Appendix B:
Water Quality Model Description

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B-1 INTRODUCTION

A water quality model was developed to assess the potential impacts of the proposed development in Rancho Mission Viejo on the receiving water quality, and to evaluate the effectiveness of the proposed stormwater treatment systems. Three different conditions were evaluated with the water quality model:

1. pre-development
2. post-development without treatment
3. post-development with treatment

The water quality model is an empirical model that applies monitored water quality data to modeled stormwater runoff flows. The model was developed to provide a simple yet reasonably reliable method for predicting pollutant loads and concentrations that occur as a result of development. Average annual loads and concentrations are calculated and presented for the dry, wet and total period of record. The model also predicts the improvement in water quality due to the implementation of Best Management Practices (BMPs). The objectives of the water quality model are as follows:

- Compare predicted loads and concentrations for pre-development, post-development, and post-development with BMP conditions (example shown in Figure B-1).

- Estimate the percent change in pollutant loads and concentrations by comparing pre-development condition to post-development conditions with BMPs.

- Compare concentrations of pollutants in post-development condition with BMPs with the appropriate water quality criteria, and/or water quality design standards.

The water quality model was used to evaluate the following pollutants for pre-development conditions and post-development conditions with and without treatment:

- Total Suspended Solids
- Total Phosphorus
- Dissolved Phosphorus
- Nitrogen (total, nitrate)
- Total Aluminum
- Dissolved Cadmium
- Total and Dissolved Copper
- Total and Dissolved Lead
- Total and Dissolved Zinc

These pollutants are commonly associated with runoff from urban areas. The pollutant event mean concentrations (EMCs) used in the model were adapted from local monitoring data.

As with all environmental modeling, the accuracy of model results is heavily dependent on how well the hydrologic, water quality, and BMP effectiveness data describe the actual site characteristics. Consequently, local and regional data (as opposed to national data) are used to the fullest extent possible. This particular model allows for the selection of inputs that reflect regional conditions such as local water quality monitoring data and modeled runoff volumes that incorporate site-specific rainfall, soil and vegetation parameters. BMP effectiveness was estimated using The National Stormwater Best Management Practices Database (UWRRC, 2000).

B-2 WATER QUALITY MODEL METHODOLOGY

In general, pollutant loads are calculated by first estimating average annual runoff volumes for each land use within a given catchment. Runoff volumes from each land use are then multiplied by there corresponding pollutant EMCs to estimate the pollutant loads. BMP effectiveness was determined by multiplying monitored BMP effluent quality by the treated runoff volume. The EMCs and BMP effluent data utilized in the water quality model are summarized in subsequent sections of this appendix. The following sections describe the methodologies and equations used in water quality model.

B-2.1 Average Annual Pollutant Loads

Pollutant loads for each land use were estimated by multiplying the average annual runoff volumes by the corresponding land use EMCs:

$$L_{lu} = Q_{lu} * C_{lu} * 2.719 \frac{lbs/acre-ft}{mg/L} \qquad (1)$$

Where:

L_{lu} = Average annual pollutant load for each land use (lbs/yr)

Q_{lu} = Annual runoff volume for each land use (acre-ft/yr)

C_{lu} = EMC for each land use (mg/L)

This provides the average annual pollutant load for each land use within a given catchment. The pollutant loads are then summed for each land use within a sub-basin to provide the total annual pollutant load:

$$L_T = \sum L_{lu} \qquad (2)$$

Where:

L_T = Average annual pollutant load for each sub-basin (lbs/yr)

B-2.2 Average Annual Pollutant Concentrations

The average annual pollutant concentrations for each sub-basin are determined by first calculating the total annual runoff volume for the entire sub-basin.

$$Q_T = \sum Q_{lu} \tag{3}$$

The total pollutant load is then divided by the total runoff volume, yielding the average annual pollutant concentration for each sub-basin:

$$C_T = \frac{L_T}{Q_T} * 0.368 \frac{mg / L}{lbs / acre - ft} \tag{4}$$

Where:

Q_T = Total annual runoff volume for each sub-basin (acre-ft/yr)

C_T = Average annual pollutant concentration for each sub-basin (mg/L)

