ACTION MEMORANDUM CHATFIELD WATERSHED AUTHORITY

Date: April 17, 2023

TO: CWA Board

FROM: Alan J. Leak, P.E., CWA Technical Consultant

SUBJECT: Lynker's Chatfield Watershed Model – Point Source Model Results Memorandum dated March 30, 2023.

SUMMARY OF ACTION REQUESTED: Accept Lynker's Chatfield Watershed Model – Point Source Model Results Memorandum dated March 30, 2023.

RECOMMENDED EFFECTIVE DATE: Not Applicable

COST IMPACTS: No cost impacts

PURPOSE / BACKGROUND: The CWA contracted with Lynker to use the Authority's Watershed model (prepared by Lynker) to perform additional model runs to investigate the potential changes in phosphorus loads and concentrations entering Chatfield Reservoir from changes in phosphorus loads from wastewater treatment facilities in the Chatfield watershed. The attached Memorandum presents and documents the assumptions, analysis, and results of Lynker's modeling. This memorandum completes Lynker's contracted modeling tasks.

RECOMMENDATION(S): Recommend the CWA TAC Board Approve Lynker's Chatfield Watershed Model – Point Source Model Results Memorandum

Attachment: Lynker Chatfield Watershed Model – Point Source Model Results Memorandum dated March 30, 2023.

MEMORANDUM

To:	Chatfield Watershed Authority Technical Advisory Committee
cc:	Diane Kielty, Colorado Watershed Assembly; Alan Leak, RESPEC
From:	Bill Szafranski, Lynker Technologies
Subject:	Chatfield Watershed Model – Point Source Model Scenarios
Date:	March 30, 2023

Introduction

The Chatfield watershed model was built to simulate total phosphorus loading in the Chatfield watershed. The model was built in 2016 using the Hydrologic Simulation Program – FORTRAN (HSPF) and was set up to run from January 1, 1995 to September 30, 2015 at an hourly time step. The model was calibrated using water quality records from 2000 to 2015. The model currently simulates five point source discharges in the watershed: Plum Creek Water Reclamation Authority (PCWRA), Lockheed Martin, Sageport wastewater treatment facility (WWTF), Waucondah WWTF, and the Roxborough WWTF (see Figure 1). In most instances the point sources are simulated in the model from 2000 to 2015 using average monthly data. The Louviers and Town of Larkspur WWTFs were not included in the model because they had not recently discharged to the watershed when the model was built (Leonard Rice Engineers and Lynker Technologies, 2016).

Purpose

In this analysis, we evaluate the impact of changes to the point source discharges in the watershed by simulating the point source discharges a) off and b) increased to the full wasteload allocation. In the first analysis, to evaluate the impact of these point sources on total phosphorus loading in the Chatfield Reservoir watershed, we ran the model with these five point source discharges turned off and compared the results to the watershed model representing historical conditions (point sources following historical operations). In the second analysis, we ran the model with the point source dischargers set to their full wasteload allocation and we compared the results with the watershed model representing historical conditions.

Point Source Observational Data

For each of the point sources, we calculated average monthly orthophosphorus and organic phosphorous loads from available observational total phosphorus data. The observational data were collected at different frequencies and durations for each of the point sources, as summarized below.

