DFG Exhibit 4

Effects of Water Temperature on Anadromous Salmonids in the San Joaquin River Basin

California Department of Fish and Game
Central Region
1234 E. Shaw Avenue
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Prepared for the Informational Proceeding to Develop
Flow Criteria for the Delta Ecosystem
Necessary to Protect Public Trust Resources
Before the State Water Resources Control Board

Beginning March 22, 2010

Effects of Water Temperature on Anadromous Salmonids in the San Joaquin River Basin

In February 2007, the Department of Fish and Game (DFG) responded to the Central Valley Regional Water Quality Control Board's "Public Solicitation of Water Quality Data and Information for 2008 Integrated Report – List of Impaired Waters and Surface Water Quality Assessment," and DFG proposed a Clean Water Act section 303(d) listing for temperature impairment of the lower Stanislaus, Tuolumne, and Merced Rivers. (DFG 2007). In 2009, the Central Valley Regional Water Quality Control Board (Board) placed these Rivers on the Section 303(d) list (Category 5). The Board used the same temperature data that DFG used for its analysis, but used a different methodology to analyze those data. The proposed list was approved in June 2009 by the Board and has been forwarded to the California State Water Resources Control Board for review and approval. Once approved by the State Board, the 303(d) list will be forwarded to the U.S. Environmental Protection Agency for review and approval.

DFG presented water temperature results collected from the San Joaquin River and its tributaries (1998 through 2006) in support of our concern that elevated water temperatures are impairing fishery beneficial uses and commonly exceeding the "cool" water quality standards within the relevant Water Quality Control Plans (Basin Plans). The DFG proposal emphasized temperature protections for the last remaining unblocked reaches (downstream from the dams), for all life stages, for the last remaining genetic population of Chinook salmon and steelhead in the San Joaquin River Basin. The presence of dams at the upper end of these reaches has now blocked Anadromous fish that once could migrate up to higher elevation cooler waters.

Rivers in the San Joaquin Basin do not meet (cool) temperature water quality criteria to protect anadromous fish beneficial uses (The Criteria are presented in Table 1). DFG believes that one critical factor limiting anadromous salmon and steelhead population abundance is high water temperatures which exist during critical life-stages in the tributaries and the main-stem. This results largely from water diversions, hydroelectric power operations, water operations and other factors. Figures 1 to 4 provides a visual summary of the percent of habitat-impaired areas for the 52-mile reach of the Tuolumne River downstream from La Grange Dam. Figure 1 shows the extreme length of adult Chinook salmon migration habitat impairment across weeks for all years including above normal and wet water years. Figure 2 provides spawning habitat impaired areas within the 24-mile reach down stream from La Grange Dam. Except for the last three to four weeks in the season (i.e., December), length of impairment across years including above normal and wet water years is extreme. Figure 3 provides percent of smoltification habitat-impaired areas within the entire 52-mile reach down stream from the La Grange Dam. The differences of impairment across weeks between the wet years (1998, 2005, 2006) are extreme compared to the dry years (2001, 2002, 2004). Figure 4 provides a visual summary of the percent steelhead rearing habitat impaired areas within the first 10 miles downstream from the La Grange Dam. The differences of impairment across weeks between the wet years (1998, 2005, and 2006) are extreme compared to the dry years (2001, 2002, 2004). Figures 5 to 12 provide a visual summary of the percent of habitat-impaired areas for the 52-mile reach of the Merced River downstream from Crocker Dam and the Stanislaus River downstream from Goodwin Dam. Similar to the Tuolumne River, river miles of habitat are impaired across years including wet to above normal years.

Table 1. EPA temperature thresholds for Pacific migratory salmonid species and life stages.

Salmonid Life History Phase Terminology	**EPA-based Recommended Temperature Thresholds to Protect Salmon and Trout**[1] (Criteria are based on the 7-day average of the daily maximum values)
Adult migration	<64°F (<18°C) for salmon and trout migration <68°F (<20°C) for salmon and trout migration - generally in the lower part of river basins that likely reach this temperature naturally, if there are cold-water refugia available
Incubation	<55°F (<13°C) for salmon and trout spawning, egg incubation, and fry emergence
Juvenile rearing (early year)	<61°F (<16°C) for salmon "core" juvenile rearing - generally in the mid- to upper part of river basins
Smoltification	<59°F (<15°C) for salmon smoltification <57°F (<14°C) for steelhead smoltification (for composite criteria steelhead conditions are applied)
Juvenile rearing (late year)	<64°F (<18°C) for juvenile salmon and steelhead migration plus non-Core Juvenile Rearing - generally in the lower part of river basins

[1] Water temperature thresholds taken from: United States Environmental Protection Agency (EPA). 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. EPA 910-B-03-002. 49 pp. April. The EPA identified temperature unit is: Seven day average of the daily maximum water temperature (7DADM).

DFG considers the reproduction and recruitment success of the entire population across multiple generations in recognition of the evolution and importance of the multi-year class life history strategy of salmon and steelhead. Unlike the use of "tolerance" temperatures which apply to the survival of a group of individuals across a short time line, our systematic approach is the more comprehensive method in assuring the survival of the population over time. In order to use this approach, DFG's recommended temperature criteria emphasize the following life stages for managing the species: Chinook salmon adult migration, egg incubation, smoltification, smolt migration, and steelhead summer rearing.

Fish are exothermic (e.g., physiologically controlled by ambient water temperature levels). As such, water temperature controls all life stage needs, such as physiological function (oxygen/carbon dioxide exchange, blood chemistry/pH, organ function, heart rate, egg and sperm viability), basic survival, food consumption, rearing location preference, ability to successfully spawn, spawning location preference, growth rates, stress factors, immune function, disease resistance, predator avoidance, etc.

Elevated water temperatures appear to be a factor in the continued decline in adult salmon escapement abundance in the San Joaquin River Basin watershed, either by: (1) inducing adult mortality as adults migrate into the San Joaquin River, and tributaries, to spawn (i.e., pre-spawn mortality); (2) reducing egg viability for eggs deposited in stream gravels (redds), (3) increasing stress levels and therefore reducing survival of juveniles within the tributary nursery habitats, and (4) reducing salmon smolt out-migration survival as smolts leave the nursery habitats within tributaries to migrate down the San Joaquin River to Vernalis and through the south Delta. For rainbow trout and anadromous steelhead, excessively warm water temperatures have the potential to limit trout/steelhead population abundance by restricting juvenile and adult resident over-summer rearing habitat to very short stream reaches, due to downstream thermal regimes. As such, too few miles of suitable habitat may exist to sustain healthy population levels.

Warm water temperatures can decrease dissolved oxygen in the water and can act as a barrier to migration. Increased water temperatures can decrease the availability of dissolved oxygen to the eggs, decrease egg hatchability, and decrease the survival of fry once they emerge from the eggs. Warm temperatures can decrease, inhibit, or reverse the physiological function of smoltification, as well as, decrease available oxygen to the smolt. Similar to adult migrants, warm water temperatures can act as a barrier to migrating smolts moving downstream, decrease physiological function and growth, and decrease dissolved oxygen availability to the fish.

Secondary effects are likely as well, especially in predator-rich systems like Central Valley rivers. As thermal optima for salmon/steelhead/rainbow trout are exceeded at temperatures above 64 to 65°F (17.7 to 18.3°C), major predators like pikeminnow, striped bass, and black bass are just entering their thermal optima. As cold water fish become stressed at temperatures above 64°F, salmon and trout become more vulnerable to predation.

Steelhead require appropriate water temperatures on a year-round basis. DFG evaluated the rearing period for this report because this is considered the most critical life stage/period for steelhead survival. The other life stage periods overlap with Chinook salmon, which if salmon water temperatures are met, by default, steelhead water temperature criteria will also be met.

The temperature criteria are chronic thresholds to protect a population of anadromous fish across multiple generations. As such, the daily water temperature range is narrow (on the higher temperature scale) in the San Joaquin River Basin, thus the fish are not briefly exposed to elevated temperatures, but are chronically exposed to warm temperatures across both a temporal (time) and spatial (space) continuum. In addition, temperature monitoring results do not indicate that fish have the benefit of a brief exposure to optimal cool temperatures (i.e., cool temperature refugia) during a 24-hour period in the San Joaquin Valley Basin river systems. These fish require extended cool water exposure over the length of the river system to successfully complete its complex life cycle. Without changes in the flow regime and water temperatures that support anadromous fish populations, they will continue to decline and remain potentially at risk to extinction.