B-2.3 BMP Treatment

The proposed BMPs were incorporated into the model to estimate there effectiveness at reducing pollutant loads into the receiving water. BMP effluent data was adapted from the National Stormwater Best Management Practices Database. This database provides effluent quality from a variety of BMPs. The pollutant loads from each of the proposed BMPs were determined by multiplying the average effluent pollutant concentration by the annual runoff volume treated by the BMP:

$$L_{BMP} = Q_{BMP} * C_{BMP} * 2.719 \frac{lbs / acre - ft}{mg / L} \tag{5}$$

Where:

L_{BMP} = Average annual pollutant load discharged from each BMP (lbs/yr)

Q_{BMP} = Annual runoff volume treated by each BMP (acre-ft/yr)

C_{BMP} = Average pollutant concentration discharged from each BMP (mg/L)

During high intensity or long duration storm events, a portion of the runoff flows could potentially bypass the BMPs. When this occurs, the bypassed flows are not effectively treated by the BMP. Pollutant loads from the bypassed flows are determined by multiplying the average annual concentration from each sub-basin (calculated by equation 4) by the total annual bypassed volume:

$$L_{bypass} = Q_{bypass} * C_T * 2.719 \frac{lbs/acre-ft}{mg/L} \quad (6)$$

Where:

L_{bypass} = Average annual pollutant load from the bypassed flows (lbs/yr)

Q_{bypass} = Annual bypassed volume (acre-ft/yr)

C_T = Average annual pollutant concentration for each sub-basin (mg/L)

To determine the total pollutant load that is being discharged into the receiving water, the treated and bypassed pollutant loads are summed:

$$L_T = L_{bypass} + L_{BMP} \quad (7)$$

Where:

L_T = Average annual pollutant load from the sub-basin (lbs/yr)

L_{bypass} = Average annual pollutant load from the bypassed flows (lbs/yr)

L_{BMP} = Average annual pollutant load from the treated flows (lbs/yr)

This yields an estimate of the total pollutant load being discharged into the receiving water during post-development conditions with BMPs.

B-3 MODEL INPUTS PARAMETERS

As previously stated, the accuracy of the water quality model is heavily dependent on how well the input parameters, such as the hydrology, water quality, and BMP effectiveness data, describe the actual site characteristics. Because of this, local data was used whenever possible. The primary input data required by the model include:

1. pre- and post-development land uses areas
2. pollutant EMC data for each land use
3. average annual runoff volumes for each land use

4. BMP effluent quality

The following sections describe the source for each of the input parameters.

B-3.1 <u>Pre- and Post Development Land Uses</u>

Land use data was obtained for the existing and proposed conditions for each of the modeled alternatives. The land use types were defined as transportation, single family residential, multi-family residential, commercial, golf course, estates, nurseries, parks, schools, and open space. Each land use type was assigned a pollutant concentration (based on monitoring data) to determine the pollutant loads generated from each land use. Sources of the land use data are described in Appendix A, Section A-3.

B-3.2 <u>EMC Monitoring Data</u>

The most accurate estimates of pollutant concentrations are based on the analysis of stormwater sampling information collected during monitoring programs conducted near or at the project site. However, due to the variable nature of runoff concentration data, it takes numerous monitored storms collected over several years to gather enough data to produce statistically significant results. Therefore it is not practical or cost effective to collect local data for each development project. More commonly, average pollutant concentrations estimated in published historical studies are applied.

Several sources of information for estimating land use water quality are available. National average pollutant concentrations for land use types were estimated in Nationwide Urban Runoff Program's Final Report published in 1983 (US EPA, 1983). More recently, a number of municipalities have conducted stormwater monitoring programs including Ventura County and LA County, which has conducted stormwater-monitoring programs since 1996. Because of there extensive databases, pollutant EMCs for each land use type were estimated from the monitoring data collected by the LA County and Ventura County Stormwater Monitoring Programs.

B-3.2.1 LA County Stormwater Monitoring Program

The Los Angeles County Stormwater Monitoring Program was initiated with the goal of providing technical data and information to support effective watershed stormwater quality management programs in Los Angeles County. Specific objectives of this project included monitoring and assessing pollutant concentrations from specific land uses and watershed areas. In order to achieve this objective, the County undertook an extensive stormwater sampling project that included 7 land use stations and 5 mass emission stations, which were tested for 82 water quality parameters. These data were published in the *Los Angeles County*

1994-2000 Integrated Receiving Water Impacts Report (Los Angeles County Department of Public Works, 2000a).