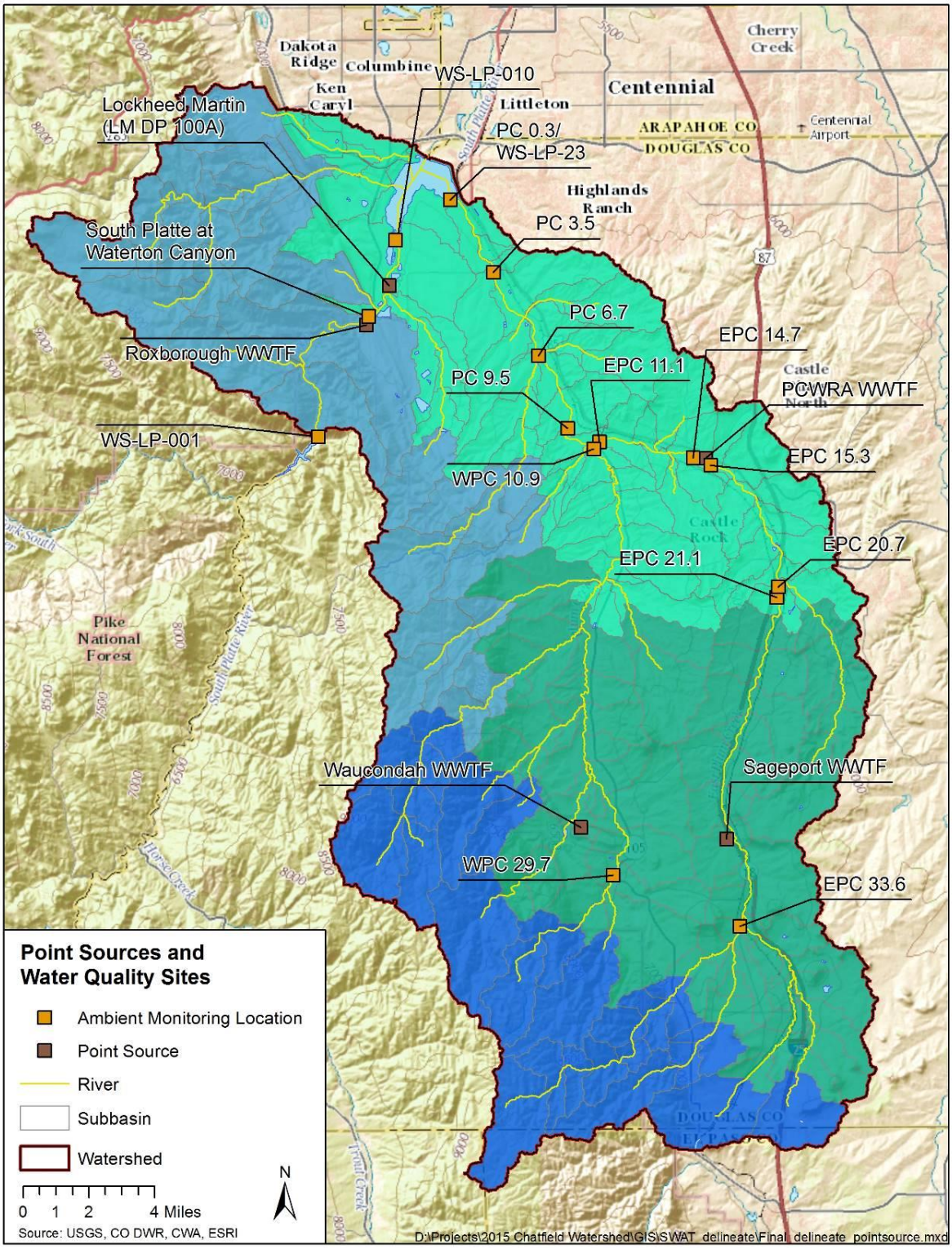
- The Plum Creek Water Reclamation Authority (PCWRA) is located on East Plum Creek at Highway 85 and West Happy Canyon Road, and the data are loaded into the model in reach 52. The PCWRA total phosphorus point source data typically include four to five data points per month between January 2000 and October 2012 and one data point per month between November 2012 and July 2015, with average monthly values used from August 2015 to September 2015.

- The Lockheed Martin facility discharges to the South Platte River near Waterton Canyon, and the data is loaded into the model in reach 16. The Lockheed Martin total phosphorus point source data typically include four data points per month from January 2000 to October 2007 and one data point per month from November 2007 to June 2015, with average monthly values used from July 2015 to September 2015.
- The Sageport wastewater treatment facility (WWTF) discharges to East Plum Creek, and the data is loaded into model reach 116. The Sageport point source data include one total phosphorus measurement per month from January 2005 to December 2014, with data from 2009 and 2015 filled using average monthly values.
- The Waucondah WWTF discharges into Bear Creek, a tributary to West Plum Creek, and the data is loaded into model reach 113. The Waucondah point source data include one total phosphorus measurement per month from January 2005 to December 2014, with data from 2015 filled using average monthly values. This data was used to calculate average monthly orthophosphorus and organic phosphorus loads to use in the model.
- The Roxborough WWTF is located near the South Platte River, and the data are loaded into model in reach 29. The Roxborough point source data typically includes 4 to 5 data points per month from January 2000 to September 2007, except for September through December 2001 and all months in 2003, which were filled using average monthly values. Roxborough stopped discharging into the Chatfield watershed after 2007 when it conveyed its effluent to the Littleton Englewood WWTF (Leonard Rice Engineers and Lynker Technologies, 2016).

A summary of the annual total phosphorus point source loads included in the model is provided in Table 1.