References

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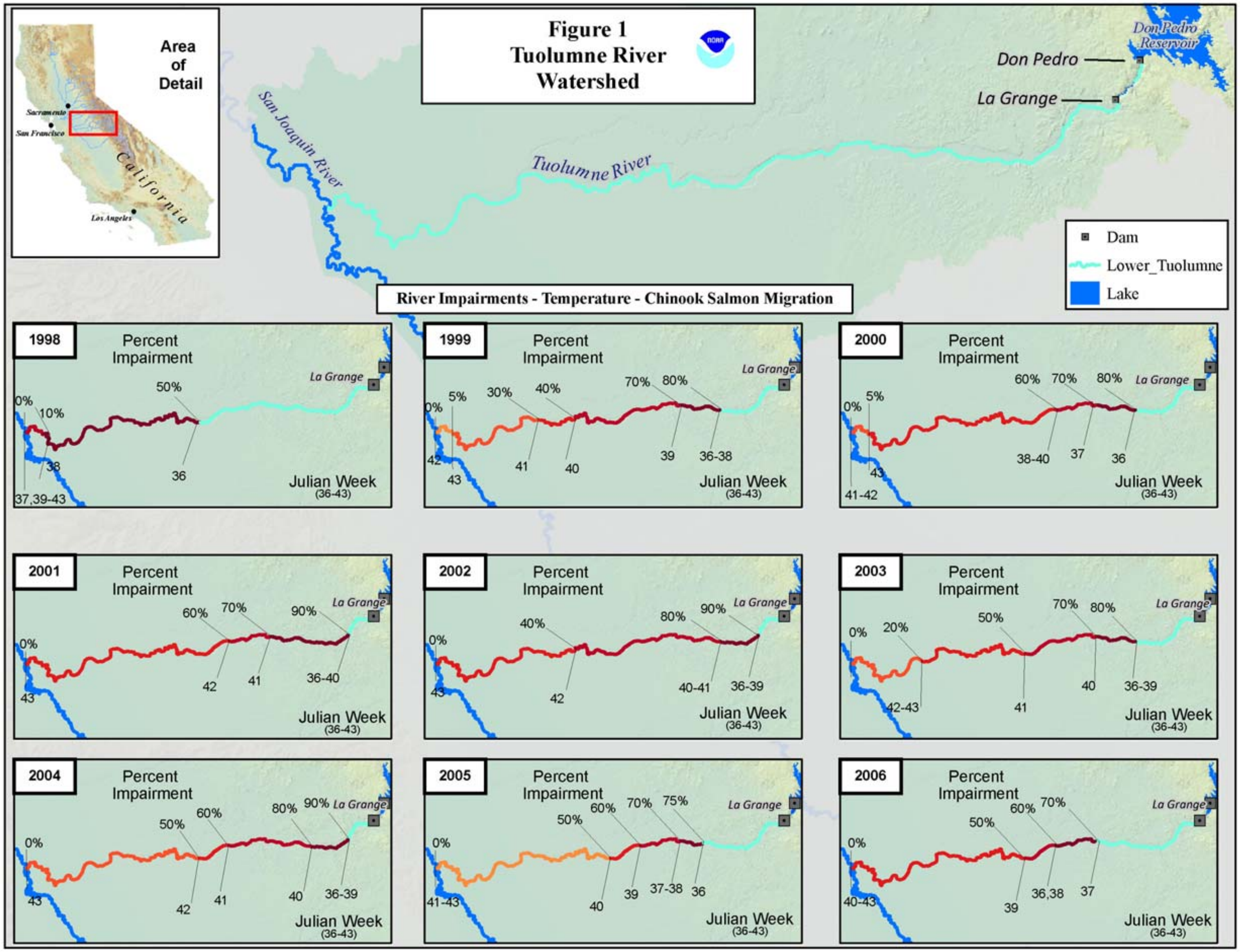
Figure 1
Tuolumne River Watershed
Area of Detail
Sacramento
San Francisco
Los Angeles
California
Don Pedro Reservoir
Don Pedro
La Grange
San Joaquin River
Tuolumne River
Dam
Lower_Tuolumne
Lake
River Impairments - Temperature - Chinook Salmon Migration
1998
Percent Impairment
Julian Week (36-43)
1999
2000
2001
2002
2003
2004
2005
2006

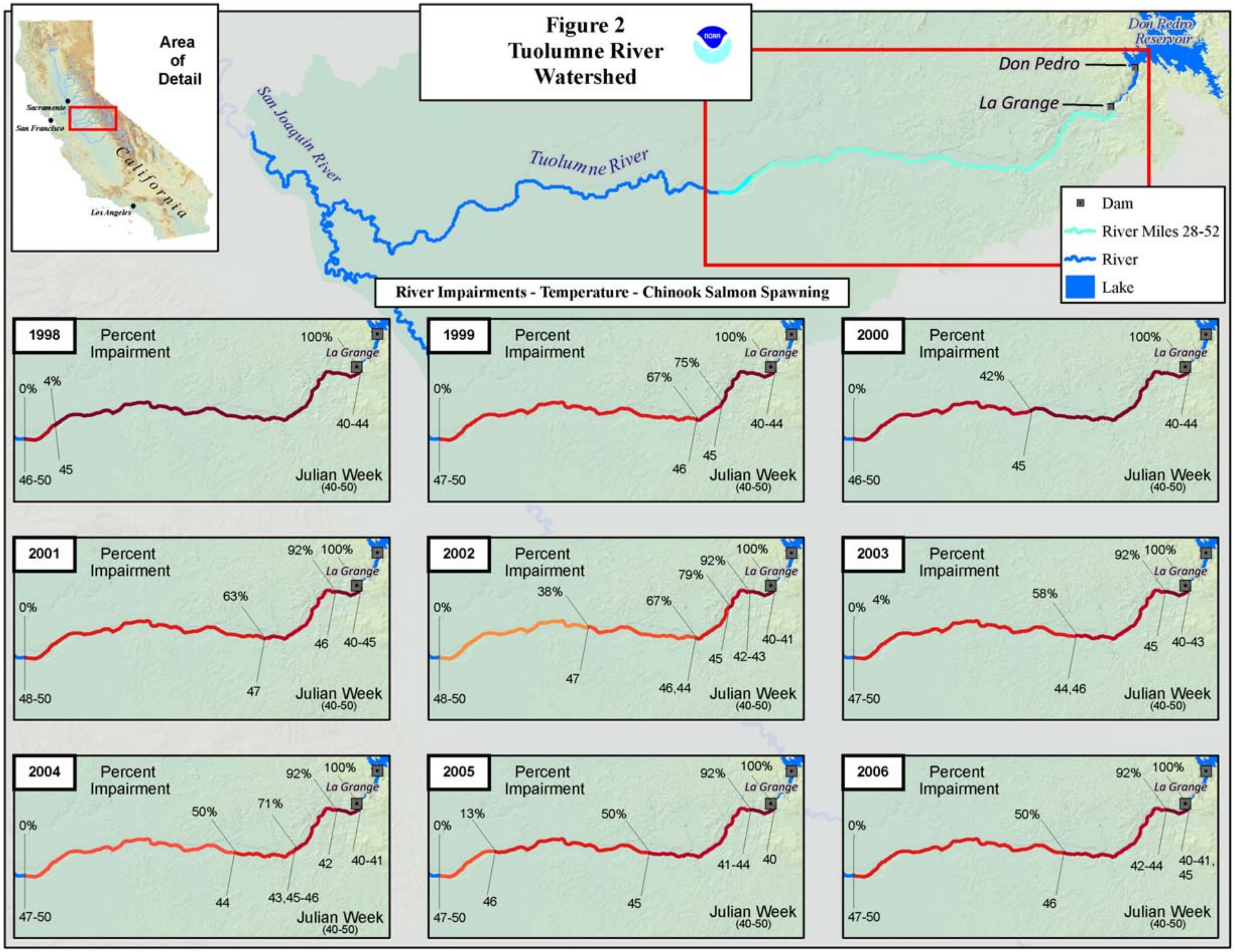
Figure 2
Tuolumne River Watershed
Area of Detail
Sacramento
San Francisco
California
Los Angeles
San Joaquin River
Tuolumne River
Don Pedro Reservoir
Don Pedro
La Grange
Dam
River Miles 28-52
River
Lake
River Impairments - Temperature - Chinook Salmon Spawning
1998
Percent Impairment
0% 4% 100%
46-50 45 40-44
1999
Percent Impairment
0% 67% 75% 100%
47-50 46 45 40-44
2000
Percent Impairment
0% 42% 100%
46-50 45 40-44
2001
Percent Impairment
0% 63% 92% 100%
48-50 47 46 40-45
2002
Percent Impairment
0% 38% 67% 79% 92% 100%
48-50 47 46,44 45 42-43 40-41
2003
Percent Impairment
0% 4% 58% 92% 100%
47-50 44,46 45 40-43
2004
Percent Impairment
0% 50% 71% 92% 100%
47-50 44 43,45-46 42 40-41
2005
Percent Impairment
0% 13% 50% 92% 100%
47-50 46 45 41-44 40
2006
Percent Impairment
0% 50% 92% 100%
47-50 46 42-44 40-41, 45
Julian Week (40-50)

