Platte River Basin Plan 2016 Update
Volume 2
Surface Water Resources Analysis

Prepared for:

Wyoming Water Development Commission

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In Association With:
Lidstone & Associates, a Wenck Company
Harvey Economics
HDR Engineering

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December 2016

Explanation of Cover Photos

Lake Marie in the Snowy Range Mountains. Lake Marie lies south in the shadow of the quartzite massif of 12,847-foot Medicine Bow Peak at an elevation of 11,000-feet. Winter and Spring precipitation in the Snowing Range constitutes an important portion of the water supply in the Platte River Basin.

The bald eagle (*Haliaeetus leucocephalus*, from Greek hali "sea", aiētos "eagle", leuco "white", cephalos "head"). It is a common, frequently observed breeding and winter resident in the North Platte Basin of Wyoming. The bird is strongly associated with large rivers, lakes and reservoirs with an abundant food supply and riparian environments with large trees used for roosting and nesting. The bald eagle is an opportunistic predator which subsists primarily on fish. During the winter, they also feed on dead or injured waterfowl and road or winter killed deer and antelope. The bald eagle is both the national bird and national animal of the United States of America. It is the most familiar success story of the Federal Endangered Species Act. During the latter half of the 20th century it was on the brink of extirpation in the contiguous United States and was one of the first species to receive protections under the precursor to the Endangered Species Act in 1967. Populations have since recovered and the species was removed from the U.S. government's list of endangered species on July 12, 1995 and transferred to the list of threatened species. It was removed from the List of Endangered and Threatened Wildlife in the Lower 48 States on June 28, 2007 but remains protected under the provisions of the Bald and Golden Eagle Protection Act.

Historical photo of flood irrigation. Flood irrigation is an ancient method of irrigating crops and was the first form of irrigation used by humans as they began cultivating crops. In the Platte River Basin, it is still commonly used to irrigate grass hay. In areas of the Platte River Basin where higher value crops are raised such as corn, sugar beets and alfalfa hay, conversion to sprinkler irrigation has the dual benefits of improved crop yields while conserving water.

The Dave Johnston Power Plant is named for W.D. “Dave” Johnston a former PacifiCorp Vice-President. The plant generates power by burning coal that produces steam under high pressure. The steam drives turbines and the turbine blades to engage generator that produce electricity. The plant was commissioned in 1958. There have been four phases of plant expansion to-date and numerous upgrades to comply with changing environmental requirements. The present power generation capacity is 817 megawatts.

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The Platte River Basin Plan 2016 Update is a planning tool developed for the Wyoming Water Development Office. It presents estimated current and estimated future uses of water in Wyoming's Platte River Basin. The Plan is not intended to be used to determine compliance with the administration of state law, federal law, court decrees, interstate compacts, or interstate agreements.

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2.0 Surface Water Resources Analysis

2.1 INTRODUCTION

> ***"Plans to protect air and water, wilderness and wildlife are in fact plans to protect man."***
> - Stewart Udall

The purpose of this volume is to summarize the surface water data collection and analyses as part of the Platte River Basin Plan Update. The document provides an overview of historic streamflow records, study period determination, indicator gage selection, gage filling and the methodology used to estimate ungaged tributary flow.

The data collection and study period selection from the Platte River Basin Plan in 2006 (TriHydro, 2006) were used as a baseline for this update. The previous Basin Plan determined a study period of 1972 through 2001. Updates to the study period reflect a new study period of 1972 through 2013. The methodology for determining the study period remains the same. Rather than repeating information, the reader can reference TriHydro, 2006.

TriHydro, 2006 developed average, wet and dry year flow averages by using a basin area weighted calculation that incorporated streamflow for a six-month irrigation season from April through September to determine the annual flows for each scenario. Also, the previous Basin Plan did not perform any data filling of records that did not include non-irrigation season streamflow records and did not determine average monthly flows for a 12-month cycle. This update uses a 12-month streamflow period to determine monthly flows and calculates mean monthly streamflow for the three condition scenarios. As a result, much of the 2006 modeling results and data were not used for this analysis.

Further, the Previous Basin Plan did not estimate ungaged tributary flows, whereas this update does estimate streamflow for the ungaged tributaries. Ungaged tributary flow was estimated for the entire basin in this update. The objectives of the update include:

- Collect, update and extend historic streamflow for the study period between 1972 through 2013.
- Select indicator gages to determine the historic dry, average and wet years within the study period.
- Develop monthly streamflow for the dry, average and wet years.
- Perform data filling and extension for missing streamflow data
- Estimate inflow for ungaged tributaries.

2.2 HISTORIC STREAMFLOW RECORDS

Historic streamflow data were obtained from the United States Geological Service (USGS), National Water Information System (NWIS) daily streamflow data. This information is available from the internet. The streamflow records were obtained using the USGS's GNWISQ program to obtain the daily streamflow records. This program was developed to obtain daily mean streamflow from the USGS NWIS website. The program downloads two files associated with each gage selected. One file contains the header information for the gage; the second file is the daily mean streamflow file. All USGS gage data collected in this study was acquired using this program. Streamflow data for all gages in each of the seven subbasins with data within the study period was collected. **Tables 2.1 through 2.7** provide summaries of the annual stream flow for these gages. The driest and wettest annual stream flow amounts for the period of record are highlighted in red and yellow, respectively, for each gage.

Table 2.1: Upper Laramie Annual Stream Flow Summary

	6661000 ^*	6661585 ^	6659580 ^*	6659500 ^*
	Little Laramie River Nr Filmore	Laramie River Nr Bosler	Sand Creek at CO/WY Border	Laramie River and Pioneer Canal Nr Woods Landing
1972	81,365	96,635	4,304	113,260
1973	65,129	193,871	12,576	174,919
1974	78,179	130,495	8,057	151,840
1975	82,756	105,005	5,303	121,138
1976	62,294	72,852	4,140	96,349
1977	39,940	28,952	7,049	63,028
1978	98,444	115,148	5,088	146,794
1979	103,514	126,908	8,687	162,036
1980	87,937	118,276	10,116	148,801
1981	38,483	35,404	4,136	67,758
1982	99,942	148,138	8,204	159,839
1983	114,505	346,767	24,390	280,466
1984	102,354	296,708	12,298	210,559
1985	64,349	127,843	5,657	133,678
1986	92,315	253,987	13,215	223,259
1987	37,380	52,989	3,776	69,507
1988	71,634	114,388	7,843	123,633
1989	41,877	28,265	3,027	58,754
1990	55,920	59,255	4,318	96,475
1991	52,784	68,247	4,183	94,339
1992	36,646	43,929	5,129	83,873
1993	63,495	104,798	7,578	137,170
1994	48,490	36,078	4,376	81,241
1995	81,966	136,925	9,493	154,604
1996	76,218	116,203	6,414	163,494
1997	85,204	148,421	8,758	171,919
1998	76,732	106,722	5,672	120,957
1999	85,606	120,341	6,974	134,587
2000	44,602	57,377	3,175	99,798
2001	48,926	42,766	2,751	68,700
2002	23,793	12,574	1,281	28,925
2003	46,672	77,395	8,637	114,145
2004	42,057	47,070	4,316	68,910
2005	53,732	111,646	6,951	134,521
2006	59,673	54,999	2,875	89,181
2007	50,385	57,924	6,548	103,578
2008	58,749	91,567	6,777	139,267
2009	82,447	110,980	6,050	128,628
2010	91,070	173,767	13,829	194,401
2011	144,222	285,453	10,854	268,600
2012	42,461	23,962	3,758	61,557
2013				
Average	**68,640**	**109,293**	**7,038**	**127,914**

Notes:

1) * Denotes an index Gage
2) ^ Denotes gage data was filled
3) Source of raw data – USGS NWIS website. TS Tool was used to manipulate Data.

