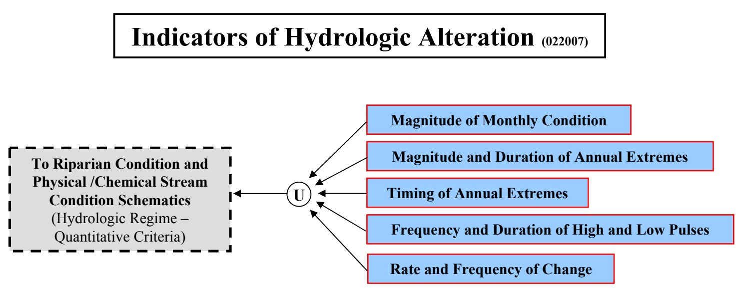

Figure 6-9 Indicators of hydrologic alteration knowledge base schematic (Smith 2006)

6.3.3 Upper watershed model

In specifically addressing the upper and lower Laguna de Santa Rosa watershed models, and a species-specific model regarding invasive *Ludwigia* sp. dynamics in sections of the lower watershed, we followed the framework for conceptual models outlined in Duever (2005) and in the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) Draft Framework for the Development of DRERIP Ecosystem Conceptual Models (May 2005). These approaches outline the conceptual relationships between drivers, stressors, effects, and attributes, showing the linkages between components, and can be applied to