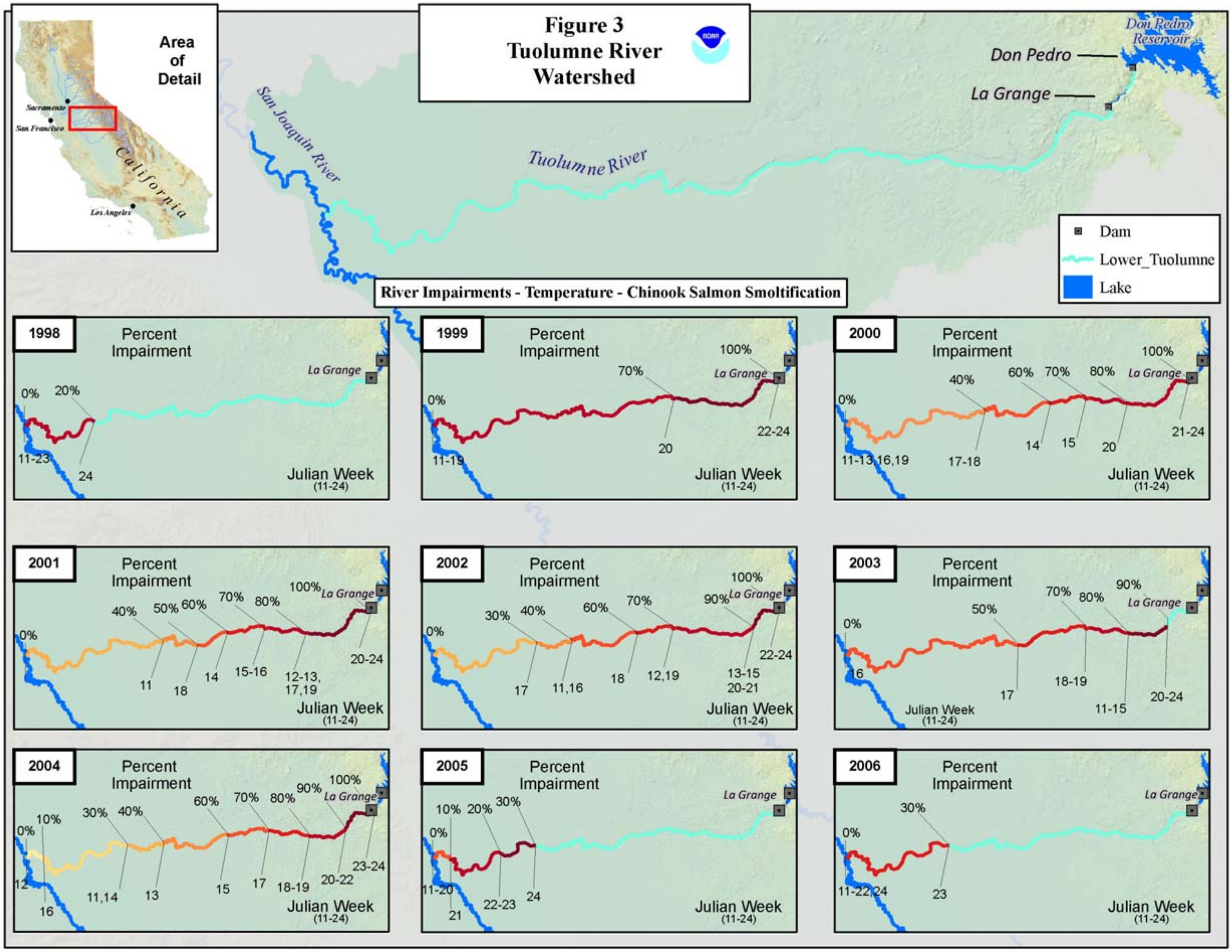
Figure 3
Tuolumne River Watershed
Area of Detail
California
San Joaquin River
Tuolumne River
Don Pedro Reservoir
Don Pedro
La Grange
Dam
Lower_Tuolumne
Lake
River Impairments - Temperature - Chinook Salmon Smoltification
1998
1999
2000
2001
2002
2003
2004
2005
2006
Percent Impairment
Julian Week (11-24)

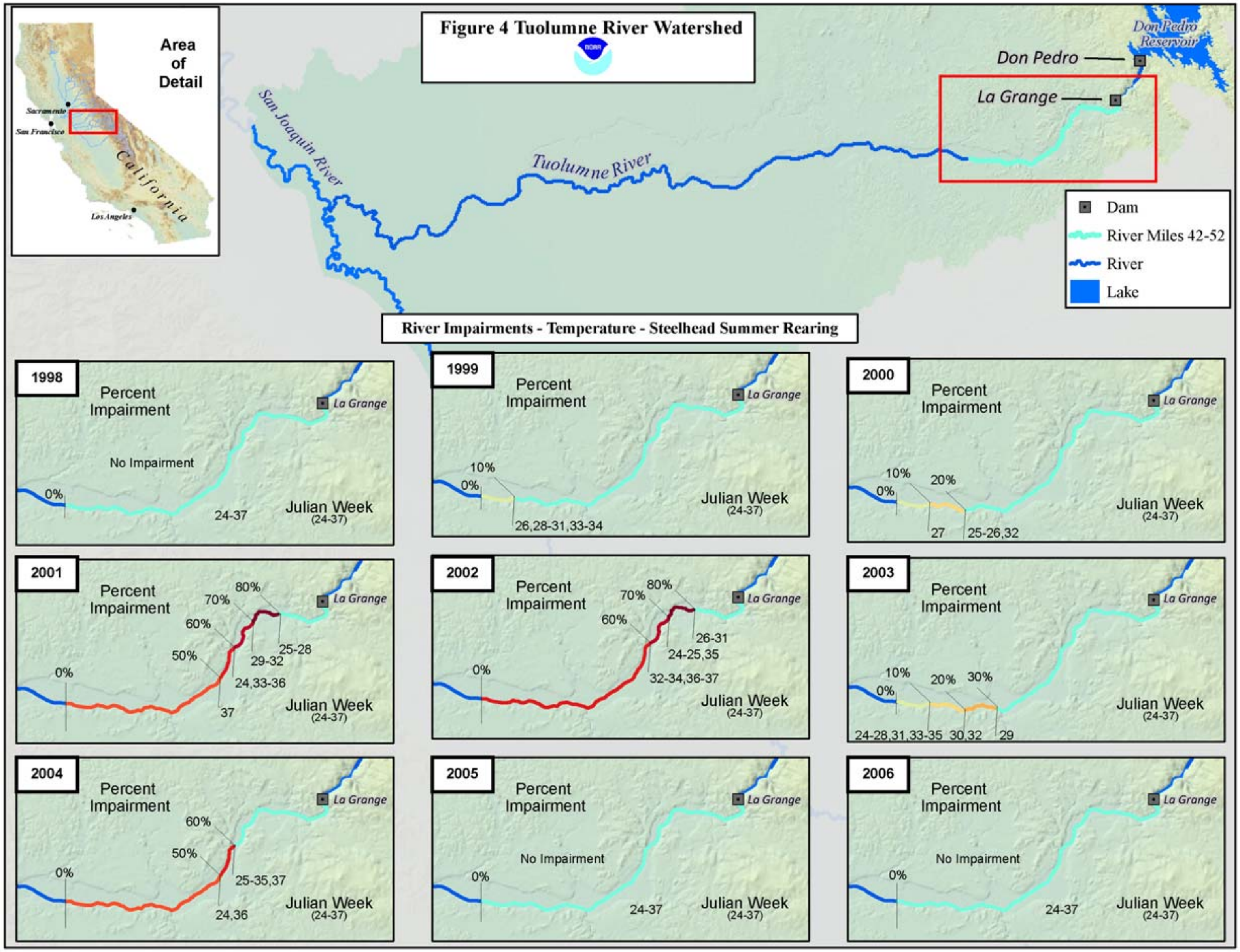
Figure 4 Tuolumne River Watershed
Area of Detail
Sacramento
San Francisco
California
Los Angeles
San Joaquin River
Tuolumne River
Don Pedro Reservoir
Don Pedro
La Grange
Dam
River Miles 42-52
River
Lake
River Impairments - Temperature - Steelhead Summer Rearing
1998
Percent Impairment
No Impairment
0%
24-37
Julian Week (24-37)
1999
Percent Impairment
10%
0%
26,28-31,33-34
Julian Week (24-37)
2000
Percent Impairment
10%
20%
0%
27
25-26,32
Julian Week (24-37)
2001
Percent Impairment
80%
70%
60%
50%
0%
25-28
29-32
24,33-36
37
Julian Week (24-37)
2002
Percent Impairment
80%
70%
60%
0%
26-31
24-25,35
32-34,36-37
Julian Week (24-37)
2003
Percent Impairment
10%
20%
30%
0%
24-28,31,33-35
30,32
29
Julian Week (24-37)
2004
Percent Impairment
60%
50%
0%
25-35,37
24,36
Julian Week (24-37)
2005
Percent Impairment
No Impairment
0%
24-37
Julian Week (24-37)
2006
Percent Impairment
No Impairment
0%
24-37
Julian Week (24-37)