Table 1: Annual Total Phosphorus Point Source Load

Year	PCWRA (lbs)	Lockheed Martin (lbs)	Sageport WWTF (lbs)	Waucondah WWTF (lbs)	Roxborough WWTF (lbs)
2000	1,250	310	0	0	480
2001	1,630	140	0	0	450
2002	2,650	190	0	0	550
2003	3,310	180	0	0	770
2004	3,910	200	0	0	830
2005	2,650	230	62	103	1,180
2006	2,300	170	66	107	760
2007	2,180	280	51	144	970
2008	2,660	80	53	209	0
2009	2,880	20	47	101	0
2010	1,850	20	40	93	0
2011	2,210	10	34	81	0
2012	2,510	10	25	69	0
2013	1,860	20	25	85	0
2014	1,900	20	29	91	0
Average (when discharging)	**2,380**	**120**	**43**	**105**	**750**



Source: Figure 2-12 (Leonard Rice Engineers and Lynker Technologies, 2016)

Figure 1: Point Source Locations

Watershed Simulated without Point Source Discharges

We used the Chatfield watershed model to run scenarios with the point sources operating normally (the historical model) and with the point sources turned off. When the point sources are turned off, all five point sources (PCWRA, Lockheed Martin, Sageport WWTF, Waucondah, and Roxborough WWTF) no longer discharge flow, total phosphorus, and other water quality constituents into the watershed.

We ran the model for the full period of record (January 1995 to September 2015) and analyzed the results from January 2000 to December 2014, representing the calibrated model record. Here we provide simulated annual total phosphorus loads for the South Platte (model reach 16) and Plum Creek (model reach 15) (Table 2). On average, the total phosphorus contribution from the South Platte River decreased by 360 pounds per year and the total phosphorus contribution from Plum Creek decreased by 1,740 pounds per year when the model simulates the watershed without point source discharges.

Table 2: Simulated Annual Total Phosphorus Load

Year	South Platte River Total Phosphorus Load (lbs)			Plum Creek Total Phosphorus Load (lbs)		
	Historical Model	Point Sources Off	Difference	Historical Model	Point Sources Off	Difference
2000	5,610	5,030	590	4,110	3,370	750
2001	3,010	2,700	310	4,100	3,080	1,020
2002	3,550	3,090	450	3,090	1,390	1,700
2003	7,440	6,800	640	10,630	8,270	2,350
2004	7,050	6,330	720	6,870	3,990	2,880
2005	8,730	7,760	960	6,720	4,630	2,080
2006	4,310	3,710	600	5,610	3,920	1,690
2007	17,090	16,130	960	19,190	17,340	1,850
2008	4,020	3,940	70	5,110	3,070	2,040
2009	5,320	5,300	20	7,750	5,590	2,170
2010	4,860	4,850	20	15,260	13,840	1,420
2011	1,590	1,580	10	4,960	3,400	1,560
2012	680	680	10	4,420	2,690	1,730
2013	2,060	2,040	10	4,010	2,750	1,260
2014	5,950	5,920	20	5,070	3,710	1,370
Average	**5,420**	**5,060**	**360**	**7,130**	**5,400**	**1,720**

Full Wasteload Allocation Simulation

We used the Chatfield watershed model to run scenarios with four of the five point sources discharging their full wasteload allocation to represent future potential buildout conditions in the Chatfield Reservoir watershed. In this scenario the Roxborough WWTF point source does not discharge into the watershed due to a change in wasteload ownership (Table 3). In Table 3, we show the total phosphorus load from the last 10-years of the historical record in the model (2005-2014), which is used in the development of parameters for the wasteload allocation scenario. We note that the total phosphorus load in the 10-year historical record (2005-2014) is similar to the total phosphorus load for the most recent historical data (2021), representing a reasonable approximation of current conditions. The total phosphorus load simulated by the model in the wasteload allocation scenario is 5,699 pounds (lbs)/year (as shown in Table 3), which represents 75% of the total phosphorus wasteload allocation for all point sources in the watershed (7,605 lbs/year) (CWA, 2021).

Table 3: Total Phosphorus Annual Historical and Wasteload Allocation

Permittee	CDPHE Permit	Total Phosphorus Load (2005-2014) (lbs/yr)	Total Phosphorus Load (2021) (lbs/yr)	Total Phosphorus Wasteload Allocation (lbs/yr)
Plum Creek Water Reclamation Authority (PCWRA)	CO0038547	2,035	2,044	4,256
Lockheed Martin Space Systems Company	CO0001511	57	22.1	1,005
Perry Park Water and Sanitation District (Sageport)	CO0043044	41	59.4	73
Perry Park Water and Sanitation District (Waucondah)	CO0022551	107	173.8	365
Total		**2,241**	**2,299**	**5,699**

Note: The Roxborough WWTF stopped discharging to the watershed in 2007, and its wasteload allocation is owned by the Dominion Water and Sanitation District, which was not modeled for this analysis.