Table 2.2: Above Pathfinder Annual Stream Flow Summary

	6630000*	6635000*	639000^	6620000	6622700	6622900^	6623800	6625000	6627800^	6628900^	6632400	6634620
	North Platte Ab Seminoe	Med. Bow River Ab Seminoe	Sweet Water River Nr Alcova	North Platte R Nr Northgate	North Brush Creek Nr Saratoga	S. Brush Creek Nr Saratoga	Encampment R. Ab Hog Park	Encampment at Mouth	Jack Cr. Ab Coyote Draw	Pass Cr. Nr Elk Mountain	Rock Cr. Ab King Canyon	Little Med. Bow R at Boles Spring
1972	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1973	1,133,552	388,532	147,133	407,284	43,152	27,170	72,447	184,555	NA	55,066	71,114	NA
1974	1,078,233	187,774	136,360	405,132	41,837	24,232	97,035	226,938	NA	46,384	79,895	NA
1975	907,138	145,210	117,493	301,694	30,870	19,515	92,564	214,488	NA	25,179	57,846	NA
1976	661,999	118,831	89,106	194,264	28,417	15,408	74,090	162,379	NA	25,716	53,877	NA
1977	350,385	72,304	37,697	85,782	21,828	17,348	36,974	74,133	NA	15,992	35,337	NA
1978	1,001,231	169,779	96,214	363,659	40,976	25,728	105,891	226,585	NA	36,909	81,876	NA
1979	979,976	132,209	90,557	408,444	30,796	19,059	106,532	225,280	NA	26,113	68,173	NA
1980	998,946	181,647	170,886	374,104	33,553	22,457	94,311	205,124	NA	34,795	62,016	NA
1981	404,005	53,481	46,045	122,600	24,187	15,951	47,396	100,415	NA	19,436	36,993	NA
1982	1,066,092	174,310	102,812	359,658	48,919	26,460	115,963	268,110	NA	40,762	84,715	NA
1983	1,476,613	350,367	213,108	572,500	60,068	33,550	107,397	248,848	NA	56,165	96,023	NA
1984	1,587,234	297,464	131,688	623,487	52,329	30,986	110,751	268,643	NA	62,611	66,757	NA
1985	944,810	93,845	64,806	384,012	32,555	23,240	86,774	183,363	NA	25,762	48,573	19,174
1986	1,381,474	191,334	172,582	599,838	45,353	24,819	109,755	254,638	NA	42,495	76,887	48,427
1987	446,524	80,518	78,313	172,370	21,093	9,921	46,081	94,573	NA	18,829	38,868	23,622
1988	744,556	138,910	52,273	296,188	27,760	15,360	71,930	162,191	NA	25,190	57,589	34,585
1989	424,669	44,099	39,834	142,310	19,744	11,291	52,222	106,996	NA	15,154	36,562	11,441
1990	544,691	66,261	47,595	172,418	31,379	16,687	60,759	123,630	NA	22,168	49,198	13,946
1991	556,764	119,364	83,639	197,620	25,806	18,157	58,315	127,783	14,155	22,090	47,410	33,893
1992	399,745	55,871	34,221	136,580	26,096	13,766	42,128	85,005	11,127	20,704	38,867	8,853
1993	987,712	155,038	104,006	325,711	43,605	25,274	87,004	223,392	26,780	39,719	64,842	44,133
1994	535,343	72,830	67,640	150,851	27,772	17,611	56,220	123,638	15,596	22,321	45,700	15,148
1995	1,149,986	221,091	163,425	378,359	42,468	25,704	111,368	251,083	32,318	36,859	75,363	63,221
1996	1,093,436	137,712	79,347	461,005	37,952	22,624	95,793	229,904	20,472	25,757	67,625	26,192
1997	1,342,246	166,715	140,285	581,503	44,806	21,825	112,107	280,856	31,516	30.209	66,909	52,124
1998	906,289	112,411	100,056	304,150	38,127	22,921	92,405	211,612	22,543	31,829	59,958	16,640
1999	975,650	196,759	127,581	275,258	54,882	23,803	103,102	217,394	27,599	47,957	78,528	62,957
2000	569,060	78,812	54,520	219,524	30,718	17,847	67,967	141,927	12,441	20,125	40,141	31,456
2001	451,453	74,307	37,980	150,429	23,768	12,811	58,279	125,813	13,351	18,432	43,804	28,218
2002	187,582	25,691	28,355	64,013	12,625	7,934	32,706	60,201	8,226	8,138	22,142	8,840
2003	587,402	81,608	33,170	218,080	37,266	28,104	74,090	150,702	14,254	22,349	52,860	16,405
2004	464,885	38,780	62,944	163,831	20,121	13,058	63,016	132,480	14,549	13,879	35,578	11,067
2005	858,046	85,928	90,341	346,355	37,598	26,692	87,016	193,816	26,104	29,052	53,426	13,446
2006	711,267	67,521	56,796	271,559	34,587	23,613	90,660	194,915	20,802	23,447	50,572	12,481
2007	622,353	65,781	56,952	216,533	26,385	16,056	72,102	147,118	17,931	20,217	43,610	20,061
2008	1,046,812	123,009	80,572	396,012	43,809	25,639	111,649	238,803	42,180	35,767	59,105	37,246
2009	1,071,800	162,106	81,890	307,202	51,594	33,046	117,635	250,008	43,865	43,667	68,747	30,384
2010	1,248,544	232,363	127,832	325,599	59,674	42,537	105,621	263,605	39,288	70,815	80,257	45,804
2011	1,994,441	284,678	135,306	731,604	88,813	54,893	159,065	379,947	46,660	67,963	106,433	75,186
2012	384,462	52,756	59,352	123,465	21,905	12,420	57,525	107,030	11,793	16,984	36,201	14,531
2013	496,020	33,271	NA	212,740	23,109	NA	63,918	132,641	NA	NA	39,596	5,773
Average	**848,132**	**134,909**	**91,018**	**305,945**	**36,300**	**22,138**	**83,136**	**185,380**	**23,343**	**31,575**	**58,048**	**28,457**

Notes:
1) * Denotes an index Gage
2) ^ Denotes gage data was filled
3) Source of raw data – USGS NWIS website. TS Tool was used to manipulate Data.