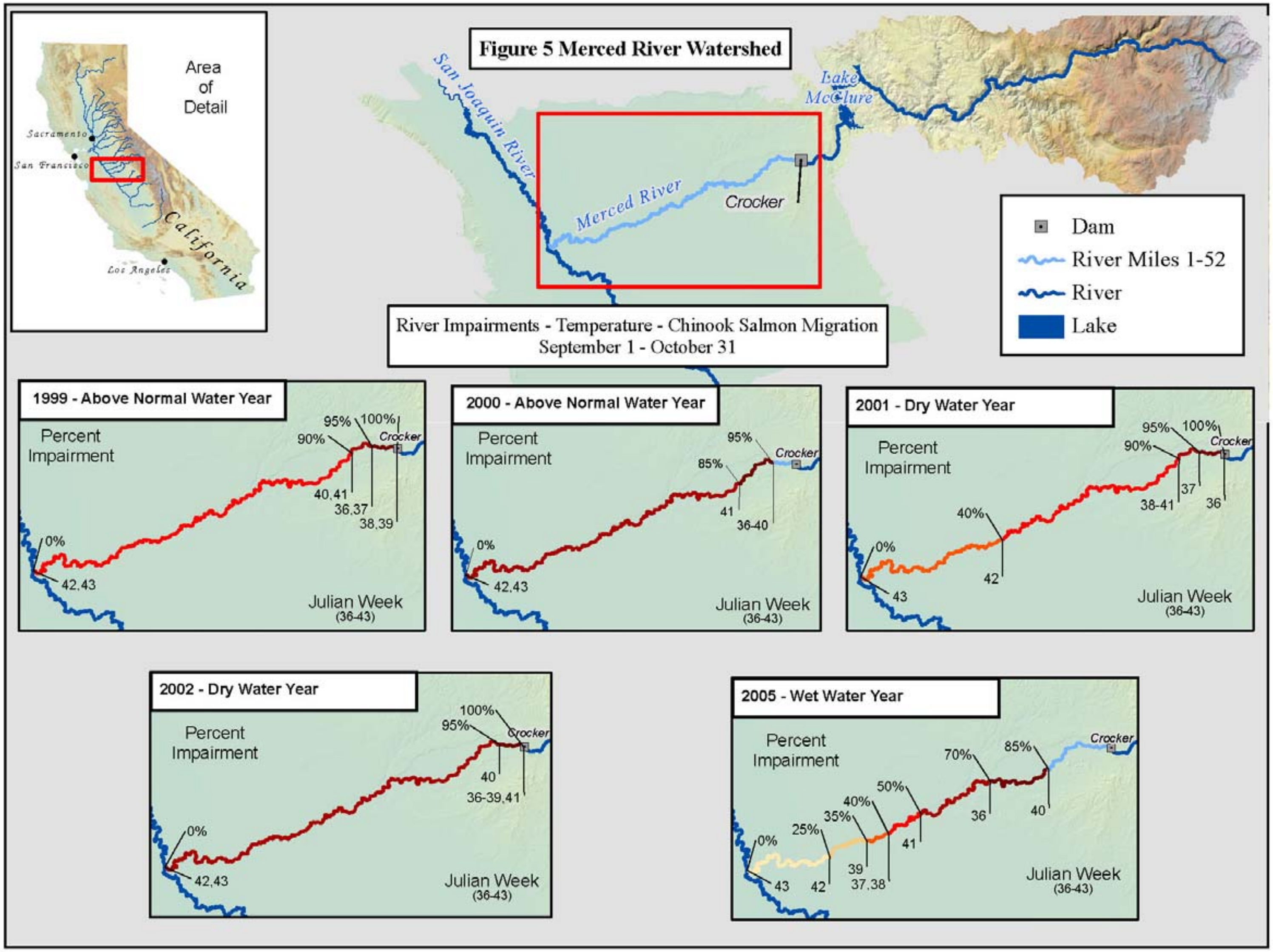
Figure 5 Merced River Watershed
Area of Detail
Sacramento
San Francisco
Los Angeles
California
San Joaquin River
Merced River
Crocker
Lake McClure
Dam
River Miles 1-52
River
Lake
River Impairments - Temperature - Chinook Salmon Migration
September 1 - October 31
1999 - Above Normal Water Year
Percent Impairment
95%
100%
90%
Crocker
40,41
36,37
38,39
0%
42,43
Julian Week (36-43)
2000 - Above Normal Water Year
Percent Impairment
95%
85%
Crocker
41
36-40
0%
42,43
Julian Week (36-43)
2001 - Dry Water Year
Percent Impairment
95%
100%
90%
Crocker
37
38-41
36
40%
0%
42
43
Julian Week (36-43)
2002 - Dry Water Year
Percent Impairment
100%
95%
Crocker
40
36-39,41
0%
42,43
Julian Week (36-43)
2005 - Wet Water Year
Percent Impairment
Crocker
70%
85%
50%
40%
35%
25%
0%
36
40
41
39
37,38
43
42
Julian Week (36-43)

