variations can also be attributed to phytoplankton, zooplankton and other biological material in the water.

The TSS and turbidity assessments were conducted in a qualitative manner based on anticipated changes in these factors.

Microcystis

Microcystis has an annual life cycle characterized by two phases. The first is a benthic phase, during which cysts overwinter in the sediment. In the second planktonic phase, during summer and fall, *Microcystis* enters the water column and begins to grow. When environmental conditions, such as sufficiently warm water temperatures, trigger *Microcystis* recruitment from the sediment, the organism is resuspended into the water column through a combination of active and passive processes (Verspagen et al. 2004; Mission and Latour 2012). In the Delta, there are five primary environmental factors that trigger the emergence and subsequent growth of *Microcystis*.

1. Warm water temperatures (>19°C) (Lehman et al. 2013).
2. Nutrient availability (e.g., nitrogen and phosphorus) (Smith 1986; Paerl 2008 as cited in Davis et al. 2009).
3. Water column irradiance and clarity (surface irradiance >100 Watts per square meter per second and total suspended solid concentration <50mg/L (Lehman et al. 2013).
4. Flows and long residence times (Lehman et al. 2013).

Microcystis blooms typically develop over a period of several weeks after cells emerge from the benthic state (Marmen et al. 2016). Because environmental conditions and benthic recruitment drive *Microcystis* formation within the water column, it is common for many *Microcystis* cells to enter the water column at the same time. Once in the water column, and when environmental conditions are favorable, *Microcystis* rapidly multiplies. One study found the doubling time of *Microcystis aeruginosa* strains ranged from 1.5 to 5.2 days, with an average doubling time of 2.8 days (Wilson et al. 2006). This fast growth rate allows cells to form colonies which come together to form a "scum" layer at the water surface. In the Delta, scums are primarily composed of the colonial form of *Microcystis*, but single cells are also present (Baxa et al. 2010).

Like many cyanobacteria species, *Microcystis* possess specialized intracellular gas vesicles that enable the organism to regulate its buoyancy (Reynolds 1981 as cited in Paerl et al. 2014). This buoyancy allows *Microcystis* to take advantage of near surface areas with optimal growth conditions (e.g., light). The collection of cells at the surface, primarily in calm waters, allows *Microcystis* to sustain a competitive advantage over other phytoplankton species by optimizing their photosynthetic needs while shading out other algal species, which they compete with for nutrients and light (Huisman et al. 2004).

Wind and tides can enhance the aggregation of *Microcystis* cells in slow moving waters (Baxa et al. 2010), but in faster moving, turbulent waters, the ability of *Microcystis* to maintain its positive buoyancy is reduced (Visser et al. 1996). Therefore, high flow rates make it difficult for *Microcystis* to collect and form dense colonies at the water surface. Turbulence effects metabolic processes and cell division (Koch 1993; Thomas et al. 1995 as cited in Li et al. 2013) and thus can be a negative growth factor (Paerl et al. 2001 and articles cited within). Turbulent water mixes all algae throughout the photic zone of the water column and reduces light through turbidity which allows faster growing chlorophytes (green algae) and diatoms to outcompete the slower growing cyanobacteria, including *Microcystis* (Wetzel et al. 2001; Huisman et al. 2004; Li et al. 2013). Although the amount of flow required to disrupt a *Microcystis* bloom varies by system, in the Zhongxin Lake system China, flow velocities of 0.5–1.0 feet/second shifted the dominant phytoplankton species from cyanobacteria to green algae and diatoms (Li et al. 2013).

As described under Impact WQ-29 (Effects on TSS and Turbidity), changes in TSS and turbidity levels within the Delta under the project alternatives could not be quantified, but are expected to be similar under the project alternatives to Existing Conditions and the No Action Alternative. Minimal changes in water clarity would result in minimal changes in light availability for *Microcystis* under the project alternatives. As such, the project alternatives' influence on *Microcystis* production in the Delta, as influenced by the project alternatives' effects on Delta water clarity, is considered to be negligible.