Table 2.3: Pathfinder to Guernsey Annual Stream Flow Summary

	6646000	6647500 *	6649000 ^	6682000	6652800
	Deer Creek	Box Elder Creek	La Prele Creek	N. Platte at Orin	N. Platte Below Glendo Res.
1972	NA	27,602	29,823	1,276,271	1,296,908
1973	NA	48,217	63,385	2,132,453	1,992,697
1974	NA	24,800	20,651	1,748,800	1,841,662
1975	NA	26,353	16,531	1,248,318	1,224,077
1976	NA	26,786	19,079	1,146,901	1,160,203
1977	NA	21,128	13,788	1,029,815	998,842
1978	NA	29,304	24,933	1,061,301	1,090,131
1979	NA	13,841	9,887	1,091,780	1,055,487
1980	NA	23,508	24,656	1,364,882	1,318,311
1981	NA	10,560	5.085	936,091	968,419
1982	NA	22,419	14,174	914,608	915,451
1983	NA	60,191	68,918	2,063,381	1,958,412
1984	NA	33,483	34,788	2,272,054	2,288,373
1985	NA	7,148	2,855	1,460,320	1,406,555
1986	54,343	29,798	33,537	1,688,046	1,644,521
1987	37,510	13,159	8,020	955,690	984,282
1988	47,332	29,726	26,773	1,099,353	1,103,876
1989	9,810	5,050	1,330	890,958	931,987
1990	18,310	11,426	6,142	706,414	731,103
1991	35,867	24,614	28,567	894,088	860,508
1992	16,080	8,888	NA	735,496	743,921
1993	57,685	33,473	NA	950,446	882,865
1994	29,500	15,642	NA	NA	1,076,084
1995	93,727	52,528	NA	NA	979,621
1996	57,783	29,611	NA	1,289,235	1,232,916
1997	75,157	40,622	NA	1,634,517	1,513,547
1998	35,315	18,927	NA	1,308,803	1,370,692
1999	57,790	41,577	NA	1,353,191	1,465,469
2000	40,976	26,308	NA	1,165,390	1,208,878
2001	37,351	20,058	NA	1,059,116	1,038,822
2002	NA	6,782	NA	621,250	678,042
2003	NA	19,915	NA	740,940	698,652
2004	NA	7,833	NA	601,427	621,022
2005	NA	13,928	NA	772,623	758,119
2006	NA	15,853	NA	NA	915,582
2007	NA	22,766	NA	NA	897,256
2008	NA	36,517	NA	NA	879,758
2009	NA	25,252	NA	865,510	851,610
2010	NA	43,728	NA	1,584,699	1,440,463
2011	NA	35,777	NA	2,538,836	2,495,923
2012	NA	11,612	NA	1,127,213	1,213,194
2013	NA	17,594	NA	810,059	759,639
Average	**44,033**	**24,626**	**22,646**	**1,220,007**	**1,178,426**

Notes:

1) * Denotes an index Gage
2) ^ Denotes gage data was filled
3) Source of raw data – USGS NWIS website. TS Tool was used to manipulate Data.

Table 2.4: Guernsey to State Line Annual Stream Flow Summary

	6657000 *	6674500 *	6670500 *
	N Platte River Below Whalen Divers Dam	N Platte River and Wyoming – Nebraska State Line	Laramie River near Ft. Laramie
1972	504,715	648,055	89,841
1973	1,237,720	1,658,984	341,271
1974	898,258	1,085,502	99,753
1975	344,618	455,681	53,042
1976	285,360	417,662	63,346
1977	255,579	350,163	45,972
1978	298,881	410,079	71,961
1979	277,726	374,102	54,612
1980	518,065	690,191	128,667
1981	257,219	346,212	20,571
1982	244,527	345,599	24,816
1983	1,339,893	1,977,968	513,096
1984	1,495,054	2,122,075	473,297
1985	496,052	644,874	70,672
1986	924,895	1,220,777	190,827
1987	283,327	426,421	46,372
1988	310,221	425,812	50,064
1989	276,583	328,404	31,605
1990	219,381	288,030	32,045
1991	250,234	339,883	48,028
1992	227,737	277,457	34,384
1993	237,059	349,397	50,012
1994	260,319	352,829	34,727
1995	401,026	604,337	130,082
1996	438,292	551,909	63,889
1997	804,853	940,871	56,159
1998	559,157	655,971	37,266
1999	755,433	930,781	92,961
2000	341,586	451,956	73,282
2001	287,404	380,943	45,210
2002	209,433	243,482	33,932
2003	212,321	245,263	29,467
2004	196,205	201,522	21,822
2005	224,320	249,315	22,499
2006	258,494	280,731	19,754
2007	268,182	284,204	19,932
2008	292,241	329,898	22,425
2009	251,011	311,810	23,564
2010	844,856	1,057,614	157,242
2011	1,871,765	2,191,803	298,745
2012	388,260	431,558	36,820
2013	251,941	289,099	30,782
Average	**483,338**	**623,077**	**90,115**

Notes:
1) * Denotes an index Gage
2) ^ Denotes gage data was filled
3) Source of raw data – USGS NWIS website. TS Tool was used to manipulate Data.

Table 2.5: Lower Laramie Annual Streamflow Summary

	6664400 ^ Sybille Cr. Ab Mules Cr.	**6675900 ^** Sybille Cr. Ab Canal 3	**6670500** Laramie R. Nr Ft. Laramie
1972			89,841
1973			341,271
1974			99,753
1975	6,004		53,042
1976	5,627		63,346
1977	4,950		45,972
1978	8,338		71,961
1979	10,245		54,612
1980	30,362		128,667
1981	6,852	11,780	20,571
1982	6,210	18,485	24,816
1983	88,950	106,256	513,096
1984	50,504	67,993	473,297
1985	6,542	27,588	70,672
1986	10,214	34,988	190,827
1987	5,830	25,485	46,372
1988	13,222	30,893	50,064
1989	4,518	9,792	31,605
1990	12,643	18,337	32,045
1991	16,299	20,496	48,029
1992	6,535	10,788	34,384
1993	15,378	21,672	50,012
1994	7,398	15,361	34,727
1995	24,650	33,067	130,082
1996	12,659	22,235	63,889
1997	7,885	19,065	56,159
1998	9,187	20,100	37,266
1999	16,892	28,257	92,961
2000	7,381	16,553	73,282
2001	15,287	20,280	45,210
2002	4,603	3,359	33,932
2003	12,701	15,046	29,467
2004	4,739	6,456	21,823
2005	7,616	15,869	22,499
2006	6,848	10,564	19,754
2007	10,226	15,755	19,932
2008	8,626	15,507	22,426
2009	10,406	18,515	23,564
2010	44,387	60,301	157,242
2011	13,503	40,288	298,745
2012	5,932	14,662	36,820
2013			30,782
Average	**14,214**	**24,869**	**90,115**

Notes:

1) * Denotes an index Gage
2) ^ Denotes gage data was filled
3) Source of raw data – USGS NWIS website. TS Tool was used to manipulate Data.

Table 2.6: Horse Creek Annual Stream Flow Summary

	Horse Cr. Nr. Johnson Ranch Nr Lagrange USGS 06675850	Horse Cr. At WY Cross Ranch Nr Lagrange USGS 06676550	Bear Cr. Nr Lagrange USGS 06676900
1972		6,120.2	
1973		21,748.5	
1974			
1975			
1976			
1977			
1978			
1979	4,948.4		3,081.9
Average	**4,948.4**	**13,934.4**	**3,081.9**

Notes:
1) * Denotes an index Gage
2) ^ Denotes gage data was filled
3) Source of raw data – USGS NWIS website. TS Tool was used to manipulate Data.