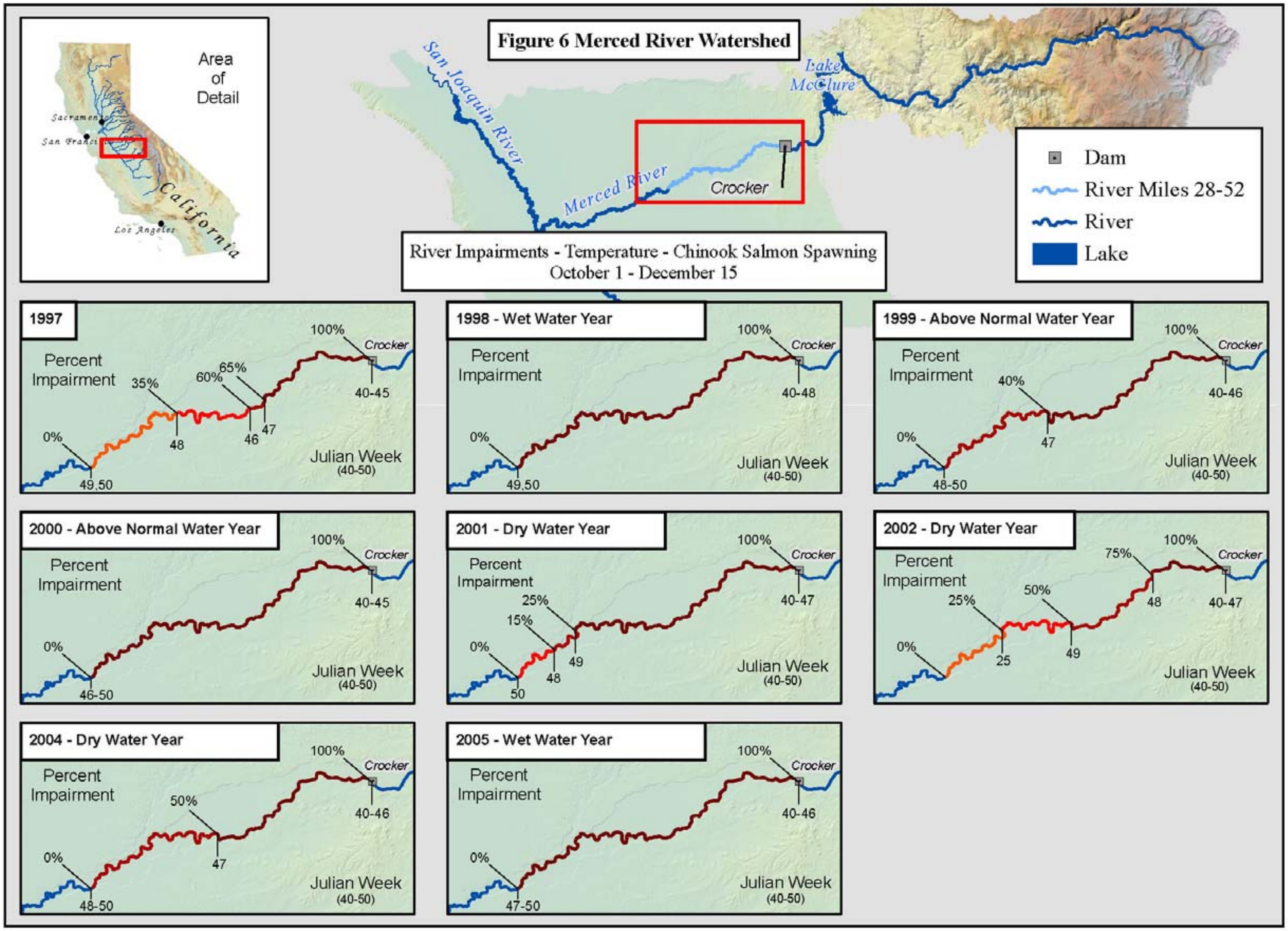
Figure 6 Merced River Watershed
Area
of
Detail
Sacramento
San Francisco
Los Angeles
California
San Joaquin River
Merced River
Crocker
Lake McClure
Dam
River Miles 28-52
River
Lake
River Impairments - Temperature - Chinook Salmon Spawning
October 1 - December 15
1997
Percent Impairment
0% 35% 60% 65% 100%
49,50 48 46 47 40-45
Crocker
Julian Week (40-50)
1998 - Wet Water Year
Percent Impairment
0% 100%
49,50 40-48
1999 - Above Normal Water Year
Percent Impairment
0% 40% 100%
48-50 47 40-46
2000 - Above Normal Water Year
Percent Impairment
0% 100%
46-50 40-45
2001 - Dry Water Year
Percent Impairment
0% 15% 25% 100%
50 48 49 40-47
2002 - Dry Water Year
Percent Impairment
0% 25% 50% 75% 100%
25 49 48 40-47
2004 - Dry Water Year
Percent Impairment
0% 50% 100%
48-50 47 40-46
2005 - Wet Water Year
Percent Impairment
0% 100%
47-50 40-46
Julian Week (40-50)

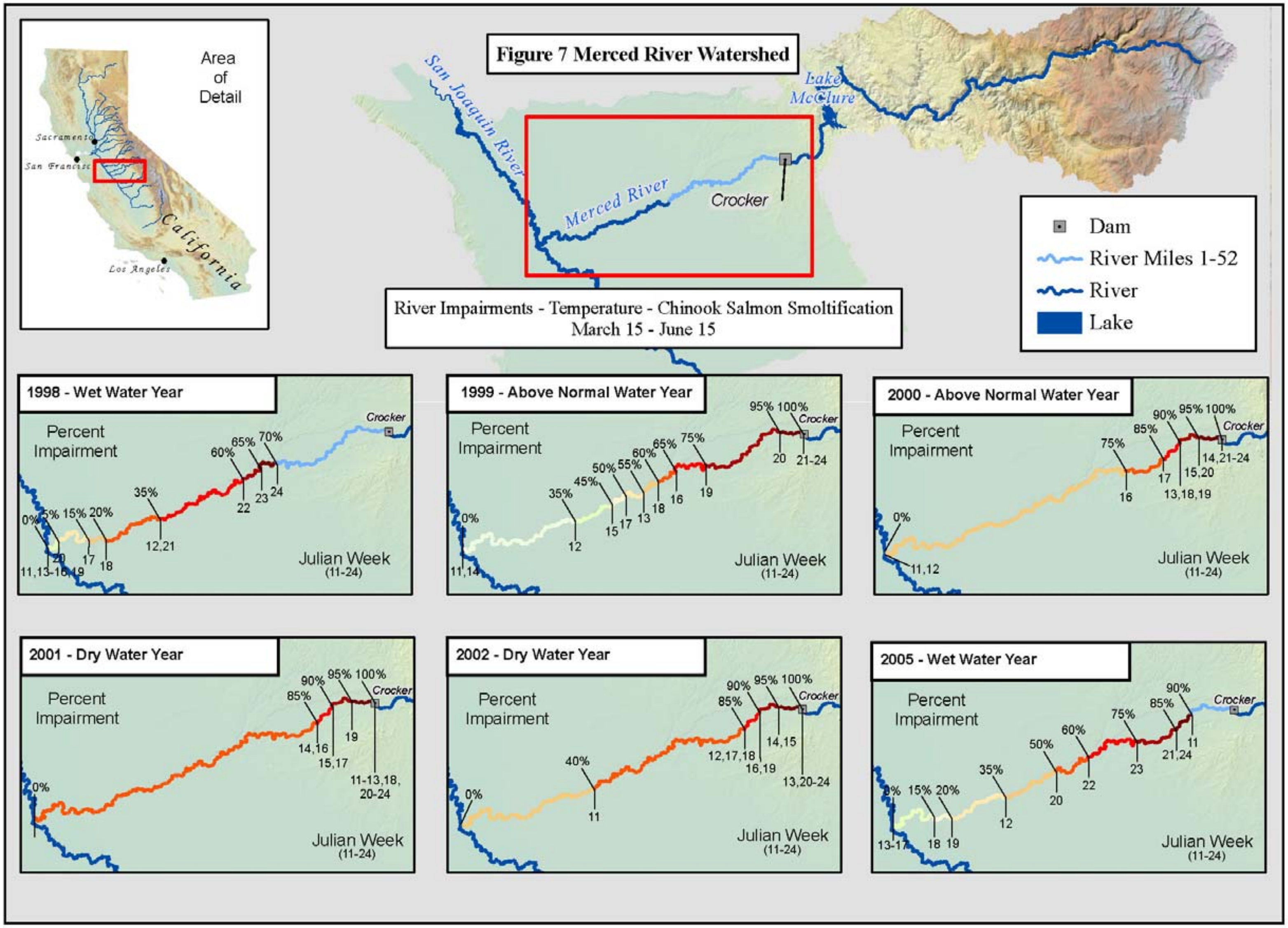
Figure 7 Merced River Watershed
River Impairments - Temperature - Chinook Salmon Smoltification
March 15 - June 15
Area of Detail
Sacramento
San Francisco
Los Angeles
California
San Joaquin River
Merced River
Crocker
Lake McClure
Dam
River Miles 1-52
River
Lake
1998 - Wet Water Year
1999 - Above Normal Water Year
2000 - Above Normal Water Year
2001 - Dry Water Year
2002 - Dry Water Year
2005 - Wet Water Year
Percent Impairment
Julian Week (11-24)