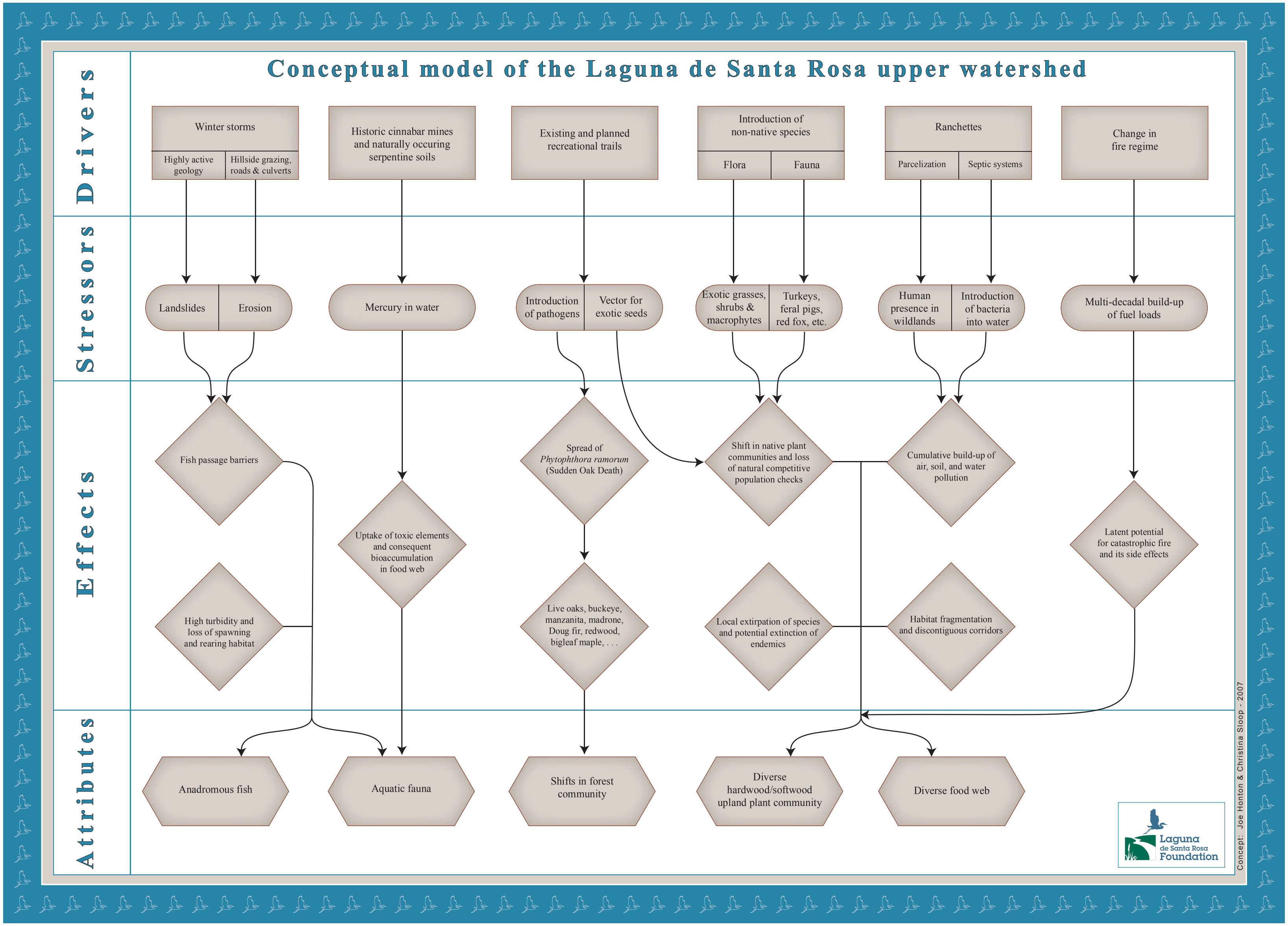

Figure 6-10
Conceptual model of upper watershed

several scales of investigation. This level of conceptual modeling may or may not incorporate directional relationship and various levels of predictability, depending on the status of available data.

The upper watershed conceptual model is laid out in four rows with one row each showing drivers, stressors, effects, and attributes, and with arrows representing the major connections between the model's components. Drivers are the large events, either natural or anthropogenic, that trigger responses in the environment. Some of these drivers occur synchronously, some periodically and some stochastically: only a few of them can be modulated with human endeavor. Stressors are the expression of these drivers in the environment: many of these stressors are the logical target of management decisions—with time and effort some of these stressors can be reduced. Effects are the observable changes in the environment: measurement of the magnitude of these effects gives us indirect feedback on the severity of the stressor. Finally, attributes are the tangible things in the environment (flora, fauna, water, soil, etc.) that are impacted by the effects.

The upper watershed model, as diagrammed in Figure 6-10, shows six key drivers:

- Winter storms in concert with a highly active geology that trigger landslides, especially on the Taylor Ridge; and winter storms in connection with hillside grazing, unpaved roads and driveways, and inadequately sized culverts that trigger sheet and rill erosion and cause fish passage barriers.
- Historic cinnabar mines and naturally occurring serpentine soils that leach mercury into the waterways.
- Existing and planned recreational trails that can act as a repeated source for the introduction of new pathogens (from footwear and tire treads), and these same trails acting as a vector for exotic invasive plants to enter upland habitats.
- The introduction of non-native flora including exotic grasses, forbs, shrubs, and macrophytes that cause a shift in native plant communities, the loss of natural competitive population checks, the potential for local extirpation of species, and the potential for extinction of endemics; and the introduction of non-native fauna such as turkeys, red fox, feral pigs and feral cats causing similar effects in habitat shift and local population loss.
- The presence of ranchettes in the watershed is a dual driver: Parcelization in its own right leads to increased human presence in the watershed, disruption of corridors, and additional pollutants to the soil, air, and water; while septic systems in particular—as they were often constructed on soils that didn't meet today's percolation standards—have added bacteria into the waterways, with unknown effects to the wildlife.
- Fire suppression and indeed an entire change in the fire regime have dramatically built up fuel loads in the mixed conifer/hardwood forests, leading to the latent potential for large-scale catastrophic fire and its side effects, including the potential for massive erosion, and the certain shift in the diversity of upland communities. This driver, if unleashed will have both beneficial and non-beneficial consequences: benefits will accrue from the release of closed-cone seeds as well as dormant subsoil ruderals that take advantage of disturbance.