Table 2.7: South Platte Annual Stream Flow Summary

	Crow Creek Ab 19th Street USGS Gage 06755960
1994	1,805.2
1995	8,964.6
1996	4,714.2
1997	11,199.8
1998	10,544.5
1999	28,183.4
2000	3,409
2001	3,007.8
2002	1,682.5
2003	1,429.6
2004	1,091.7
2005	1,397.3
2006	1,165.2
2007	1,383.9
2008	2,127.9
2009	3,054.2
2010	14,786.2
2011	5,894.6
2012	1,552.1
2013	9,797.9
Average	**5,859.58**

Notes:
1) * Denotes an index Gage
2) ^ Denotes gage data was filled
3) Source of raw data – USGS NWIS website. TS Tool was used to manipulate Data.

2.3 GAGE DATA MANIPULATION AND DATA EXTENSION

The computer program TS Tool was used to manipulate the daily streamflow data to convert data units, study periods, conversion to monthly and annual flows and data extension. TS Tool was developed by Riverside Technology, Inc. funded by the State of Colorado, Water Conservation Board under the Colorado River Decision Support System. TS Tool was selected to perform the data manipulation because it is an integral tool for more advanced modeling techniques such as StateMOD, which is used in many of the Wyoming Water Development Commission's (WWDC) ongoing efforts to model, and analyze stream systems throughout the state. This decision was made so that data collected during this update could easily be incorporated to a more robust model in the future if desired.

The USGS daily streamflow data is input into TS Tool. Using a list of built in commands; this data can be further manipulated. The first adjustment to the data was converting the flow from cubic feet per second (CFS) to acre-feet (ac-ft) per day. The next function was to fill missing data when needed. A gage with complete data (independent gage) with similar drainage area and elevation was chosen to provide a comparison to a gage with missing data (dependent gage). TS Tool utilizes a host of options for data filling. This study used two methods to fill the missing data. The methods used for this study was either by regression equations or the MOVE2 method. Regression equations are developed by using ordinary least square (OLS) regression. Regression relationships are developed using the analysis period for the time series and are applied to the fill period. This methodology is further explained in Appendix 2 of Bulletin 17B, Guidelines for Determining Flood Flow Frequency, USGS

The daily streamflow data for the complete and filled gages was then converted to monthly and annual flows using TS Tool. This data was then used to determine dry, average and wet year water years.

2.3.1 Dry, Average and Wet Years Classifications

Index gages were used to determine annual stream flow characteristics for each of the seven subbasins to classify the study period into dry, wet and average years. The index gages used were chosen by gages that contained a significant amount of flow data and were not impacted by reservoirs. The index gages selected for the dry, average and wet year classifications were previously shown in **Tables 2.1 through 2.7**. The resulting dry, average and wet year classifications for each of the subbasins are shown in **Table 2.8**.

Table 2.8: Dry, Average, Wet Water Year Determination

Year	Upper Laramie	Lower Laramie	Above Pathfinder	Pathfinder to Guernsey	Guernsey to State Line	Horse Creek	South Platte
1972	Ave	Ave	Ave	Ave	Ave		
1973	Ave	Ave	Wet	Wet	Wet		
1974	Ave	Ave	Ave	Ave	Wet		
1975	Ave	Ave	Ave	Ave	Ave		
1976	Ave	Ave	Ave	Ave	Ave		
1977	Dry	Dry	Dry	Ave	Ave		
1978	Ave	Ave	Ave	Ave	Ave		
1979	Wet	Wet	Ave	Ave	Ave		
1980	Ave	Ave	Ave	Ave	Ave		
1981	Dry	Dry	Dry	Dry	Ave		
1982	Wet	Wet	Ave	Ave	Ave		
1983	Wet	Wet	Wet	Wet	Wet		
1984	Wet	Wet	Wet	Ave	Wet		
1985	Ave	Ave	Ave	Dry	Ave		
1986	Wet	Wet	Wet	Ave	Wet		
1987	Dry	Dry	Ave	Ave	Ave		
1988	Ave	Ave	Ave	Ave	Ave		
1989	Dry	Dry	Dry	Dry	Ave		
1990	Ave	Ave	Ave	Dry	Dry		
1991	Ave	Ave	Ave	Ave	Ave		
1992	Ave	Ave	Dry	Dry	Dry		
1993	Ave	Ave	Ave	Ave	Ave		
1994	Ave	Ave	Ave	Ave	Ave		Ave
1995	Ave	Ave	Wet	Wet	Ave		Ave
1996	Ave	Ave	Ave	Ave	Ave		Ave
1997	Wet	Wet	Wet	Wet	Wet		Wet
1998	Ave	Ave	Ave	Ave	Ave		Wet
1999	Ave	Ave	Ave	Wet	Ave		Wet
2000	Ave	Ave	Ave	Ave	Ave		Ave
2001	Dry	Dry	Dry	Ave	Ave		Ave
2002	Dry	Dry	Dry	Dry	Dry		Ave
2003	Ave	Ave	Ave	Ave	Dry		Ave
2004	Dry	Dry	Dry	Dry	Dry		Dry
2005	Ave	Ave	Ave	Ave	Dry		Dry
2006	Ave	Ave	Ave	Ave	Dry		Dry
2007	Ave	Ave	Ave	Ave	Ave		Dry
2008	Ave	Ave	Ave	Wet	Ave		Ave
2009	Ave	Ave	Ave	Ave	Ave		Ave
2010	Wet	Wet	Wet	Wet	Wet		Wet
2011	Wet	Wet	Wet	Wet	Wet		Ave
2012	Dry	Dry	Dry	Dry	Ave		Ave
2013	Ave	Ave	Ave	Ave	Dry		Ave

Annual flows were calculated from the daily streamflow data using TS Tool. In subbasins where multiple indicator gages were used, summations of the annual flows were calculated to determine the total flow of the index gages. The summation of the index gages annual flows was used to determine the dry, average and wet years. In the subbasins with a single index gage, the dry, average and wet years were computed from the annual totals for that gage. The wettest and driest 20% of the study period years, on an annual flow basis were identified. The remaining 60% of years were classified as average years.

Using the dry, average and wet year classifications, average monthly flows were calculated for all of the gage records. For each gage used in the study, averages of all monthly flows for the study period were calculated each of the dry, average and wet years. The result is a single flow value for each month of the year for each of the dry, average and wet conditions.

2.3.2 Ungaged Tributary Flow Estimation

Many of the tributaries within each of the subbasins do not have gages or lack sufficient gaging station records. To estimate the flow contributions of these tributaries, annual flows were calculated using a regression equation published by H.W. Lowham in USGS Water Resources Investigation Report 88-4045 entitled "Streamflows in Wyoming" (WRIR 88-4045).

The first step of the estimation was to determine the region type as defined in WRIR 88-4045 and the correlating equations for each of the region types. The region type classifications are the Plains Region, High Desert Region and Mountainous Region. Equations to estimate the annual stream flow were provided in the WRIR 88-4045 for each of the region classifications. These equations and a listing of the variables are shown below:

Plains and High Desert Regions

$$Q_a = .0021\, A^{0.88}\, PR^{1.19}$$

Where: Q_a = mean annual flow in CFS
A = contributing drainage area, square miles
PR = average annual precipitation

Mountainous Region

$$Q_a = .0013\, A^{0.93}\, PR^{1.43}$$

Where: Q_a = mean annual flow in CFS
A = contributing drainage area, square miles
PR = average annual precipitation

GIS mapping was used to determine the region type a tributary would be classified within. Mapping of the different regions within the basin were overlaid with HUC watersheds to determine the tributary regional classification. In instances where a tributary was located in multiple region classifications, the areas were calculated pertaining to whichever region was appropriate. Physical data was then obtained from the mapping to collect the necessary variables required of the individual equations. Average annual precipitation was also collected and included in GIS. The average annual monthly precipitation data for the period 1981-2010 was obtained for the entire state from the USDA/NRCS Geospatial Data Center. The source of the data is the Oregon Climate Service at Oregon State University. PRISM (Parameter-elevation Relationships on Independent Slopes Model) is an interpolation method to develop data sets that is the current state of knowledge of spatial climate pattern in the United States.