The land use monitoring stations capture runoff from smaller watersheds (0.1 to 1 square mile) with relatively homogeneous land use, Mass Emission Stations monitored runoff from major drainage areas near their outfall to the ocean. At both of these station types, flows were measured and automated samplers were installed to collect and composite stormwater samples during storm events. For the purposes of modeling, only the data from the land use monitoring sites were utilized. Furthermore only data from developed land uses that were similar to the uses anticipated for the proposed development were selected to the extent possible (i.e. data from stormwater monitoring of a commercial site by LA County is used to represent stormwater concentrations from commercial areas within the proposed development). A description of the land use stations monitored in the LA County program of which land use EMC data were utilized in the model and the years monitored by water year are provided in Table B-1.

Table B-1: Land Use Stations Monitored in the LA County Monitoring Program

Station Name	Station ID	Modeled Land Use	Site Description	Monitoring Years
Santa Monica Pier	S08	Commercial	The monitoring site is located near intersection of Appian Way and Moss Avenue in Santa Monica. The storm drain discharges below the Santa Monica Pier. Catchment area is approximately 81 acres. The Santa Monica Mall and Third St. Promenade dominate the watershed with remaining land uses consisting of office buildings, small shops, restaurants, hotels and high-density apartments.	1996-1999
Sawpit Creek	S11	Open Space (Vacant)	Located in Los Angeles River watershed in City of Monrovia. The monitoring station is Sawpit Creek, downstream of Monrovia Creek. Sawpit Creek is a natural watercourse at this location. Catchment area is approximately 3300 acres.	1996-2000
Project 620	S18	Single Family Residential	Located in the Los Angeles River watershed in the City of Glendale. The monitoring station is at the intersection of Glenwood Road and Cleveland Avenue. Land use is predominantly high-density, single-family residential. Catchment area is approximately 120 acres.	1996-2000
Dominguez Channel	S23	Freeway	Located within the Dominguez Channel/Los Angeles Harbor watershed in Lennox, near LAX. The monitoring station is near the intersection of 116th Street and Isis Avenue. Land use is predominantly transportation and includes areas of LAX and Interstate 105.	1996-2000
Project 1202	S24	Industrial	Located in the Dominguez Channel / Los Angeles Harbor Watershed in the City of Carson. The monitoring station is near the intersection of Wilmington Avenue and 220th Street. The overall watershed land use is predominantly industrial.	1996-2000

Station Name	Station ID	Modeled Land Use	Site Description	Monitoring Years
Project 474	S25	Education	Located in Los Angeles River watershed in the Northridge section of the City of Los Angeles. The monitoring station is located along Lindley Avenue, one block south of Nordoff Street. The station monitors runoff from the California State University of Northridge. Catchment area is approximately 262 acres.	1997-2000
Project 404	S26	Multi-Family Residential	Located in Los Angeles River watershed in City of Arcadia. The monitoring station is located along Duarte Road, between Holly Ave and La Cadena Ave. Catchment area is approximately 214 acres.	1997-2000
Project 156	S27	Mixed Residential	Located within the Los Angeles Watershed in the City of Glendale. The station is located along Wilson Avenue, near the intersection of Concord Street and Wilson Avenue. The land use of the drainage area is classified as mixed residential.	1997-2000

Source: Los Angeles County 1999-2000 Draft Stormwater Monitoring Report (Los Angeles County Department of Public Works, 2000)

B-3.2.2 Ventura County Monitoring Program

As part of its NPDES permit, the Ventura County Flood Control District conducts storm water monitoring to determine water quality of stormwater runoff from areas with specific land uses, including agriculture. These data were published in the *Ventura Countywide Stormwater Monitoring Reports* (Ventura County Flood Control Department, November 1997; November 1998; November 1999 and July 2001).