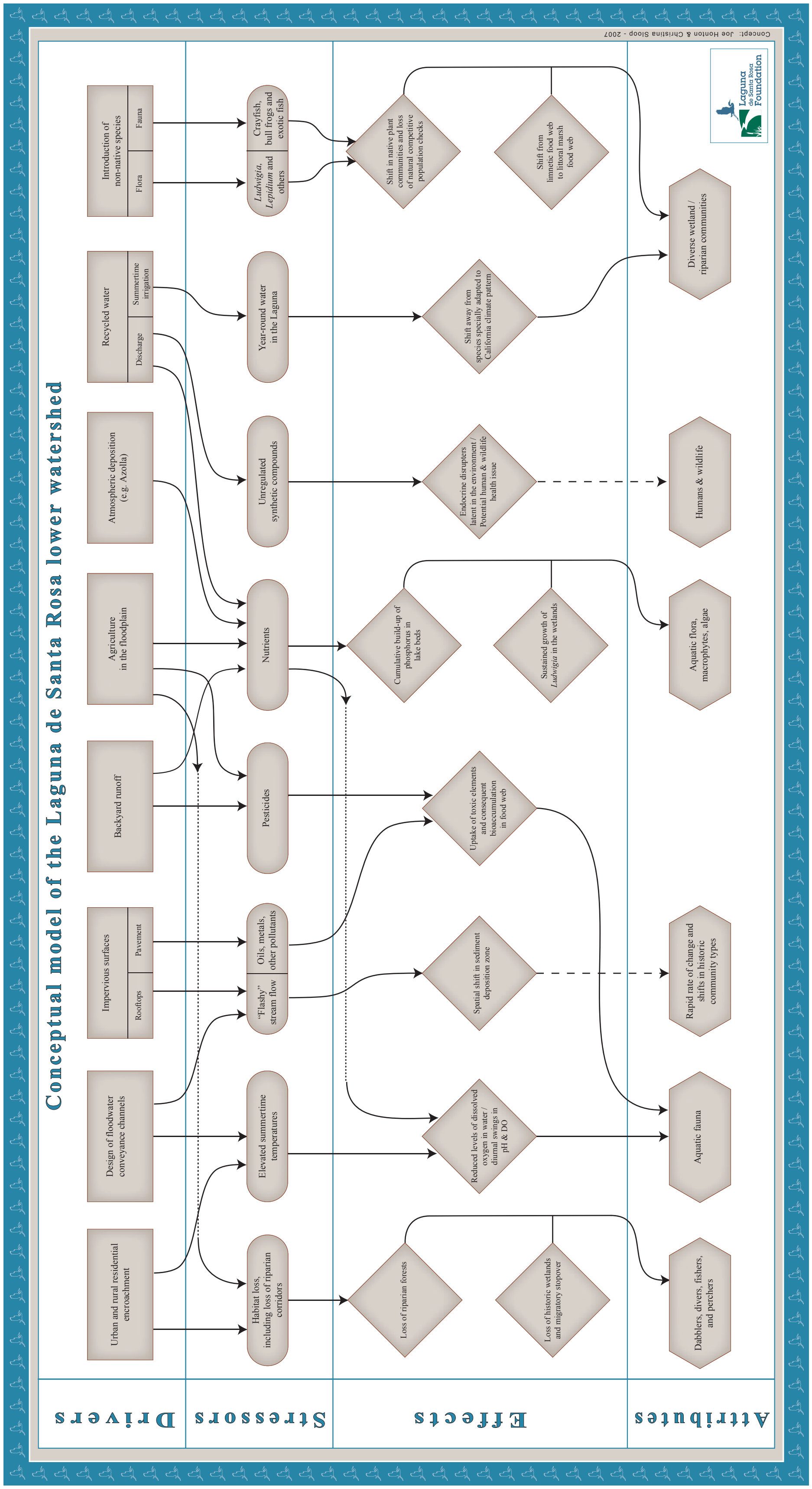

Figure 6-11
Conceptual model of lower watershed

6.3.4 Lower watershed model

The lower watershed conceptual model is laid out similarly to the upper watershed model with the same four rows of components: drivers, stressors, effects, and attributes. The model is composed of seven key drivers, which connect in a slightly more interconnected way than the simpler top-to-bottom connections diagramed for the upper watershed. The lower watershed model, as diagrammed in Figure 6-11, shows these seven key drivers:

- Urban and rural residential encroachment has led to the loss of riparian buffers and the constricting of channels such that the former wiggle room of creeks is eliminated and the need for public safety and property protection trumps the needs for water, sediment transport and deposition, and habitat succession. The result is an artificial need for regular maintenance to keep these stream systems operating in a more-or-less static way. In the flood plain near the Laguna's ponded areas, the loss of wetlands from this encroachment is a problem most apparent in the Sebastopol area.
- The design of floodwater conveyance channels leads to dual effects: channel banks kept clear of woody over-story have elevated temperatures with the consequence that macroinvertebrates are unable to survive and fish and birds are displaced upstream or downstream to cooler habitats that support higher levels of oxygen in the water. The design of floodwater conveyance channels also cause an accumulated effect downstream as more water arrives in the Laguna's ponded and low lying areas in much less time, causing a greater than normal reliance on the floodplain to buffer this flow as it makes its way towards the Forestville Narrows.
- Impervious surfaces, in the form of rooftops, led to the same stressors and effects as floodwater conveyance channels: flashy stream flow. Impervious surfaces, such as roads and parking lots, have the added stressor of acting as sources of oils, metals, and other pollutants from cars. An often unnoticed pollutant is Styrofoam, rubber, plastic bottles, and other trash that floats downstream and becomes entangled in localized collection spots along the Laguna's lowland.
- Backyard runoff is the source of both pesticides and nutrients running off into the waterways. A significant amount of this comes from rural residential units, where the bare soil is seen by some as a sign of tidiness and weedy patches are seen as a sign of an unkempt property. A significant source of pesticides also comes from road maintenance activities which in recent years has begun to rely less on mechanical mowers, and more on herbicides, to remove vegetation from the areas directly adjacent to highways.
- Agriculture in the floodplain leads to the same loss of riparian corridors through encroachment as that described for urban and rural residences. Agriculture in the floodplain also adds nutrients to the system, especially when dairy and cattle pastures are directly in the zone of annual inundation.
- Recycled water discharged into the Laguna leads to elevated nutrient levels in the water column and over time has probably lead to the accumulation of phosphorus in the soil of these water bodies. The sustained growth of invasive *Ludwigia* sp. and other macrophytes in the water column are likely an effect

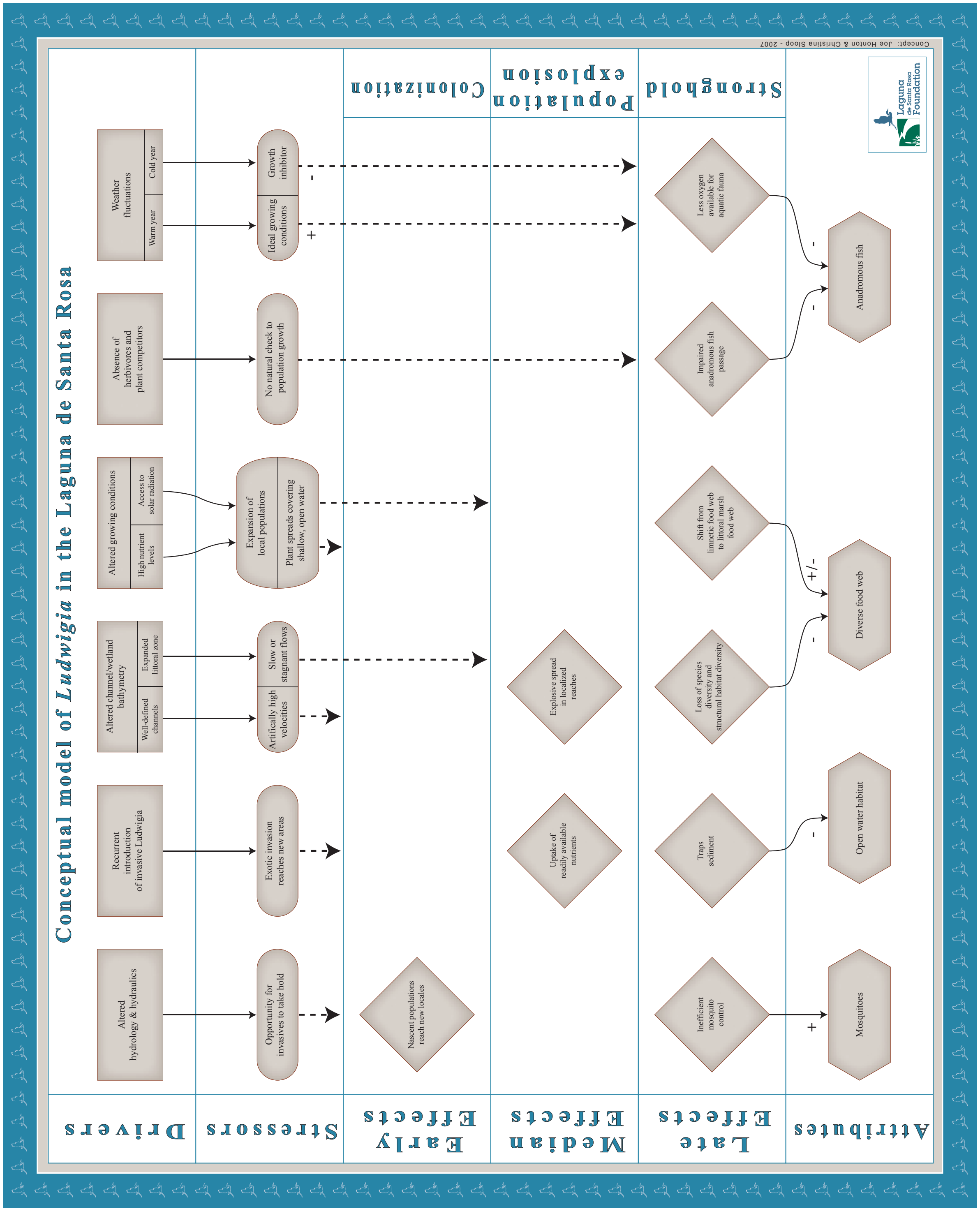

Figure 6-12
Conceptual model of invasive *Ludwigia* sp.