Variables used to determine annual flow were: 1) area of the reach, 2) "region" as defined in Plate 1 of WRIR 88 4045, and average annual precipitation. The values used for each reach were determined using USGS data and ArcGIS. Monthly averages were assumed to be a fraction of the annual flow based on gage data from the nearest, most hydrologically similar gage. The results of these estimations are presented in **Table 2.9**.

Table 2.9: Ungaged Flow Calculation

	Reach	Mountainous Reach Area (Sq. Miles)	High Desert Reach Area (Sq. Miles)	Mountainous Average Annual Precipitation (in.)	High Desert Average Annual Precipitation (in.)	Mountainous Mean Annual Flow from Precip Regression (Acre-Ft)	High Desert Mean Annual Flow (Acre-Ft)	Total Mean Annual Flow per Reach all precip (Acre-Ft)
Upper Laramie	1001	173	15	24	15	99794	407	99794
	1002	38	0	18	0	16734	0	16734
	1004	1	94	13	13	485	1752	2237
	1005	1	182	18	16	819	4113	4932
	1007	64	37	16	13	24340	770	25110
	1008	12	125	16	12	5278	2054	7332
	1009	51	29	17	13	20410	624	21033
	1011	37	144	18	12	16649	2417	19066
	1012	173	190	24	12	108995	3053	112048
	1012A	161	0	25	0	102857	0	102857
	1014	16	61	12	7	4194	547	4741
	1015	0	90	0	12	0	1601	1601
	1017	23	165	22	14	14823	3052	17875
	1018	0	215	0	13	0	3654	3654
	1019	0	94	0	13	0	1796	1796
Above Pathfinder	2001	243	0	24	0	146565	0	146565
	2002	201	0	24	0	122135	0	122135
	2003	27	0	27	0	22585	0	22585
	2004	62	0	36	0	72978	0	72978
	2006	97	9	32	15	95776	265	96041
	2006.A	66	0	36	0	52702	0	52702
	2006.B	31	9	32	15	32874	265	33139
	2008	47	23	27	14	36409	552	36962
	2009	35	33	20	14	18317	735	19052
	2010	211	51	36	13	227015	1016	228031
	2012	44	22	33	13	46185	494	46680
	2013	2	56	18	13	1195	1078	2272
	2014	34	18	25	14	24477	461	24938
	2016	75	61	33	13	76876	1182	78058
	2018	24	65	21	11	14277	1057	15334
	2019	0	45	0	10	0	707	707
	2020	73	66	25	14	49736	1421	51157
	2021	0	73	0	11	0	1152	1152
	2022	79	172	19	12	38234	2765	41000
	2024.A	114	0	24	0	71278	0	71278
	2025	16	686	16	10	6208	7586	13794
	2026	16	301	0	11	0	4076	4076
	2027	28	187	21	12	16356	2919	19275
	2028	0	289	0	12	0	4419	4419
	2029	8	490	32	13	9787	7438	17226
	2030	157	283	27	13	113629	4680	118309
	2031	162	533	18	12	66721	7525	74247
	2032	8	472	19	10	4109	5429	9538
	2033	243	2759	21	11	122697	27775	150471
	2034	115	908	22	13	63614	12775	76389
Pathfinder to Guernsey	3001	0	266	0	12	0	3956	3956
	3002	161	236	16	15	57467	4780	62247
	3003	0	0	0	0	0	0	0
	3004	0	301	0	12	0	4515	4515

Table 2.9: Ungaged Flow Calculation

	Reach	Mountainous Reach Area (Sq. Miles)	High Desert Reach Area (Sq. Miles)	Mountainous Average Annual Precipitation (in.)	High Desert Average Annual Precipitation (in.)	Mountainous Mean Annual Flow from Precip Regression (Acre-Ft)	High Desert Mean Annual Flow (Acre-Ft)	Total Mean Annual Flow per Reach all precip (Acre-Ft)
	3005	0	0	0	0	0	0	0
	3006	0	657	0	12	0	8764	8764
	3007	279	146	19	13	119244	2698	121941
	3008	172	41	20	12	84081	792	84873
	3009	0	210	0	12	0	3284	3284
	3010	0	81	0	12	0	1380	1380
	3011	0	35	0	11	0	596	596
	3012	153	49	21	12	77798	903	78701
	3013	0	51	0	12	0	902	902
	3014	0	149	0	12	0	2336	2336
	3015	0	31	0	12	0	613	613
	3016	120	56	21	13	61969	1139	63108
	3017	0	201	0	12	0	3253	3253
	3018	38	74	20	14	19773	1534	21307
	3019	0	0	0	0	0	0	0
	3020	188	103	20	15	91794	2178	93972
	3021	0	84	0	13	0	1575	1575
	3022	0	0	0	0	0	0	0
	3023	0	242	0	13	0	4101	4101
	3024	0	66	0	14	0	1354	1354
	3025	0	343	0	14	0	5928	5928
	3026	0	61	0	15	0	1441	1441
	3027	0	223	0	14	0	4174	4174
	3028	0	93	0	14	0	1859	1859
	3029	0	0	0	0	0	0	0
	3030	100	112	20	16	48072	2603	50676
	3031	0	242	0	14	0	4437	4437
	3032	0	330	0	14	0	6015	6015
	3033	46	148	17	15	19383	3076	22459
	3034	0	0	0	0	0	0	0
Lower Laramie	4001	175	183	16	15	58954	3619	62573
	4002	42	324	15	15	14775	6422	21197
	4003	3	151	15	15	1160	3165	4325
	4004	0	0	0	0	0	0	0
	4005	251	282	18	14	101682	4977	106659
	4006	0	551	0	14	0	9193	9193
	4007	1	638	19	16	867	11949	12817
	4008	0	0	0	0	0	0	0
	7002	28	1043	21	16	16213	18432	34645
Horse Creek	6001	48	1125	19	16	23478	20028	43506
	6002	0	424	0	15	0	8088	8088
South Platte	7001	0	450	0	15	0	8241	8241
	7002	28	1043	21	16	16213	18432	34645

2.4 AGRICULTURAL CONSUMPTIVE USE

Agricultural consumptive use and depletion amounts are described in the Agricultural Use Section of Volume 3 of this study. Agricultural consumptive use, represented by monthly depletion amounts, was developed for each of the seven subbasins based on the amount of irrigated acreage within the basin. Information in the Agricultural Use Section of Volume 3 was used to provide data for agricultural consumptive use for this task. This data was further refined to determine the locations and quantity of consumptive use in relation to the streams and reaches developed in the spreadsheet model. Further refinement included the use of GIS mapping to determine the points of diversions that supplied water for the river systems to the irrigated lands. Point of diversion data provided by the SEO included linking of irrigated lands to a point of diversion on a river or stream. For use in the development of the model, the points of diversions were assigned to a river reach in the model. The amount of irrigated lands being supplied by each point of diversion was then summarized and tied to specific reaches in the model. The result of this analysis determined a total amount of irrigated land that was being supplied water diverted from each of the reaches in the model. Using the consumptive use values provided in the Agricultural Use Section of Volume 3, a total amount of agricultural water use in every reach of the model was developed. It should be noted that the consumptive use values were based on the unit consumptive use rates within the specific subbasin as described within the Wyoming Depletion Plan and the 2006 Platte River Basin Plan and were not calculated based on typical consumptive use calculations. The Wyoming Depletion Plan is the document that the Wyoming State Engineer's Office (SEO) follows in addressing the State of Wyoming's participation in the Platte River Recovery Implementation Program.