The wasteload allocation modeling scenario simulates an increase of approximately 3,458 pounds of total phosphorus per year compared to the 10-year historical average (2005-2014), of which about 950 pounds are distributed to the South Platte River and 2,500 pounds are distributed to Plum Creek (see Table 4).

Table 4: Total Phosphorus Wasteload Allocation by River Basin (lbs)

Watershed	Wasteload Allocation	Historical (2005-2014)	Difference
South Platte	1,005	376	629
Plum Creek	4,694	2,183	2,511
Total	**5,699**	**2,559**	**3,458**

The total phosphorus load is the product of concentration and flow volume. Therefore, when simulating the wasteload allocation we evaluated increases to total phosphorus concentrations and flow. For this analysis, we assumed that future total phosphorus concentrations would remain similar to historical total phosphorus concentrations, as dischargers are trying to meet concentration limits, so the increase in total phosphorus load is simulated by an increase in the total effluent (total flow) from the facility.

The historical total phosphorus concentrations and flow for each facility from the last 10 years of the historical record available in the model (2005-2014) are shown in Table 5 along with the modified total phosphorus concentrations and flow for the full wasteload allocation scenario. The average historical total phosphorous concentrations (2005-2014) were used as the basis of the total phosphorus concentrations in the wasteload allocation scenario. For each facility, historical and wasteload total phosphorus concentrations are similar while flows have been increased, contributing to the increase in total phosphorus load. The total phosphorus concentrations and flows from Table 5 were used to calculate a monthly total phosphorus load for each point source (Table 6), which sum to the total phosphorus annual wasteload allocation shown in Table 3 (5,699 pounds).

Table 5: Simulated Total Phosphorus Annual Wasteload Allocation

Point Source	Historical Data (2005-2014)		Wasteload Allocation Scenario	
	Total Phosphorus Concentration (mg/L)	Flow (ft^3/s)	Total Phosphorus Concentration (mg/L)	Flow (ft^3/s)
Plum Creek Water Reclamation Authority (PCWRA)	0.22	4.70	0.22	9.87
Lockheed Martin Space Systems Company	0.16	0.19	0.16	3.22
Perry Park Water and Sanitation District (Sageport)	0.24	0.23	0.26	0.71
Perry Park Water and Sanitation District (Waucondah)	0.30	0.07	0.31	0.12

Table 6: Total Phosphorus Monthly Wasteload Allocation (lbs)

Month	PCWRA	Lockheed	Sageport	Waucondah	Roxborough	Total
January	361	85.4	6.1	30.4	0	483
February	326	77.1	6.1	30.4	0	440
March	361	85.4	6.1	30.4	0	483
April	350	82.6	6.1	30.4	0	469
May	361	85.4	6.1	30.4	0	483
June	350	82.6	6.1	30.4	0	469
July	361	85.4	6.1	30.4	0	483
August	361	85.4	6.1	30.4	0	483
September	350	82.6	6.1	30.4	0	469
October	361	85.4	6.1	30.4	0	483
November	350	82.6	6.1	30.4	0	469
December	361	85.4	6.1	30.4	0	483
Total	**4,256**	**1,005**	**73**	**365**	**0**	**5,699**

South Platte Historical Diversions

In the South Platte River, to quantify the total phosphorus load from point sources that reach Chatfield Reservoir, we needed to thoroughly document modeled historical diversions in the watershed. In the historical model, the Roxborough WWTF point source discharges into model reach 29 from 2000-2007, with discharges ending in 2007. In the same model reach (reach 29), there are two diversions (Denver Conduit #20 and Highline Canal) that divert water out of the watershed using historical diversion data. These diversions also remove total phosphorus from the watershed. In the historical model, they divert on average 2,690 pounds of total phosphorus annually (2000-2014) and in the point sources off scenario they divert on average 2,540 pounds of total phosphorus annually (2000-2014), about 140 less pounds. The difference in total phosphorus between these two diversions occurs from 2000 to 2007, when the Roxborough WWTF point source is active. Therefore, this difference needs to be accounted for when comparing the full wasteload allocation scenario to the historical scenario. Since the Roxborough WWTF point source is always off in the full wasteload allocation scenario, the difference in total phosphorus from the diversions needs to be accounted for when tracking the transport of total phosphorus in the watershed. See the *Discussion of Results* Section of this memorandum for a discussion of how this difference is accounted for in the model results.