of this multi-decadal input and binding to the soil substrate. Recycled water also contains unregulated synthetic compounds such as estrogenic compounds (birth control pills), other pharmaceuticals and cosmetics, whose affects have not been quantified in the Laguna but which may be causing the disruption of the endocrine systems of wildlife, especially the amphibian populations. These unregulated pollutants may also be a human health issue. Recycled water causes a second set of stressors simply by keeping water levels artificially high throughout the year. Subsurface flow from nearby irrigated fields keeps water in areas well past their normal drying period. This stressor has allowed the shift away from species specially adapted to California's climate pattern. It also favors the late season, or year round, population of some wildlife that would otherwise seek water in the perennial streams of the montane region.

- The introduction of non-native plants such as invasive *Ludwigia* sp., *Lepidium latifolium* and others has caused a shift in the native plant community and the loss of natural competitive population checks. In the open-water bodies of the Laguna, especially with regard to invasive *Ludwigia* sp., this has meant a shift from a limnetic food web to a littoral marsh food web. The overall diversity of wetland communities and riparian communities has decreased with fewer types of plants and animals being found.

6.3.5 Invasive *Ludwigia* sp. model

In addition to the two watershed-scale models, we also looked in depth at the vexing problem of invasive *Ludwigia* sp., and have developed a targeted model of water quality just for this macrophyte species.

The conceptual model of invasive *Ludwigia* sp. follows basically the same layout structure as the upper and lower watershed models, but this model is confined to the processes related to this single species. Also, this model presents a three-tiered time structure which accounts for the progression of the plant from colonization to population explosion to the long list of late effects which set in when it has reached a stronghold. The model is shown as Figure 6-12.

- Altered hydrology—which in this watershed means more water than normal passing through the system (extra water diverted from the Russian River through the city's distribution system, and being flushed through the treatment plant)—provides a suitable home for invasive *Ludwigia* sp., an emergent macrophyte. Altered hydraulics, such as the construction of flood conveyance channels, provides high than normal velocities through the system, causing floating living plant fragments to break free and be distributed downstream. These alterations allow the plant to reach new locales forming nascent populations that will eventually develop along the lines described below.
- The recurrent introduction of invasive *Ludwigia* sp. into the system, occurs via the re-distribution of plant fragments during floods downstream, through natural transport by wildlife (e.g. seeds or shoots get moved via birds), and possibly through recurrent "escapes" of nursery plants from garden ponds (this has occurred with water hyacinth, *Eichhornia crassipes*). No good working hypothesis

has yet been agreed upon regarding this important question: the role of wildlife and the role of water transport in the introduction of the species to new areas deserves more attention.

- Altered channels lead to the bifurcation of the stream into sections with artificially high velocities, and sections with slow or stagnant flows. In areas of slow or stagnant flow, young invasive *Ludwigia* sp. plants take root, the uptake of readily available nutrients occurs, solar energy is at its optimum for uptake, and the stage is set for a population explosion.
- Altered growing conditions include the high nutrient levels in the water column and in the substrate, together with access to solar radiation associated with denuded riparian habitats. This driver may cause local populations to expand rapidly. It also allows plants to spread out covering shallow open water, especially in the slow or no flow areas.
- The absence of associated invasive *Ludwigia* sp. herbivores and plant competitors from their native range means that no natural check to population growth is present. During the initial colonization phase there are no natural population growth checks, and so vast monoculture-like mats of invasive *Ludwigia* sp. establish and as an ecosystem engineer (Crooks 2002) completely change the dynamics of the system.
- Fluctuations in weather may be a toggle-type driver. If invasive *Ludwigia* sp. growth is tied to temperature and frost-free days, then warm frost-free winters will likely see ideal growing conditions and cold frosty winters will likely act as a growth inhibitor. More investigation of this phenomenon is warranted.