To convert the annual irrigation totals to monthly depletion values for the model, a large irrigation diversion in each subbasin was evaluated for each of the three years, 2011, 2012 and 2013. Diversion records for these large diversions were used to determine what percentage of the total irrigation was delivered and consumed during each month of the irrigation season. A percentage of the annual diversion was calculated by dividing the total monthly diversion for each month by the total seasonal diversion. This percentage was then applied to the total annual agricultural depletion quantity assigned to each reach to determine the monthly consumptive use values for each of the reaches in the basin.

2.5 IMPORTS AND EXPORTS

The spreadsheet models quantify transbasin diversions and the volumes of water diverted in Wyoming for out-of-state water needs. The transbasin diversions are reported as exports and imports within the water balance summary tables. Water transferred out of a subbasin is quantified in the export column of the spreadsheets. Water transferred into a subbasin is quantified in the import column. The irrigation diversions serving out-of-state agricultural needs, mandated under Federal projects and contracts, are quantified in the "Federal Canal Diversion Out-of-State Delivery" columns.

The City of Cheyenne Board of Public Utilities owns and operates a complicated water supply system that imports water from the Little Snake River Basin to the North Platte River Basin. The water is released to the North Platte River in exchange for diversions from the Douglas Creek drainage within the Above Pathfinder subbasin in the Medicine Bow Mountains. The diversions from the Douglas Creek drainage are captured and stored in Rob Roy Reservoir and Lake Owen and conveyed to the South Platte Basin via a series of pipelines and reservoirs owned by the City of Cheyenne and eventually delivered to the City's water treatment plant when the reservoirs are drawn down to serve municipal water needs.

The Wheatland Irrigation District located in the Lower Laramie subbasin imports water for irrigation through diversions from the Rock Creek drainage within the Above Pathfinder subbasin by capturing and conveying water in a series of reservoirs and ditches. The main conveyance structure is the Canon Ditch that diverts from Rock Creek just above the Town of Arlington.

Within the Guernsey to the State Line reach of the North Platte River, water supplies are diverted and conveyed within Federal Canals for serving agricultural irrigation needs of North Platte Project and Warren Act Contractors within Wyoming and Nebraska. The one North Platte Project contractor in Wyoming is Goshen Irrigation District located south of the North Platte River immediately west of the Nebraska State Line. The three Wyoming Warren Act contractors are Lingle Water Users, Hill Irrigation District, and Rock Ranch Irrigation District. Irrigation water is diverted directly from the North Platte River and applied to the lands of the federal contractors within Wyoming. The agricultural consumptive use of the federal contractors within Wyoming is considered a consumptive use loss within this subbasin reach of the model. The water diverted from the North Platte River within Wyoming and delivered to out-of-state federal contractors in Nebraska is based on historical diversion records.

2.6 SPREADSHEET MODELS

Individual spreadsheets were developed for each of the seven major subbasins of the Platte River System. Each subbasin was then divided into river reaches with a starting and ending node. The nodes were developed where a gage was present; a natural flow location was quantified, at a tributary confluence or the location of a major diversion. Water supply and use were imparted onto each reach to determine the amount of water anticipated within each reach during a dry, wet and average hydrologic condition.

Each spreadsheet provides the water balance for each of the subbasins. The water balance estimates the amount of water provided to the entire subbasin by using either gaged flow or estimated flow from regression equations.

2.6.1 Spreadsheet Model Data

The spreadsheet contains several tables that contain the input data into the water balance equations for each reach of the river systems. Each of the tables contains data for the dry, wet and average hydrologic year. Tables include:

- Gaged flow – Data includes stream flow gage data for each hydrologic condition by month and total annual flow in acre-feet.
- Flow from Precipitation – Data includes estimated monthly and annual flow derived from regression equations.
- Agricultural Consumptive Use – Data includes monthly and annual consumptive use estimated from irrigated lands and applying the depletion factors to the amount of irrigated acres within each river reach.
- Municipal Diversion – Data includes monthly and annual diversions from each river reach for supply to municipalities. This data was obtained from other technical memoranda developed in separate tasks of this project.
- Industrial Diversions – Data includes diversions monthly and annual diversions from each river reach for supply to industrial uses. This data was obtained from other technical memoranda developed in separate tasks of this project.
- Instream Flows – Data includes monthly and annual requirements to satisfy instream flow permits. Instream flow data was obtained from the SEO website.
- Return Flows – Data includes monthly and annual flows that return to the river from municipal and industrial uses. This data was obtained from other technical memoranda developed in separate tasks of this project.
- Reservoir Release – Data includes flows from a reservoir release into each reach of the river system. Reservoir release data was obtained from the U.S. Bureau of Reclamation's (USBR) website for the federal reservoirs in the system and from the SEO website and hydrographer's reports.
- Reservoir Evaporative Losses – Data includes monthly and annual water losses from evaporation of reservoir storage. Evaporative data was obtained from the previous Basin Plan.

- Reservoir Storage Totals – Data includes end of month storage volumes. Reservoir storage data was obtained from the USBR's website for the federal reservoirs in the system and from the SEO website and hydrographer's reports.
- Import – data includes water imported into a river reach via a transbasin delivery. This data was obtained from the SEO website and hydrographer's reports.
- Export - Data includes water exported from a river reach via a transbasin delivery. This data was obtained from the SEO website and hydrographer's reports.

The data is entered in the "Data" tab of the spreadsheet. Data entered in the table on the "Data" tab are then used in calculations in each individual "Reach" tab of the spreadsheet.

2.6.2 Reaches

River reaches were developed to represent mainstem stream or river components and contributing tributary streams. Each river reach is bound by a node. The nodes represent either an ungaged tributary flow, stream gage, confluence of two rivers or a reservoir. **Table 2.10** provides a description of each modeled river reach, reach number and subbasin.

Each river reach within a subbasin has a dedicated worksheet tab in the spreadsheet. Data entered into the "Data" tab sheet is automatically retrieved for inclusion in the Reach tabs. The "Reach" tab then performs calculations to predict and summarize the water supply and uses for each river reach. An overall map generated in GIS is also displayed on each "Reach" tab that highlights the portion of the subbasin being depicted with the river reach. The outflow of each reach is calculated for each river reach using data retrieved from the Data worksheet. The results of the calculations are then presented in graphics. Six graphs are produced to provide a visual summary of the calculations for each reach. The six graphs are; Total Outflows and Losses by Month, total Annual Gains and Losses by Type, Total Annual inflow, Flow from Precipitation, Storage Capacity, Dry Year Gains and Losses by Month and Type, Average Year Gains and Losses by Month and Type, and Wet Year Gains and Losses by Month and Type. Node and river reach mapping is presented in **Figures 2.1 through 2.7**.