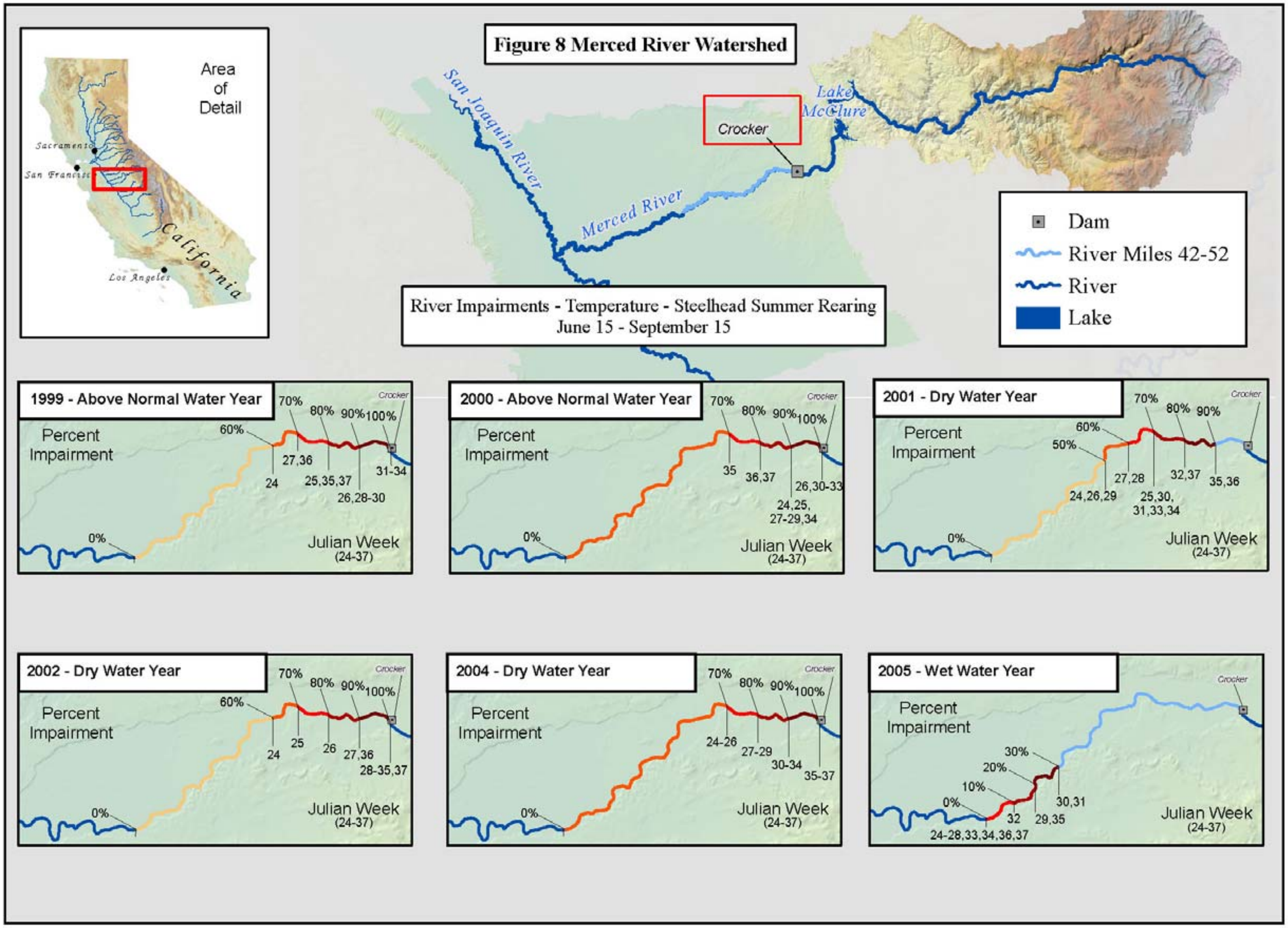
Figure 8 Merced River Watershed
Area of Detail
Sacramento
San Francisco
Los Angeles
California
San Joaquin River
Merced River
Crocker
Lake McClure
Dam
River Miles 42-52
River
Lake
River Impairments - Temperature - Steelhead Summer Rearing
June 15 - September 15
1999 - Above Normal Water Year
Percent Impairment
0%
60%
70%
80%
90%
100%
Crocker
24
27,36
25,35,37
26,28-30
31-34
Julian Week (24-37)
2000 - Above Normal Water Year
Percent Impairment
0%
70%
80%
90%
100%
Crocker
35
36,37
24,25, 27-29,34
26,30-33
Julian Week (24-37)
2001 - Dry Water Year
Percent Impairment
0%
50%
60%
70%
80%
90%
Crocker
24,26,29
27,28
25,30, 31,33,34
32,37
35,36
Julian Week (24-37)
2002 - Dry Water Year
Percent Impairment
0%
60%
70%
80%
90%
100%
Crocker
24
25
26
27,36
28-35,37
Julian Week (24-37)
2004 - Dry Water Year
Percent Impairment
0%
70%
80%
90%
100%
Crocker
24-26
27-29
30-34
35-37
Julian Week (24-37)
2005 - Wet Water Year
Percent Impairment
0%
10%
20%
30%
Crocker
24-28,33,34,36,37
32
29,35
30,31
Julian Week (24-37)

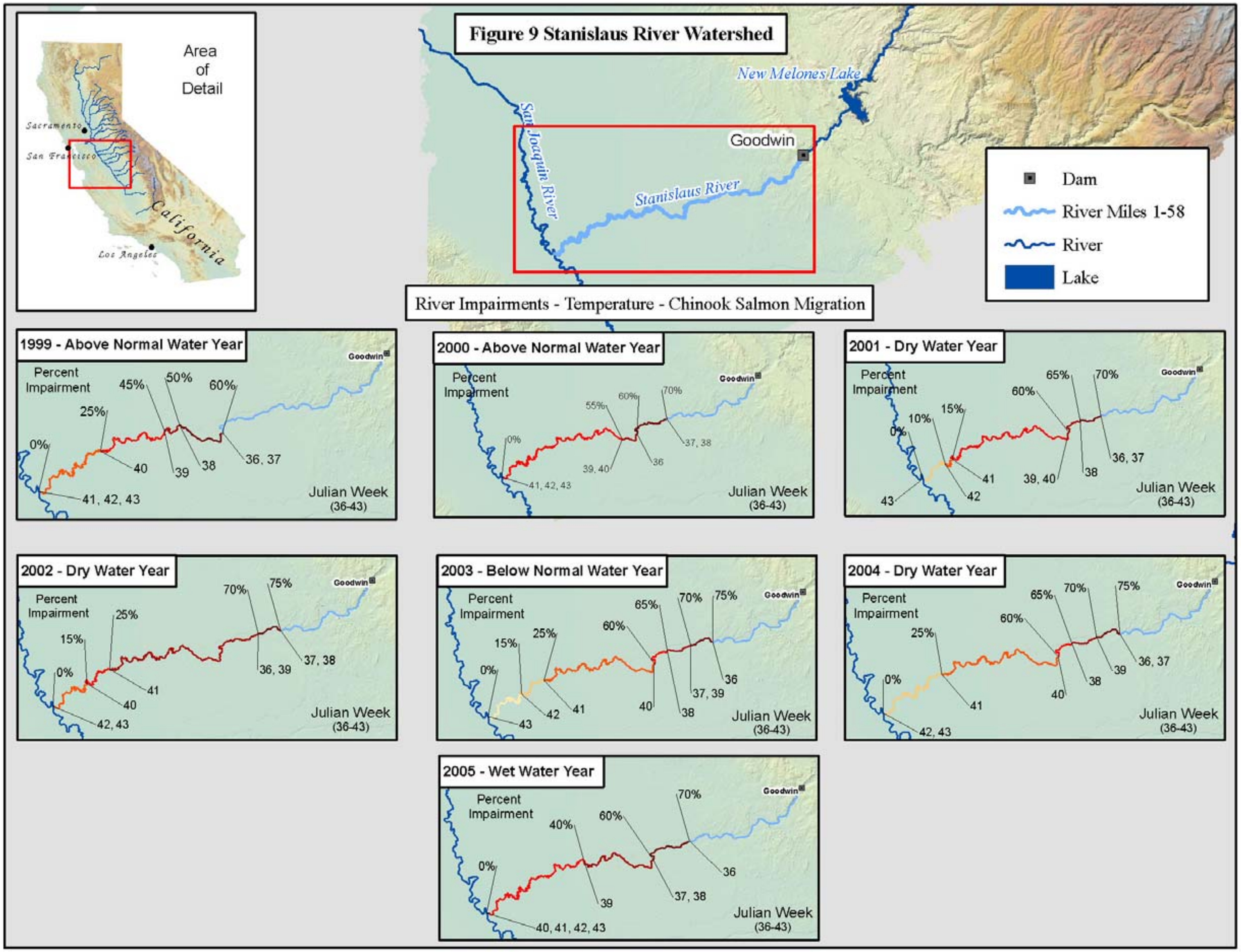
Figure 9 Stanislaus River Watershed
Area of Detail
Sacramento
San Francisco
California
Los Angeles
New Melones Lake
Goodwin
San Joaquin River
Stanislaus River
Dam
River Miles 1-58
River
Lake
River Impairments - Temperature - Chinook Salmon Migration
1999 - Above Normal Water Year
2000 - Above Normal Water Year
2001 - Dry Water Year
2002 - Dry Water Year
2003 - Below Normal Water Year
2004 - Dry Water Year
2005 - Wet Water Year
Percent Impairment
Julian Week (36-43)

