DRAFT 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 Results
Date:	October 28, 2022

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 setup 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 with point sources operating normally. 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 are loaded into the modal in reach 52. The PCWRA total phosphorus point source data typically includes four to five data points per month between January 2000 and October 2012 and one data point per

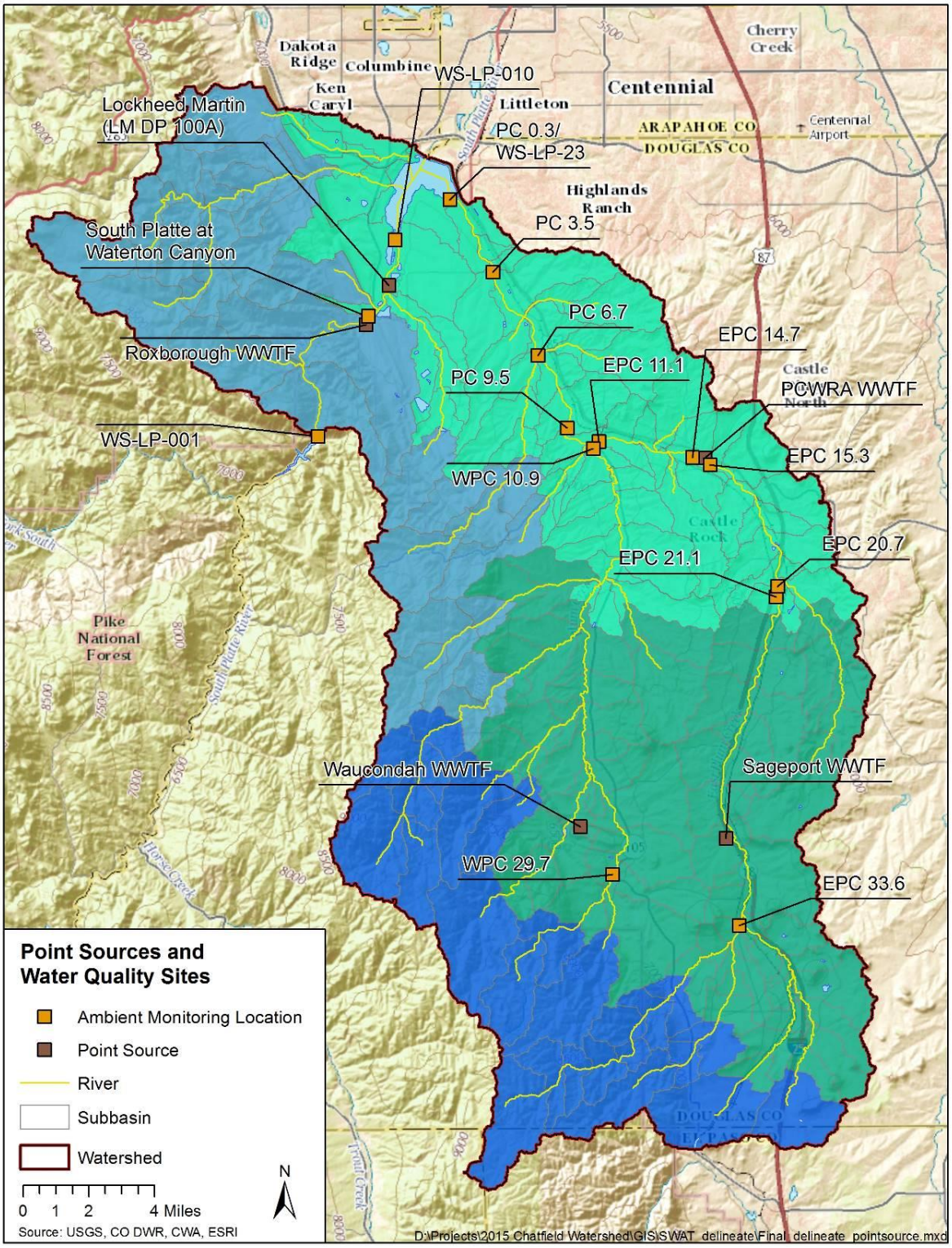
month between November 2012 and July 2015, with average monthly values used from August 2015 to September 2015.

- 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 includes 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 includes 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 includes 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 is loaded into model 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	**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. 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	5,600	5,000	590	3,420	2,680	730
2001	2,970	2,650	320	3,510	2,500	1,010
2002	3,480	3,030	450	2,800	1,070	1,720
2003	7,230	6,590	640	8,540	6,050	2,490
2004	6,980	6,260	720	6,300	3,220	3,080
2005	8,720	7,750	970	5,890	3,800	2,090
2006	4,300	3,690	610	5,110	3,440	1,670
2007	16,800	15,830	970	16,220	14,390	1,830
2008	4,050	3,970	70	4,700	2,690	2,010
2009	5,080	5,060	20	6,770	4,610	2,160
2010	3,980	3,970	20	11,690	10,300	1,390
2011	1,580	1,560	10	4,240	2,650	1,590
2012	640	630	10	3,840	2,100	1,750
2013	2,030	2,010	10	3,440	2,180	1,260
2014	5,950	5,920	20	4,250	2,920	1,340
Average	**5,290**	**4,930**	**360**	**6,050**	**4,310**	**1,740**

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 point source does not discharge into the watershed due to a change in ownership of the wasteload (Table 3). 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 (2010-2014) (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: Roxborough stopped discharging to the watershed in 2007, and their 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 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	57	948
Plum Creek	4,694	2,183	2,511
Total	**5,699**	**2,241**	**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 comes from an increase in the total effluent (total flow) of the facility.

The historical total phosphorus concentrations and flow for each facility are shown in Table 5 along with the modified total phosphorus concentrations and flow for the full wasteload allocation scenario. For each facility, historical and wasteload concentrations are similar while flows have 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 show in Table 3 (5,699 pounds).

Table 5: Simulated Total Phosphorus Annual Wasteload Allocation

Point Source	Historical Total Phosphorus Concentration (mg/L)	Historical Flow (ft^3/s)	Wasteload Total Phosphorus Concentration (mg/L)	Wasteload Allocation 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**

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). For the South Platte River, we note that the average annual increase is really 960 pounds (using years 2008-2014), because the Roxborough point source discharges from 2000 to 2007 in the historical model but does not discharge at all in the wasteload allocation simulation, which causes an anomalously low difference from 2000 to 2007. This increase is comparable to the increase for the South Platte shown in Table 4, indicating that all of the simulated increase in total phosphorus load reaches Chatfield Reservoir. In Plum Creek, the simulation shows that on average approximately 73% of the increase in the wasteload allocation is discharged to Chatfield Reservoir, indicating there is some loss from the point source dischargers to Plum Creek before reaching the 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.

References

Chatfield Watershed Authority, 2021. 2021 Annual Report. Accessed September 2022. Available online https://www.chatfieldwatershedauthority.org/annual-reports.

Leonard Rice Engineers and Lynker Technologies, 2016. Chatfield Watershed HSPF Model Report.