These sites include the Wood Road at Revolon Slough Station (A-1). The watershed for this site is approximately 350 acres, and is located in Oxnard, Ventura County. The watershed is located in the flat coastal plain. The monitoring station is located in-stream, on Revolon Channel just downstream of Laguna Road. The drainage area land use is primarily row crops, including strawberries that incorporate plastic sheeting mulch. The watershed contains a small number of farm residences and ancillary farm facilities for equipment maintenance and storage. With regard to irrigation practices, sprinklers are used for plant establishment; once the plants are established, farmers switch to drip irrigation. Plastic cover is utilized during certain life stages of some crops, namely strawberries.

Stormwater samples were collected as either grab samples or flow-weighted composite samples. The water quality data from water years 1996/97, 1997/98, 1998/99, and 2000/01, were available for the Wood Road site. During this period 9 grab samples and 10 flow-weighted composite samples were obtained during runoff events. The data from the flow-weighted composite samples were used to determine model input concentrations (i.e. station average concentrations), as these are more appropriate for estimating pollutant loads from the nurseries.

B-3.2.3 Statistical Analysis

Data analysis conducted by Los Angeles County substituted values equal to half the laboratory detection limit in order to estimate descriptive statistics (e.g. mean and standard deviation) for event mean concentrations (EMCs) for each monitored pollutant at each land use monitoring station. These summarized data are reported in Table 4-12 of the *Los Angeles County 1994-2000 Integrated Receiving Water Impacts Report.* While substituting half the detection limit is a common practice due to its ease of implementation, this method is known to introduce bias into the estimates for both the mean and standard deviation (Singh et al. 1997).

Previous studies have suggested that stormwater pollutant runoff concentrations tend to be logarithmically distributed. If the distribution of a data set is known, values below the detection limit can be estimated using a maximum likelihood estimator (Helsel and Hirsh 1993). For this evaluation, the individual event mean concentrations (raw data) for each of the land use monitoring sites in Table B-1 were obtained from the Los Angeles Department of Public Works Watershed Management Division/NPDES Section.

Detection limits for the modeled pollutants are shown in Table B-2. In an effort to derive more robust estimates of EMCs for the modeled pollutants, a maximum likelihood estimator method was used to analyze the monitoring data. This method ranks the log-transformed data above the detection limit, arbitrarily assigns ranks to the below the detection limit data, and extrapolates to estimate probable values of data below the detection limit using the Cunnane plotting position formula[1]. These values are then used with the detect data to estimate the descriptive statistics. As described in the *Los Angeles County 1994-2000 Integrated Receiving Water Impacts Report*, the majority of pollutants from the monitored land uses are best characterized with a lognormal distribution, so all data sets were analyzed assuming the lognormal distribution. Using this assumption, the probability of a concentration value occurring can be assigned to each event in the log-converted data set (including the non-detect values). If the probability of the pollutant concentration occurring is plotted against the log of the concentration for the events above the detection limit (based on the probabilities assigned using the entire data set), a line can be fit to the data above the detection limit and the slope and intercept can be calculated. The slope corresponds to the standard deviation of the data set and intercept corresponds to the median. From these parameters station mean concentrations can be calculated using the statistical relationships between central tendency and error that exist for log-converted data. A mean calculated in this manner would take into account the non-detect values as if each was assigned an actual value based on the distribution of the data set. Again, from the calculated log transformed data means and variances, the population arithmetic means and arithmetic standard deviations can be calculated for each of the parameters.

Table B-3 provides a summary of the mean stormwater runoff pollutant concentrations calculated from the land use stations from the LA County stormwater monitoring data. Table B-4 provides the estimated coefficient of variation for the modeled parameters and land uses. These values represent the summarized data from all of the sampling events for each station, which were log transformed and adjusted for non-detects as described earlier.

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[1] The Cunnane plotting position formula is $p=r - a/(n+1-2a)$, where $a = 0.4$, p is the probability or plotting position, r is the rank, and n is the total number of data points, both above and below the detection limit.