Table 2.10: Summary of River Reaches

Reach	Description
Upper Laramie	
1001	Laramie River Colorado Border to Fox Creek Confluence
1002	Fox Creek Headwaters to Laramie River Confluence
1003	Confluence of Laramie River and Fox Creek To Pioneer Gage
1004	Pioneer Gage to Confluence of Laramie River and Sand Creek
1005	Sand Creek Gage to Confluence of Laramie River and Sand Creek
1006	Laramie River Between Sand Creek and Five Mile Creek
1007	Five Mile Creek Headwaters to Confluence with Laramie River
1008	Laramie River Between Five Mile Creek and Harney Creek
1009	Harney Creek Headwaters to Confluence with Laramie River
1010	Laramie River Between Harney Creek and Laramie City
1011	Laramie River Between Laramie City and Little Laramie River
1012	Little Laramie River Gage to Laramie River
1013	Laramie River Between Little Laramie River and Four Mile Creek
1014	Four Mile Creek Headwaters to Laramie River
1015	Laramie River Between Four Mile Creek and Gage near Bosler
1016	Laramie River Between Gage near Bosler and Dutton Creek

Table 2.10: Summary of River Reaches

Reach	Description
1017	Dutton Creek to Confluence with Laramie River
1018	Laramie River Between Dutton Creek and Wheatland Res. #2
1019	Laramie River Between Wheatland Reservoir #2 and #3 Dutton
Above Pathfinder	
2001	N. Platte River - CO Border to Big Creek
2002	Big Creek
2003	N. Platte River - Big Creek to French Creek
2004	French Creek
2005	N. Platte River - French Creek to Brush Creek
2006	Brush Creek
2007	N. Platte River - Brush Creek to Beaver Creek
2008	Beaver Creek
2009	N. Platte River - Beaver Creek to Encampment River
2010	Encampment River
2011	N. Platte River - Encampment River to Cow Creek
2012	Cow Creek
2013	N. Platte River - Cow Creek to Cedar Creek
2014	Cedar Creek
2015	N. Platte River - Cedar Creek to Spring Creek
2016	Spring Creek
2017	N. Platte River - Spring Creek to Lake Creek
2018	Lake Creek / Dry Creek
2019	N. Platte River - Lake Creek to Jack Creek
2020	Jack Creek
2021	N. Platte River - Jack Creek to Sage Creek
2022	Sage Creek
2023	N. Platte River - Sage Creek to Pass Creek
2024	Pass Creek
2025	N. Platte River - Pass Creek to Gage 06630000
2026	N. Platte River - Gage 06630000 to Seminoe Reservoir
2027	Medicine Bow River - Gage 6635000 to Seminoe Reservoir
2028	Medicine Bow River - Little Medicine Bow River to Gage 6635000
2029	Rock Creek
2030	Medicine Bow River - Medicine Bow River headwaters to Little Medicine Bow River
2031	N. Platte River - Seminoe Reservoir to Pathfinder Reservoir
2032	Sweetwater River - Gage 6639000 to Pathfinder Reservoir
2033	Sweetwater River - Headwaters to Gage 6639000
2034	Little Medicine Bow River
Below Pathfinder	
3001	N. Platte River - PF Reservoir to Bates Cr.
3002	Bates Creek
3003	N. Platte River - Bates Creek to Poison Spider Creek
3004	Poison Spider Creek
3005	N. Platt River - Poison Spider Creek to Casper Creek
3006	Casper Creek
3007	N. Platte River - Casper Creek to Deer Creek
3008	Deer Creek
3009	N. Platte River - Deer Creek to Sand Creek
3010	Sand Creek
3011	N. Platte River - Sand Creek to Box Elder Creek
3012	Box Elder Creek
3013	N. Platte River - Box Elder Creek to Sage Creek

Table 2.10: Summary of River Reaches

Reach	Description
3014	Sage Creek
3015	N. Platte River - Sage Creek to La Prele Creek
3016	La Prele Creek
3017	N. Platte River - La Prele Creek to Wagonhound Creek
3018	Wagonhound Creek
3019	N. Platte River - Wagonhound Creek to La Bonte Creek
3020	La Bonte Creek
3021	N. Platte River - La Bonte Creek to Gage 6652000
3022	N. Platte River - Gage 6652000 to Shawnee Creek
3023	Shawnee Creek
3024	N. Platte River - Shawnee Creek to Glendo Reservoir
3025	Lost Creek
3026	Elkhorn Creek
3027	Muddy Creek
3028	N. Platte - Glendo Reservoir to Gage 6652800
3029	N. Platte River -Gage 6652800 to Horseshoe Creek
3030	Horseshoe Creek
3031	N. Platte River - Horseshoe Creek to Guernsey Reservoir
3032	Broom Creek
3033	Cottonwood Creek
3034	N. Platte River - Guernsey Reservoir to Basin Boundary
Lower Laramie	
4001	Laramie River - Basin Boundary to Sybille Creek
4002	Sybille Creek - Headwaters to USGS Gage 6664400
4003	Sybille Creek - USGS 6664400 to Laramie River
4004	Laramie River - Sybille Creek to N. Laramie River
4005	North Laramie River
4006	Laramie River - North Laramie River to Chugwater Creek
4007	Chugwater Creek
4008	Laramie River - Chugwater Creek to USGS 6670500
Guernsey to State Line	
5001	N. Platte River - USGS Gage 6657000 to Rawhide Creek
5002	N. Platte River -Rawhide Creek to USGS Gage 6674500
Horse Creek	
6001	Horse Creek - Headwaters to Bear Creek
6002	Horse Creek - Bear Creek to State Line
South Platte	
7001	Crow Creek
7002	Lodgepole Creek

2.6.3 Model Map

The "Model Map" tab show a schematic of the river reaches that represents the subbasin river and its tributaries. The schematic shows the nodes and node types, and lines representing the river reach. The sheet also contains a drawing of the entire subbasin with the reaches and nodes displayed for reference. The lines representing the river reaches in the schematic vary in line thickness. The variable weight indicates the amount of outflow from each reach. For example, the line thickness for each reach is representative of the average year annual outflow for that reach with a ratio of 1 pt. line thickness = 60,000 acre feet (Ac.Ft.); i.e., Reach 1004 has a line weight of 1.5.

2.6.4 Summary Tab

The “Summary” tab combines the cumulative input data and calculation results on a single graph. This graph displays all of the data and results for each of the three hydrologic conditions.