Results

We ran the model for the full period of record (January 1995 to September 2015) and analyzed the results from January 2000 to December 2014, representing the calibrated model record. In this analysis, we compare the results of the wasteload allocation scenario, which represents steady-state conditions where the total phosphorus point source load is always 5,699 pounds per year, to the historical model in which the total phosphorus point source load varies from year to year based on the historical data. The results from the model simulation are shown at key locations in the watershed, South Platte River at Chatfield Reservoir and Plum Creek at Chatfield Reservoir for total phosphorus (Table 7) and total flow (Table 8). Supplementary

model results are provided for the point source locations in Table 9 including, PCWRA (reach 52), Lockheed Martin (reach 16), Sageport (reach 116), and Waucondah (reach 113).

The model simulation shows there is an average annual increase in total phosphorus of approximately 620 pounds in the South Platte River and an average annual increase in total phosphorus of approximately 1,830 pounds in Plum Creek (Table 7). A more thorough analysis of the model results can be found in the *Discussion of Results* Section, where we compare the fractions of total phosphorus point source load that is transported to Chatfield Reservoir.

In Table 8, the simulated flows for the South Platte at Chatfield Reservoir and Plum Creek at Chatfield Reservoir are provided to show the increase in flow between the wasteload allocation scenario and the historical model results. In Table 9, we show the simulated total phosphorus loads for each reach where a point source discharges into the watershed. The table shows the wasteload allocation scenario, the historical scenario, and the difference between the two model scenarios. The results confirm that the largest increases in total phosphorus load occur in the reaches where the PCWRA and Lockheed Martin discharge into the watershed.

Table 7: Total Phosphorus Annual Wasteload Allocation at Chatfield Reservoir

Year	Wasteload Allocation (lbs)		Modeled Historical (lbs)		Difference (lbs) (wasteload – historical)	
	South Platte at Chatfield Reservoir (Reach 16)	Plum Creek at Chatfield Reservoir (Reach 15)	South Platte at Chatfield Reservoir (Reach 16)	Plum Creek at Chatfield Reservoir (Reach 15)	South Platte at Chatfield Reservoir (Reach 16)	Plum Creek at Chatfield Reservoir (Reach 15)
2000	6,020	6,940	5,610	4,110	410	2,820
2001	3,680	6,600	3,010	4,100	670	2,500
2002	4,080	4,810	3,550	3,090	530	1,720
2003	7,790	11,810	7,440	10,630	350	1,190
2004	7,310	7,570	7,050	6,870	270	700
2005	8,750	8,240	8,730	6,720	20	1,530
2006	4,690	7,470	4,310	5,610	380	1,870
2007	17,120	21,140	17,090	19,190	30	1,950
2008	4,930	6,590	4,020	5,110	920	1,480
2009	6,280	9,180	5,320	7,750	960	1,430
2010	5,840	17,490	4,860	15,260	970	2,220
2011	2,550	6,890	1,590	4,960	960	1,940
2012	1,630	6,130	680	4,420	950	1,720
2013	3,030	6,190	2,060	4,010	970	2,180
2014	6,920	7,260	5,950	5,070	970	2,190
Average	**6,040**	**8,950**	**5,420**	**7,130**	**620**	**1,830**

Table 8: Total Flow Annual Wasteload Allocation

Year	Wasteload Allocation (acre-foot (af))		Modeled Historical (af)		Difference (af) (wasteload – historical)	
	South Platte at Chatfield Reservoir (Reach 16)	Plum Creek at Chatfield Reservoir (Reach 15)	South Platte at Chatfield Reservoir (Reach 16)	Plum Creek at Chatfield Reservoir (Reach 15)	South Platte at Chatfield Reservoir (Reach 16)	Plum Creek at Chatfield Reservoir (Reach 15)
2000	71,200	23,160	69,510	17,670	1,690	5,490
2001	52,910	19,390	51,260	14,210	1,650	5,180
2002	34,710	10,650	32,980	5,600	1,730	5,040
2003	53,520	30,330	51,960	25,610	1,560	4,730
2004	48,760	22,700	47,230	18,180	1,530	4,520
2005	76,180	29,400	74,780	25,190	1,400	4,220
2006	86,600	20,080	85,190	16,050	1,400	4,020
2007	258,780	65,650	257,230	62,000	1,550	3,650
2008	114,900	21,180	112,660	17,360	2,240	3,810
2009	113,850	30,010	111,610	26,560	2,240	3,450
2010	105,560	47,680	103,310	43,960	2,250	3,720
2011	61,860	17,050	59,600	13,400	2,260	3,650
2012	25,620	16,820	23,340	13,020	2,280	3,800
2013	55,900	17,010	53,630	13,720	2,270	3,300
2014	140,000	19,580	137,730	16,590	2,270	2,990
Average	**86,690**	**26,050**	**84,800**	**21,940**	**1,890**	**4,100**