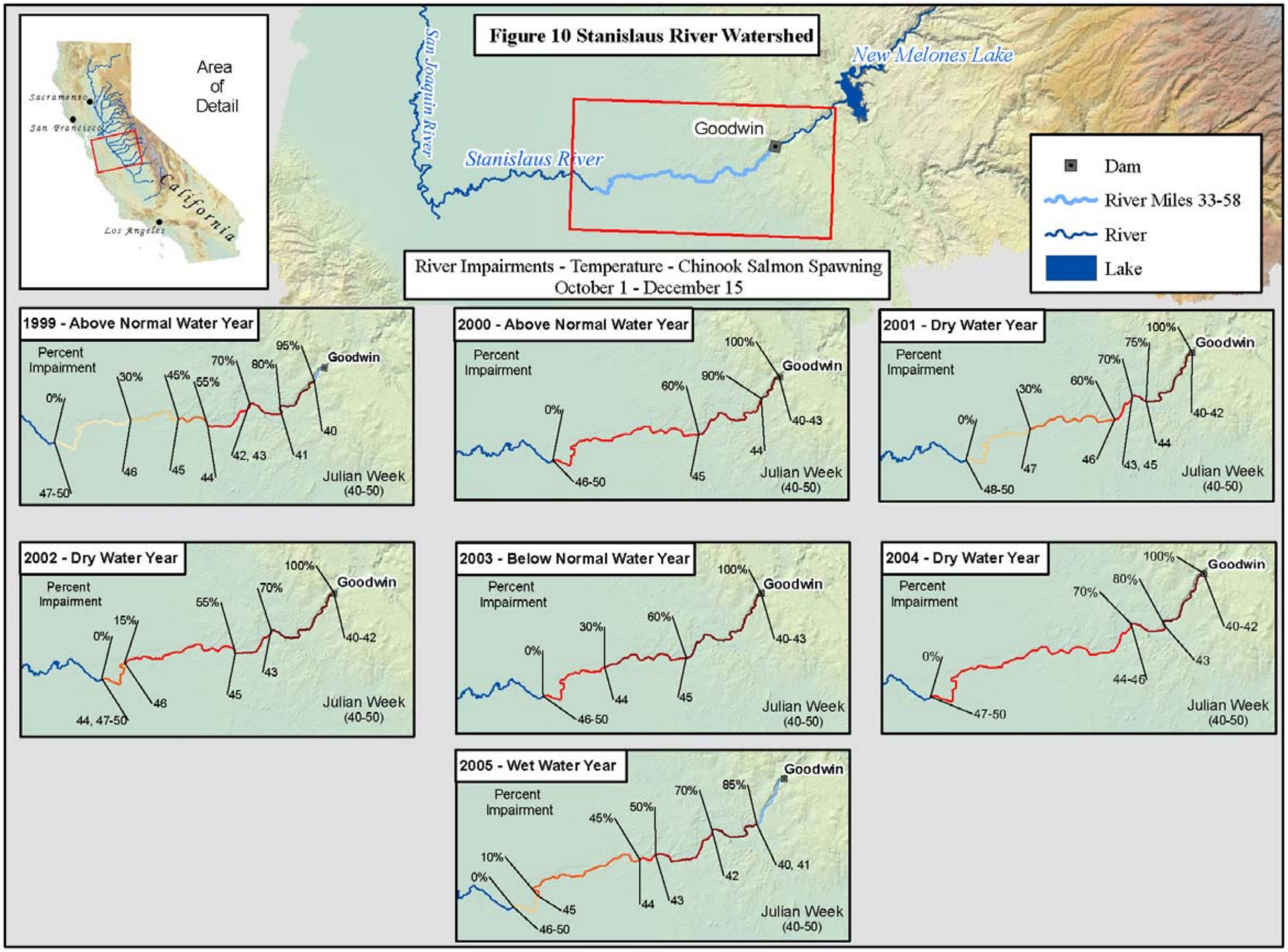
Figure 10 Stanislaus River Watershed
Area of Detail
Sacramento
San Francisco
Los Angeles
California
San Joaquin River
Stanislaus River
New Melones Lake
Goodwin
Dam
River Miles 33-58
River
Lake
River Impairments - Temperature - Chinook Salmon Spawning
October 1 - December 15
1999 - Above Normal Water Year
2000 - Above Normal Water Year
2001 - Dry Water Year
2002 - Dry Water Year
2003 - Below Normal Water Year
2004 - Dry Water Year
2005 - Wet Water Year
Percent Impairment
Julian Week (40-50)