Table B-2: Monitoring Data Detection Limits and % of Detects for Modeled Parameters & Land Uses

Constituents	TSS	TP	Diss. P	Nitrite-N	Nitrate-N	TKN	Total Al	Diss.Cd	Diss. Cu	Tot Cu	Diss. Pb	Tot. Pb	Diss. Zn	Tot. Zn
Land Use / DL	2 mg/L	0.05 mg/L	0.05 mg/L	0.03 mg/L	0.1 mg/L	0.1 mg/L	100 ug/L	1 ug/L	5 ug/L	5 ug/L	5 ug/L	5 ug/L	50 ug/L	50 ug/L
Transportation[1]	100%	99%	96%	87%	47%	100%	87%	14%	100%	100%	9%	49%	90%	100%
Light Industrial[1]	100%	95%	91%	84%	55%	100%	86%	6%	89%	100%	11%	43%	80%	98%
Mixed Residential[1]	98%	98%	96%	86%	53%	98%	82%	4%	68%	96%	9%	26%	57%	91%
MF Residential[1]	98%	97%	97%	76%	65%	100%	80%	2%	57%	93%	7%	24%	59%	89%
Educational[1]	100%	100%	98%	71%	53%	100%	93%	9%	81%	100%	4%	45%	15%	54%
HDSF Residential[1]	98%	100%	100%	65%	40%	100%	80%	2%	60%	95%	10%	38%	88%	100%
Commercial[1]	100%	97%	97%	79%	48%	97%	76%	13%	88%	100%	17%	8%	4%	13%
Vacant[1]	98%	48%	100%	30%	88%	100%	63%	0%	2%	56%	0%	100%	90%	100%
Crops[2]	100%	100%	70%	NA[3]	100%	100%	NA[3]	70%	100%	100%	60%	42%	92%	100%

Notes:

(1) Data taken from LA County database
(2) Data taken from Ventura County database
(3) NA- Not analyzed

Table B-3: Estimated Arithmetic Mean EMC Values for Modeled Parameters & Land Uses

Constituents	TSS	TP	Diss. P	Nitrite-N	Nitrate-N	TKN	Total Al	Diss. Cd	Diss. Cu	Tot Cu	Diss. Pb	Tot Pb	Diss Zn	Tot Zn
Land Use / Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Transportation[1]	39	0.3	0.25	0.05	0.33	1.05	250	1.94	24.3	34	0.52	3.52	129	173
Light Industrial[1]	178	0.31	0.2	0.07	0.61	2.28	837	0.36	17.1	28	8.38	18.16	267	335
Mixed Residential[1]	73	0.28	0.23	0.13	0.59	2.23	278	0.06	8.6	13	1.6	5.22	98	134
MF Residential[1]	40	0.24	0.2	0.11	1.36	1.81	286	0.05 [5]	6.36	11	1.01	3.25	61	97
Educational[1]	94	0.3	0.26	0.09	0.58	1.59	707	0.36	9.9	16	0.47	2.92	67	97
HDSF Residential[1]	120	0.41	0.32	0.09	0.79	2.99	570	0.05	9.51	16	5.13	8.76	31	73
Commercial[1]	68	0.4	0.4	0.15	0.55	3.11	1933	0.66	14.5	35	4.9	20.81	157	239
Vacant[1]	224	0.12	0.09	0.03	1.16	0.98	679	0.05	2.5 [6]	9	1.25 [7]	3.21 [8]	37	22
Crops[2]	1397	2.74	2.74 [3]	0.026 [4]	12.32	8.07	NA[9]	1.9	29	133	18.41	49.12	38	332

Notes:

(1) Data taken from LA County database
(2) Data taken from Ventura County database
(3) Estimates for dissolved phosphorous were higher than for total phosphorus due to larger variation. The EMC for dissolved phosphorus was set equal to the total phosphorus value
(4) Nitrite was not monitored by Ventura County for the row crops; the EMC was set equal to the open space EMC due to the lack of monitoring data.
(5) There was only one detect for dissolved cadmium for MF Residential and HDSF Residential land uses and none for vacant land use. Hence, the dissolved Cd value was set to ½ of the detection limit due to lack of data.
(6) There was only one detect for dissolved copper for open space land use, the value was set to half the detection limit due to the lack of data.
(7) There were no detects for dissolved lead for open space land use; the value was set to ½ of the detection limit due to the lack of data.
(8) One data point with a value of 113 ug/L was eliminated as an outlying value
(9) NA- Not analyzed