Table 9: Total Phosphorus Annual Wasteload Allocation at Point Source Locations

Year	Modeled Wasteload Allocation (lbs)				Modeled Historical (lbs)				Difference (wasteload – historical)			
	PCWRA	Lockheed Martin	Sageport	Waucondah	PCWRA	Lockheed Martin	Sageport	Waucondah	PCWRA	Lockheed Martin	Sageport	Waucondah
2000	6,330	6,020	610	470	3,270	5,610	540	120	3,070	410	70	360
2001	6,160	3,680	600	460	3,490	3,010	530	100	2,680	670	70	360
2002	5,240	4,080	290	410	3,560	3,550	220	50	1,670	530	70	360
2003	8,310	7,790	2,210	800	7,290	7,440	2,140	430	1,020	350	70	360
2004	6,750	7,310	640	480	6,330	7,050	570	120	410	270	70	360
2005	6,860	8,750	1,090	580	5,230	8,730	1,080	320	1,630	20	10	250
2006	6,630	4,690	1,080	560	4,680	4,310	1,070	310	1,960	380	10	250
2007	12,010	17,120	4,200	1,210	9,910	17,090	4,180	1,000	2,090	30	20	210
2008	6,140	4,930	550	470	4,520	4,020	530	310	1,620	920	20	150
2009	7,130	6,280	960	520	5,730	5,320	940	260	1,400	960	30	260
2010	10,050	5,840	3,420	1,090	7,630	4,860	3,390	820	2,420	970	30	260
2011	6,470	2,550	490	450	4,410	1,590	450	170	2,070	960	40	280
2012	5,970	1,630	430	440	4,180	680	380	150	1,790	950	50	290
2013	5,970	3,030	480	450	3,550	2,060	430	170	2,430	970	50	280
2014	6,600	6,920	520	460	4,220	5,950	480	190	2,380	970	40	270
Average	**7,110**	**6,040**	**1,170**	**590**	**5,200**	**5,420**	**1,130**	**300**	**1,910**	**620**	**40**	**290**

PCWRA is located in model Reach 52, Lockheed Martin is in Reach 16, Sageport is in Reach 116, and Waucondah is in Reach 113.

Discussion of Results

In model scenario 1) Watershed Simulated without Point Source Discharges (the no point source loading scenario) and model scenario 2) the Full Wasteload Allocation scenario, we consider three different iterations of point sources in the watershed and their total phosphorus loading implications for Chatfield Reservoir: no point sources in the watershed, historical point sources, point sources discharging with their full wasteload allocation. In these analyses we compare results using the modeling period of record (2000-2014), and a subset of the modeling period of record (2008-2014), which analyzes results after point source discharges from the Roxborough WWTF have ended. The recent modeling record (2008-2014) is helpful to demonstrate changes in the South Platte basin over time. See the *South Platte Historical Diversions* Section for further discussion of the Roxborough WWTF point source and historical diversions in the South Platte basin.

Point Sources and Watershed Loading

First, we examined how the point sources are represented in the Chatfield Reservoir watershed, by quantifying the total phosphorus load from the point sources as a fraction of the total phosphorus contributing to the reservoir (by subwatershed, South Platte versus Plum Creek). Note that this does not measure the relative contribution of total phosphorus from the point source to the reservoir (see the next section of the memorandum).

Equation 1:

$$TP\ Point\ Source\ to\ Total\ TP\ Load\ (\%) = \frac{Historical\ TP\ Point\ Source}{Simulated\ TP\ to\ Chatfield\ Reservoir\ for\ Historical\ Scenario}$$

Equation 2:

$$TP\ Point\ Source\ to\ Total\ TP\ Load\ (\%) = \frac{Full\ Wasteload\ TP\ Point\ Source}{Simulated\ TP\ to\ Chatfield\ Reservoir\ for\ Wasteload\ Scenario}$$

South Platte River

When the point sources are turned off, there are no point sources contributing total phosphorus to Chatfield Reservoir from the South Platte River. In the historical scenario the South Platte River point sources (Lockheed Martin and Roxborough) (24-524 lbs) represent 1-10% of the total phosphorus load from the South Platte River to Chatfield Reservoir (3500–5400 lbs) (depending on the period of record) (Equation 1).