Regarding nutrients the maintenance of *Microcystis* blooms in the Delta requires the availability of the nitrogen and phosphorus. However, the body of science produced by scientists studying *Microcystis* blooms in the Delta and elsewhere does not indicate that the specific levels of these nutrients, or their ratio, currently control the seasonal or inter-annual variation in the bloom. A large fraction of ammonia in the Sacramento River will be removed due to planned upgrades to the Sacramento Regional County Sanitation District's SRWTP, which will result in >95% removal of ammonia from the effluent discharge from this facility. Following the SRWTP upgrades, levels of ammonia in Sacramento River are expected to be similar to background ammonia concentrations in the San Joaquin River and San Francisco Bay (see Section 8.3.3.1, Impact WQ-1). The response of *Microcystis* production in the Delta to the substantial reduction in river ammonia levels (from removing ammonia from the SRWTP discharge) is unknown because nitrate and phosphorus levels in the Delta will remain well above thresholds that would limit *Microcystis* blooms.

Nutrient ratios in excess of the Redfield N:P ratio of 16 have also been hypothesized to favor *Microcystis* growth in the Delta (Glibert et al. 2011). However, considerable doubt has been cast on this hypothesis because median N:P molar ratios in the Delta during peak bloom periods are usually near or a little lower than the Redfield ratio of 16 needed for optimum phytoplankton growth, and when ammonia is considered the sole N source, the N:P ratio drops substantially to a median of 1.31:1 (Lehman et al. 2013). Based on this information, there is no evidence as to what type of effect small changes in nutrient concentrations and ratios would have on *Microcystis* blooms, given that such blooms are largely influenced by a host of other physical factors, including water temperature and water residence time within channels.

Based on the above, water clarity and nutrient effects on *Microcystis* were determined to not have substantial effects on *Microcystis* abundance under the project alternatives, relative to Existing Conditions and the No Action Alternative. A qualitative evaluation was performed to determine if the action alternatives would result in an increase in frequency, magnitude, and geographic extent of *Microcystis* blooms in the Delta based on the following two additional abiotic factors that may affect *Microcystis*: 1) changes to water operations and creation of tidal and floodplain restoration areas that change water residence times within Delta channels, and 2) increases in Delta water temperatures.

The methodology used to determine residence time for Alternatives 1A, 1B, 1C, 2A, 2B, 2C, 3, 4, 5, 6A, 6B, 6C, 7, 8, and 9 is described in BDCP Appendix 5.C, Section 5C.4.4.7, *Residence Time*. Briefly, residence time in different subregions of the Plan Area was assessed using the results of the DSM2 Particle Tracking Model for multiple neutrally buoyant particle release locations. Residence time

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was defined as the time at which 50% of particles from a given release location exited the Plan Area (either by movement downstream past Martinez or through entrainment at the south Delta export facilities, north Delta diversion, North Bay Aqueduct, or agricultural diversions in the Delta). The data were reduced into mean residence time by subregion and season. The data do not represent the length of time that water in the various subregions spends in the Delta in total, but do provide a useful parameter with which to compare generally how long algae would have to grow in the various subregions of the Delta. Table 8-60a shows the residence time results that are used in the *Microcystis* assessments. Results for summer and fall are most relevant for the *Microcystis* assessment, but all seasons are presented for completeness.

Table 8-60a. Average Residence Time for Subregions of the Plan Area by Season and Alternative

		Average Residence Time (days)										
Subregion	Season	Ex Cond.	No Act.	Alt 1	Alt 2	Alt 3	Alt 4 Scn H3	Alt 5	Alt 6	Alt 7	Alt 8	Alt 9
North Delta	Summer	33	38	43	38	41	39	41	43	40	46	40
	Fall	49	50	61	56	60	57	55	55	57	58	55
	Winter	36	37	40	40	40	39	41	37	37	37	40
	Spring	30	33	37	35	36	35	36	34	34	29	35
	Overall	35	38	43	41	43	41	41	40	40	40	41
Cache Slough	Summer	18	21	46	40	45	39	39	49	46	59	46
	Fall	46	46	44	39	43	40	39	39	45	56	39
	Winter	29	31	33	32	33	32	33	28	29	27	31
	Spring	22	24	33	33	33	33	33	31	30	33	31
	Overall	27	29	38	36	38	35	36	36	36	42	36
West Delta	Summer	22	24	32	28	30	28	29	40	27	33	28
	Fall	25	27	34	30	33	30	30	30	31	32	27
	Winter	18	20	21	21	21	21	21	19	19	19	19
	Spring	18	20	24	22	24	22	23	20	20	17	20
	Overall	20	22	27	25	26	25	25	27	23	24	23
East Delta	Summer	22	26	40	34	35	34	31	76	32	48	21
	Fall	15	35	33	47	32	48	48	58	55	55	21
	Winter	28	32	40	42	40	42	40	50	51	50	26
	Spring	42	47	57	54	59	54	56	61	57	54	35
	Overall	29	36	45	45	44	45	44	61	49	52	27
South Delta	Summer	8	10	16	17	14	16	11	70	23	33	35
	Fall	5	11	8	42	8	43	34	79	53	52	33
	Winter	10	11	19	19	14	16	15	59	57	56	28
	Spring	25	26	24	29	20	28	27	65	60	58	31
	Overall	13	16	18	26	15	25	21	67	49	50	32
Suisun Marsh	Summer	51	58	38	35	37	35	36	37	36	39	42
	Fall	17	19	39	34	38	34	33	32	34	34	38
	Winter	9	9	28	28	29	27	29	24	24	24	32
	Spring	45	51	32	31	31	30	30	29	28	25	33
	Overall	33	37	33	32	33	31	32	30	30	30	36