Table B-4: Estimated Coefficient of Variation for Modeled Parameters & Land Uses

Constituents	TSS	TP	Diss. P	Nitrite-N	Nitrate-N	TKN	Total Al	Diss. Cd	Diss Cu	Tot Cu	Diss Pb	Tot Pb	Diss Zn	Tot Zn
Land Use / Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Transportation[1]	0.7	0.6	0.7	0.5	0.9	0.4	0.8	0.2	0.4	0.3	4.1	1.4	0.6	0.4
Light Industrial[1]	0.8	0.9	0.8	0.7	1	0.7	2	10.2	1	0.8	3.1	4.4	0.7	0.5
Mixed Residential[1]	1.2	0.9	0.8	1.3	0.7	0.8	1.2	9.5	0.8	0.5	22	1.6	0.7	0.5
MF Residential[1]	1.3	0.9	1	1.8	0.9	0.7	0.9	NE[4]	0.7	0.4	6.7	1.8	0.9	0.5
Educational[1]	1.2	0.6	0.8	1.6	0.7	0.6	1	0.9	0.7	0.4	36.5	1.3	0.6	0.5
HDSF Residential[1]	1.3	0.8	0.7	1.9	2.2	0.9	2.1	NE[4]	1	0.6	1.3	1.5	3.7	0.8
Commercial[1]	0.7	0.8	0.8	1.7	0.7	1	6.4	0.5	0.9	0.9	6.1	8.1	0.7	0.6
Vacant[1]	7	3.3	15.9	0.4	0.6	1	4	NE[4]	2.1	2	NE[4]	0.4	0.5	5.1
Crops[2]	1.3	0.4	3.4	NA[3]	0.9	0.6	NA[3]	2	1.1	0.7	3.4	0.8	0.9	0.5

Notes:

(1) Data taken from LA County database
(2) Data taken from Ventura County database
(3) NA- Not analyzed
(4) NE - Not estimated due to lack of data

B-3.3 Average Annual Runoff Volume

Average annual runoff volumes were modeled using EPA's Storm Water Management Model (SWMM). Runoff volumes were modeled for each land use within each catchment. A detailed description of the methodology, data needs and data sources of SWMM are provided in Appendix A.

B-3.4 BMP Effluent Quality

Various data sources were examined to estimate the anticipated performance of the proposed BMPs, including the American Society of Civil Engineers (ASCE) and EPA database recently compiled by ASCE's Urban Runoff Research Council (Strecker et al., 2001). The ASCE International Stormwater Best Management Practices Database is the most recent and robust database available to analyze the effects of a variety of BMPs on storm water quality (available at http://www.bmpdatabase.org). The ASCE Database contains the results of studies that have monitored the effectiveness of a variety of BMPs in treating water quality pollutants. Typical information included in each study is a description of the BMP, the drainage area with dominant land uses, influent concentrations, effluent concentrations, and removal efficiencies. BMP treatment efficiencies for the detention basins and vegetated swales are based upon the BMP water quality monitoring data included in the ASCE Database shown in Table B-5.

When there is insufficient data in the database to provide statistically reliable effluent concentrations for certain constituents (such as aluminum), the effluent quality is assumed to be equal to the influent quality (a conservative approach that assumes no treatment).

Table B-5: BMP Performance- Modeled Effluent Concentration for Stormwater Treatment in Detention Basins and Vegetated Swales

BMP		ASCE/EPA National BMP Effluent Quality[1,2]												
		TSS	**Total P**	**Diss. P**	**TKN**	**Nitrate-N**	**Ammonia-N**	**Diss. Cd**	**Tot Cu**	**Diss. Cu**	**Tot Pb**	**Diss. Pb**	**Tot Zn**	**Diss. Zn**
Detention Basin	Concentration (mg/L)	34	0.265	0.153	1.58	0.294	0.365	5.20E-04	0.016	0.016	0.019	0.003	0.078	0.055
	# of Samples	89	74	8	58	74	12	23	95	69	94	69	104	69
Vegetated Swale	Concentration (mg/L)	24	0.345	0.252	1.19	0.516	0.07	2.40E-04	0.006	0.006	0.014	0.004	0.038	0.025
	# of Samples	148	165	105	60	133	68	37	131	62	155	62	159	62

Notes:

(1) Performance based on mean value of available ASCE database monitoring data for detention basins.
(2) Due to sparse data in the ASCE database, effluent quality for total Al was conservatively assumed to be same as influent quality

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