In the full wasteload allocation scenario, the expanded Lockheed Martin point source (1,000 lbs) represents 17-23% of the total phosphorus load from the South Platte River to Chatfield Reservoir (4,500-6,000 lbs) (depending on the period of record). The new fraction of total phosphorus in the full wasteload allocation scenario is about 10-21% of the South Platte total phosphorus load to Chatfield Reservoir (depending on the period of record) (Equation 2). We

note that the Roxborough point source is off for the full wasteload allocation scenario since it is currently treated out of the basin (see Table 10).

Plum Creek

When the point sources are turned off, there are no point sources contributing total phosphorus to Chatfield Reservoir from Plum Creek. In the historical scenario the Plum Creek point sources (PCRWA, Sageport, and Waucondah) (2,500 lbs) represent 35% of the total phosphorus load from Plum Creek to Chatfield Reservoir (7,100 lbs) (Equation 1).

In the full wasteload allocation scenario, the expanded Plum Creek point sources (4,700 lbs) represent 52% of the total phosphorus load from Plum Creek to Chatfield Reservoir. The new fraction of total phosphorus in the wasteload allocation scenario is about 20% of the Plum Creek total phosphorus load to Chatfield Reservoir (9,000 lbs) (Equation 2) (see Table 11).

Fraction of New Point Source Load to Chatfield Reservoir

In the next analysis, we used the simulations to understand how changes to point source loads in the watershed relate to changes in the amount of total phosphorus delivered to Chatfield Reservoir. By analyzing the change in total phosphorus transitioning from a simulation without point source loading, to historical point source loading, to full wasteload allocation loading, we can better understand how future potential increases in total phosphorus loads in the watershed may be delivered to Chatfield Reservoir. These data represent the simulated effects of the new (incremental) total phosphorus point source load fraction that returns to Chatfield Reservoir.

Equation 3:

$$New\ TP\ to\ Chatfield\ Reservoir\ (\%) = \frac{(Simulation\ of\ Historical\ Load - Simulation\ without\ Point\ Sources)}{(Observed\ Historical\ Load - \ Observed\ without\ Point\ Sources)}$$

Equation 4:

$$New\ TP\ to\ Chatfield\ Reservoir\ (\%) = \frac{(Simulated\ Wasteload - Simulated\ Historical\ Load)}{(Observed\ Wasteload - \ Observed\ Historical\ Load)}$$

South Platte River

In the first model scenario (no point source loading), we compare the historical model simulation with a simulation that has point source discharges turned off. By analyzing the difference in total phosphorus loads between these two models we see that 69-97% of the total phosphorus point source load is released to Chatfield Reservoir (24-360 lbs of the 24-520 lbs of total phosphorus load is transported to the reservoir, depending on the period of record) (Equation 3) (see Table 10 for results).

Over the complete period of record (2000-2014) less of the total phosphorus is transported to the reservoir (69%) because of the active diversions in reach 29 that remove some of the total phosphorus discharged into the watershed by the Roxborough WWTF. In comparison, from

2008 to 2014, 97% of the total phosphorus is transported to the reservoir when all active point sources (Lockheed Martin) are located below the diversion structures.

In the second scenario (full wasteload allocation), we compare the historical model simulation with the maximum wasteload allocation simulation. In this model run, the wasteload is 1,006 pounds and the historical load is 24-525 pounds, so the new contributing load is 480-980 pounds. By analyzing the difference in total phosphorus loads between the two models we see that 97-100% of the new (incremental) total phosphorus point source load is released to Chatfield Reservoir (480-960 lbs of the 480-980 lbs of total phosphorus load is transported to the reservoir) (Equation 4) (see Table 10).

In the South Platte River, due to the location and timing of the Roxborough WWTF point source and historical diversions from the river (model reach 29), a comparison between the full wasteload scenario and the historical scenario needed to account for the changes in these conditions. Since the full wasteload scenario did not include the historical Roxborough point source (2000-2007), we had to account for its total phosphorus removal from the basin by the historical diversions (approximately 140 pounds annually 2000-2014) during the historical scenario when comparing it to the full wasteload scenario. Table 10 shows the average annual simulated point source at the reservoir (620 lbs, 2000-2014), the additional total phosphorus removed by the diversions when Roxborough WWTF is simulated (140 lbs, 2000-2014), and the final average annual point source simulated at the reservoir by the full wasteload scenario (480 lbs, 2000-22014).