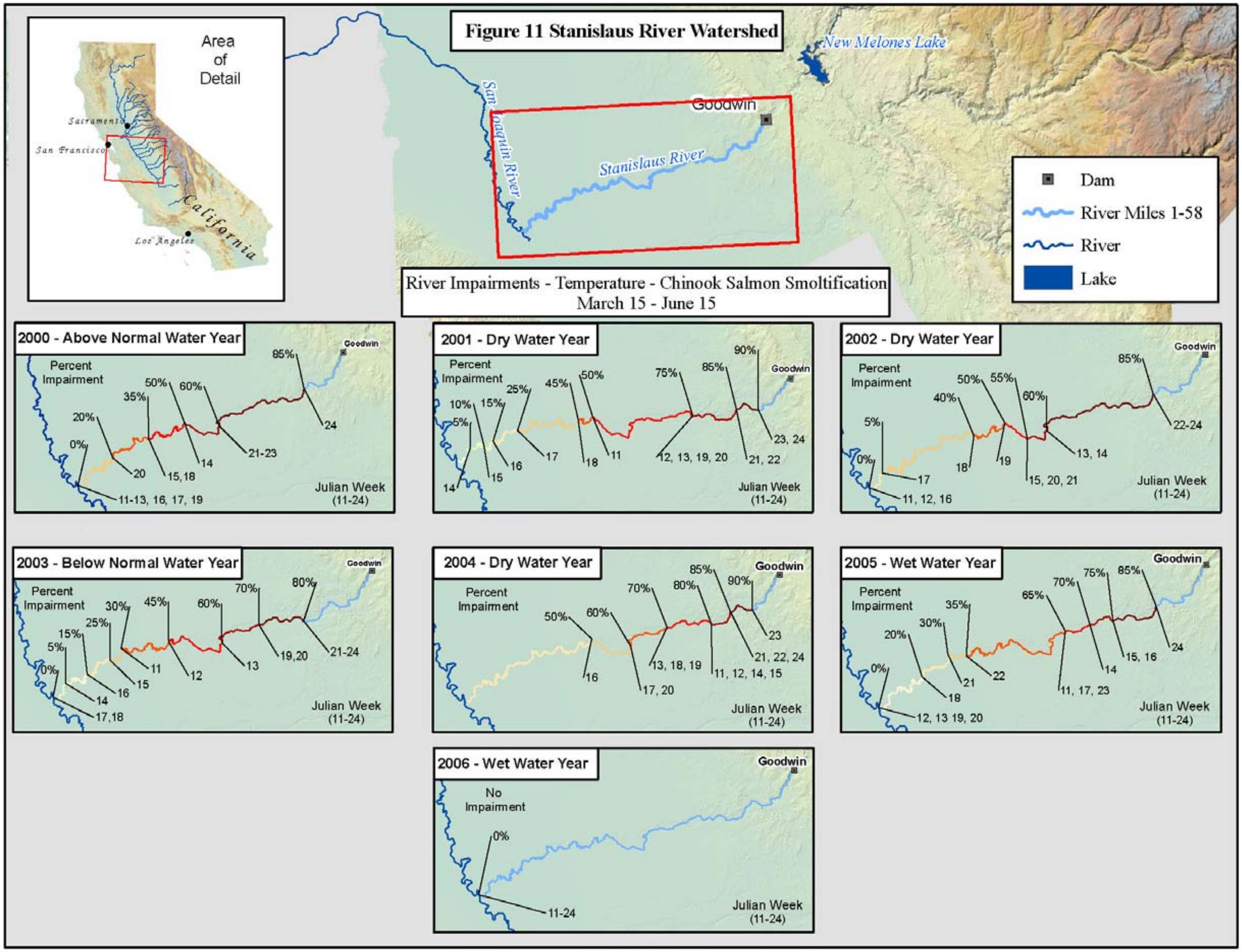
Figure 11 Stanislaus River Watershed
Area of Detail
Sacramento
San Francisco
Los Angeles
California
New Melones Lake
Goodwin
San Joaquin River
Stanislaus River
Dam
River Miles 1-58
River
Lake
River Impairments - Temperature - Chinook Salmon Smoltification
March 15 - June 15
2000 - Above Normal Water Year
Percent Impairment
0%
20%
35%
50%
60%
85%
11-13, 16, 17, 19
20
15,18
14
21-23
24
Goodwin
Julian Week (11-24)
2001 - Dry Water Year
Percent Impairment
5%
10%
15%
25%
45%
50%
75%
85%
90%
14
15
16
17
18
11
12, 13, 19, 20
21, 22
23, 24
Goodwin
Julian Week (11-24)
2002 - Dry Water Year
Percent Impairment
0%
5%
40%
50%
55%
60%
85%
11, 12, 16
17
18
19
15, 20, 21
13, 14
22-24
Goodwin
Julian Week (11-24)
2003 - Below Normal Water Year
Percent Impairment
0%
5%
15%
25%
30%
45%
60%
70%
80%
17,18
14
16
15
11
12
13
19,20
21-24
Goodwin
Julian Week (11-24)
2004 - Dry Water Year
Percent Impairment
50%
60%
70%
80%
85%
90%
16
17, 20
13, 18, 19
11, 12, 14, 15
21, 22, 24
23
Goodwin
Julian Week (11-24)
2005 - Wet Water Year
Percent Impairment
0%
20%
30%
35%
65%
70%
75%
85%
12, 13 19, 20
18
21
22
11, 17, 23
14
15, 16
24
Goodwin
Julian Week (11-24)
2006 - Wet Water Year
No Impairment
0%
11-24
Goodwin
Julian Week (11-24)

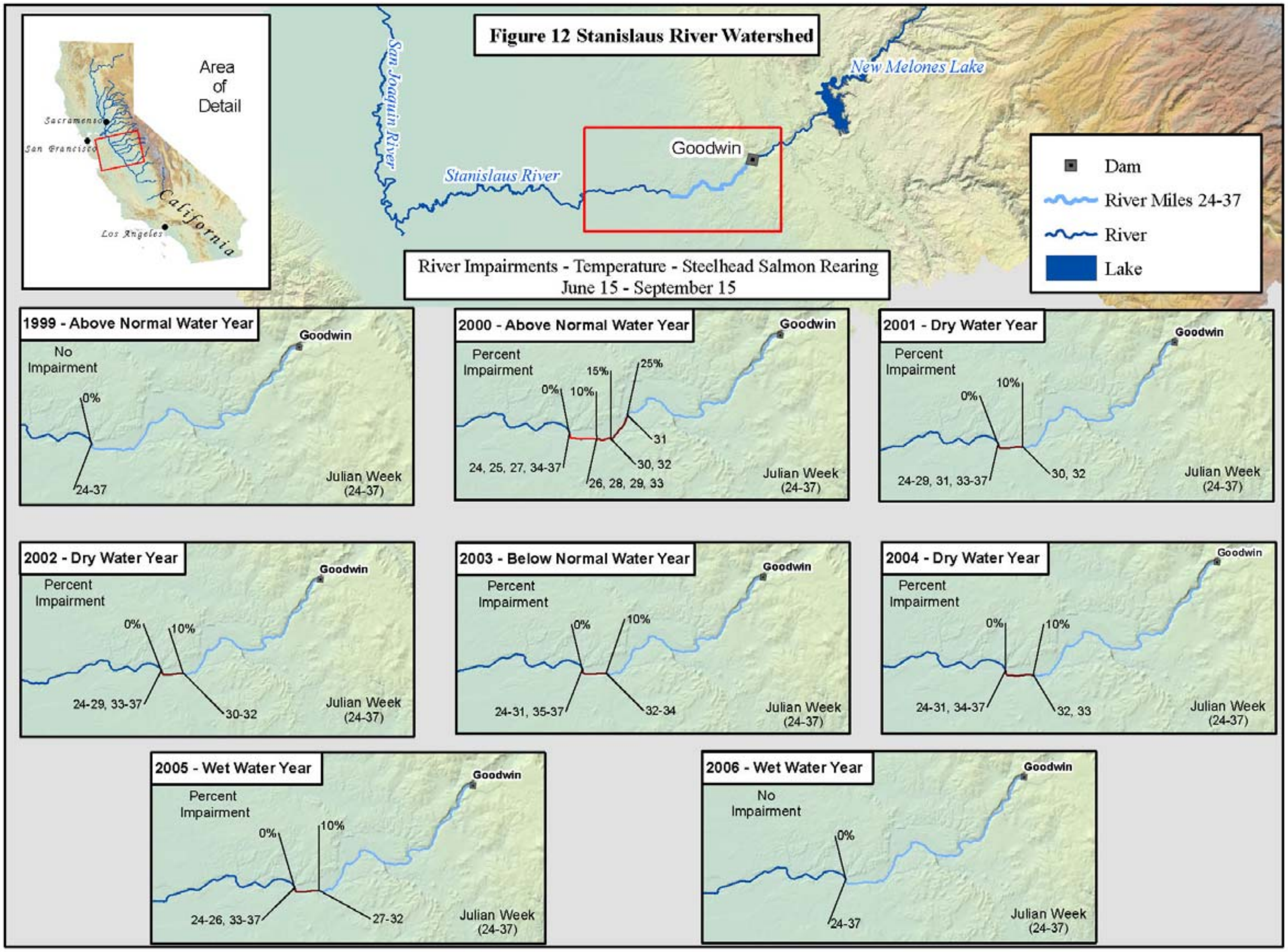
Figure 12 Stanislaus River Watershed
Area of Detail
Sacramento
San Francisco
Los Angeles
California
San Joaquin River
Stanislaus River
Goodwin
New Melones Lake
Dam
River Miles 24-37
River
Lake
River Impairments - Temperature - Steelhead Salmon Rearing
June 15 - September 15
1999 - Above Normal Water Year
No Impairment
0%
24-37
Julian Week (24-37)
2000 - Above Normal Water Year
Percent Impairment
0% 10% 15% 25%
24, 25, 27, 34-37
26, 28, 29, 33
30, 32
31
2001 - Dry Water Year
0% 10%
24-29, 31, 33-37
30, 32
2002 - Dry Water Year
0% 10%
24-29, 33-37
30-32
2003 - Below Normal Water Year
0% 10%
24-31, 35-37
32-34
2004 - Dry Water Year
0% 10%
24-31, 34-37
32, 33
2005 - Wet Water Year
0% 10%
24-26, 33-37
27-32
2006 - Wet Water Year
No Impairment
0%
24-37