The methodology used to characterize residence time changes under Alternatives 4A, 2D, and 5A relied on modeled residence times presented in the Biological Assessment for the California WaterFix (ICF International 2016) for July through November. In addition, changes in maximum daily channel velocities, as modeled by DSM2, for a number of locations in the Delta were evaluated.

8.3.1.8 San Francisco Bay

The western seaward boundary of the Plan Area has been delineated at Carquinez Strait. There are no actions proposed to occur in the bays seaward of the Plan Area. Nevertheless, because a substantial portion of Delta waters does flow seaward, an assessment of the effects of Delta water quality changes under the project alternatives on the San Francisco Bay water quality was conducted to identify potential effects in the Bay. The assessment addresses potential direct and indirect effects on water quality of areas seaward of the Delta, based on the best available scientific understanding. No hydrologic or hydrodynamic modeling was conducted seaward of Suisun Bay.

Because net Delta flows move seaward, water quality constituents present in the Delta water column could potentially be transported seaward. The Screening Analysis (see Sections 8.3.1.3, 8.3.2.1, and Appendix 8C, *Screening Analysis*) identified constituents present in Delta waters warranting detailed assessment in the Plan Area based on their historical concentrations in the water column or importance to beneficial uses of Delta waters. These same constituents were addressed in the assessment of effects on San Francisco Bay. The assessment of effects in San Francisco Bay was based on projected changes in constituent concentration/levels that would occur in the Delta and changes in Delta outflow under the project alternatives. The following sections describe constituent-specific considerations and methods for calculating changes in Delta loading that are common to the assessment of all project alternatives in the San Francisco Bay for nutrients (ammonia, nitrate, and phosphorus), mercury, and selenium.

Nutrients: Ammonia, Nitrate, Phosphorus

Constituent-specific Considerations

Nutrients in freshwater outflows from the Delta have the potential to impact the embayments that make up the San Francisco Bay, although oceanic flows in and out of the Golden Gate mute the influence of Delta-derived freshwater flows on the Central Bay, South Bay, and Lower South Bay (Senn and Novick 2013). Thus, nutrients effects to San Francisco Bay from changes in Delta outflow would be limited almost entirely to the northern part of San Francisco Bay, namely San Pablo Bay. The assessment specifically addresses effects on San Pablo Bay, but relies on research conducted in Suisun Bay, because very little research specific to San Pablo Bay has been conducted and because San Pablo Bay and Suisun Bay experience similar nutrient loading. Existing effects from nutrients on San Pablo Bay and Suisun Bay have been hypothesized, yet widespread impairment due to nutrients in these embayments is not thought to be occurring (Senn and Novick 2013).

Suisun Bay is currently characterized by levels of phytoplankton biomass and a community composition insufficient to support the pelagic food web. The highly altered phytoplankton community and low biomass levels are thought to be linked primarily to the invasive clam *Corbula amurensis*, which was established in Suisun Bay in 1987, and grazing by other aquatic macroinvertebrates, specifically zooplankton (Kimmerer and Thompson 2014). Notwithstanding, Dugdale et al. (2007; 2012) has argued that nitrate is preferred by and fuels blooms of diatoms, and that uptake of nitrate by diatoms is impaired until ammonia levels are depleted below 0.03–0.06