Plum Creek

In the first model scenario (no point source loading), we compare the historical model simulation with a simulation that has point source discharges turned off. By analyzing the difference in total phosphorus loads between these two models we see that 69% of the total phosphorus point source load reaches Chatfield Reservoir (1,720 lbs of the 2,480 lbs of total phosphorus load is transported to the reservoir) (2000-2014) (Equation 3) (see Table 11).

In the second scenario (full wasteload allocation), we compare the historical model simulation with the maximum wasteload allocation simulation. In this model run, the wasteload is 4,700 lbs and the historical load is 2,480 lbs, so the new contributing load is 2,210 lbs. By analyzing the difference in TP loads between the two models we see that 83% of the Plum Creek total phosphorus point source load is released to Chatfield Reservoir (1,830 lbs of the new 2,210 lbs total phosphorus load is transported to the reservoir) (2000-2014) (Equation 4) (see Table 11).

Summary

The point sources along the South Platte River (Lockheed Martin and Roxborough WWTF) are relatively close in distance to Chatfield Reservoir with higher flow rates, and most of the incremental total phosphorus point source load is transported to Chatfield Reservoir. In the historical scenario 69-97% of the total phosphorus point source load is transported to the reservoir. Over the complete period of record (2000-2014) less of the total phosphorus is transported to the reservoir (69%) because of the active diversions in reach 29, that remove some phosphorus from the watershed. After the Roxborough WWTF stops discharging into the

watershed (2008-2014), 97% of the total phosphorus is transported to the reservoir because the remaining point source (Lockheed Martin) is located below both of the diversion structures. In the full wasteload allocation scenario 97-100% of the new total phosphorus is load transported to Chatfield Reservoir (see Table 10).

Table 10: South Platte River Total Phosphorus Point Source Loading

	Historical Point Sources		Full Wasteload	
	2000-2014	**2008-2014**	**2000-2014**	**2008-2014**
Total Point Source				
Historical TP point source load (lbs)	520	20	1,000	1,000
Simulated TP load to Chatfield Reservoir (lbs)	5,420	3,500	6,040	4,450
TP Point Source / Total TP Load to reservoir (%)	10%	1%	17%	23%
New Point Source				
New simulated TP point source load (lbs)	360	20	620	960
Reach 29 TP modeled historical diversion (lbs) (removed from river)	---	---	140	0
Revised simulated TP point source load (lbs)	360	20	480	960
New estimated TP point source load (lbs)	520	20	480	980
New TP to Chatfield Reservoir (%)	69%	97%	100%	97%

The point sources in Plum Creek (PCWRA, Waucondah, and Sageport) are further upstream in the watershed from Chatfield Reservoir, with lower flow rates. In the first scenario (no point source to historical scenario) about 69% of the new total phosphorus load is transported to the reservoir, while in the wasteload allocation scenario about 83% of the new total phosphorus load is transported to Chatfield Reservoir (see Table 11).

Table 11: Plum Creek Total Phosphorus Point Source Loading

	Historical Point Sources		Full Wasteload	
	2000-2014	2008-2014	2000-2014	2008-2014
Total Point Source				
Historical TP point source load (lbs)	2,480	2,408	4,700	4,700
Simulated TP load to Chatfield Reservoir (lbs)	7,130	6,650	8,950	8,530
TP Point Source / Total TP Load to reservoir (%)	35%	36%	52%	55%
New Point Source				
New simulated TP point source load (lbs)	1,720	1,650	1,830	1,880
New estimated TP point source load (lbs)	2,480	2,410	2,210	2,290
New TP to Chatfield Reservoir (%)	69%	68%	83%	82%

The total phosphorus point source loads are transported fairly efficiently to Chatfield Reservoir, with a large fraction of the new incremental load present as inflow to the reservoir. However, we note that the total phosphorus load in Plum Creek may have more opportunities for loss due to adsorption to sediment, deposition of adsorbed phosphorus, and uptake by algae, for example. Additionally for Plum Creek, in the full wasteload scenario (scenario 2), a larger fraction of the total phosphorus is transported to Chatfield Reservoir (83%) than from the first scenario (no point source to historical scenario) (69%), indicating there is less total phosphorus lost within the river reach. In the South Platte, both scenarios transported most of the total phosphorus point source load to the Chatfield Reservoir (97-100%), unless the point source load was upstream of the diversions in reach 29, in which case some of the total phosphorus load is removed from the basin.

References

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