Figure 2.1: Upper Laramie Reach and Node Map

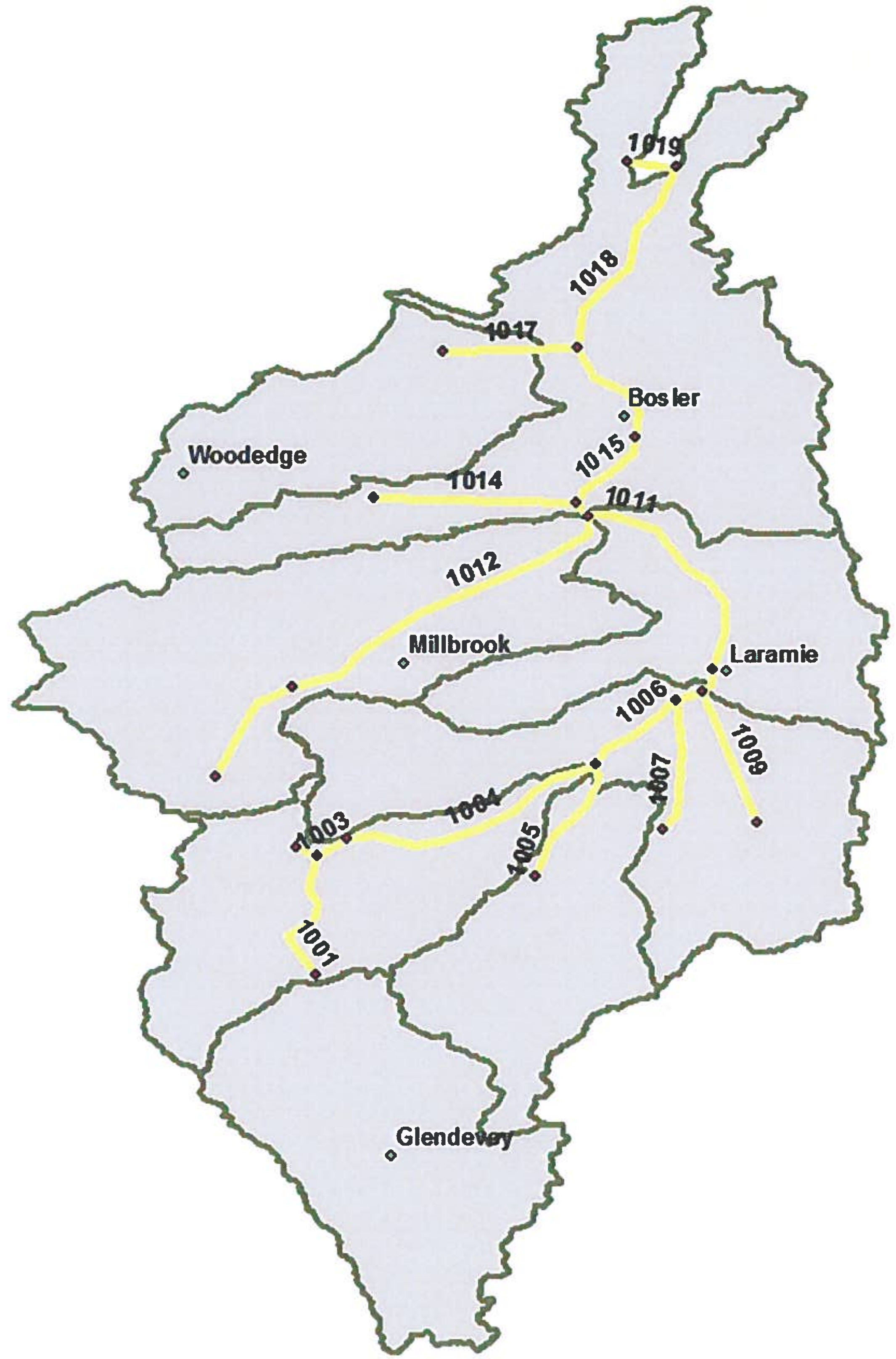

Figure 2.2: Above Pathfinder Reach and Node Map

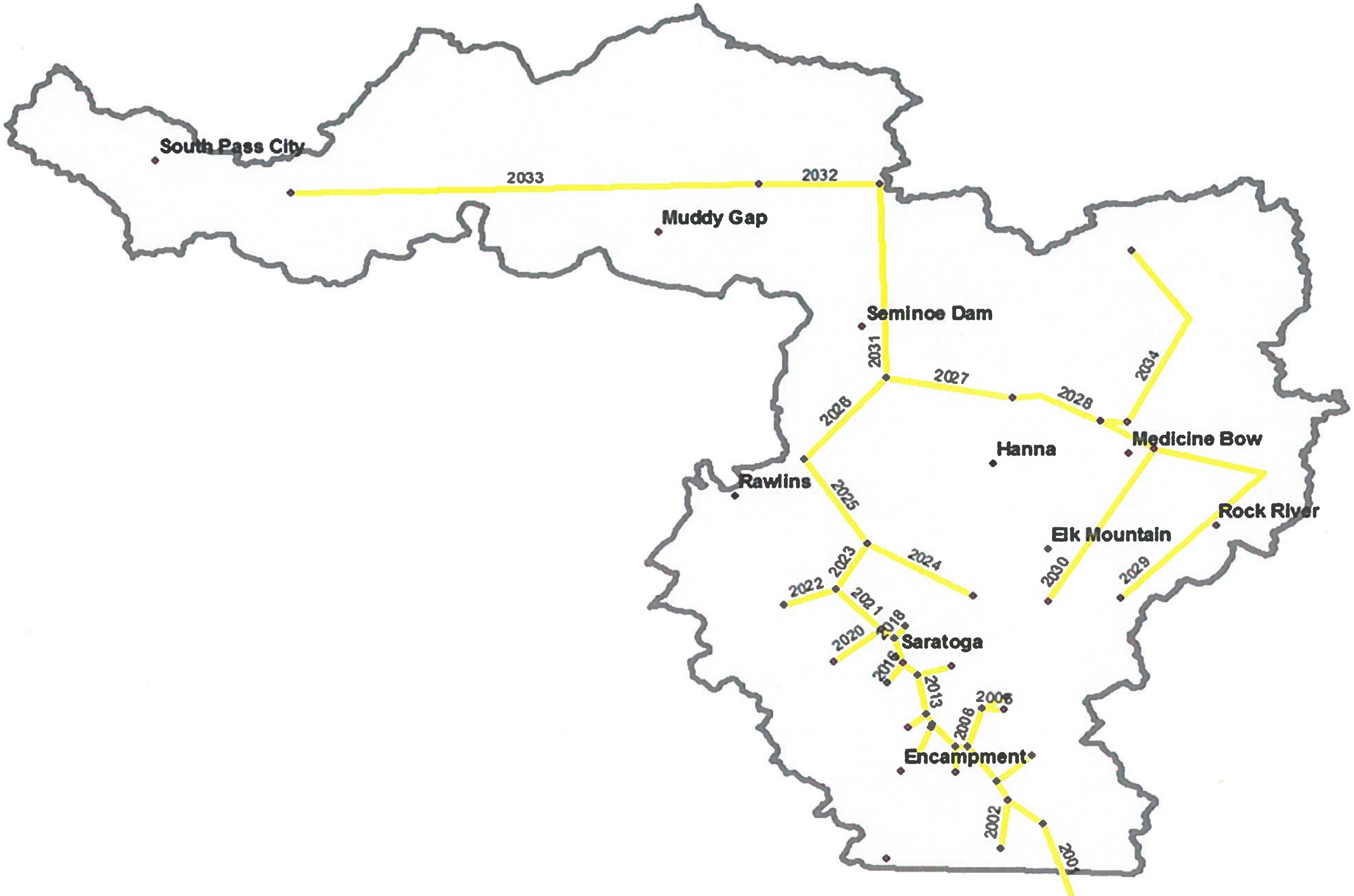

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Figure 2.3: Pathfinder to Guernsey Reach and Node Map

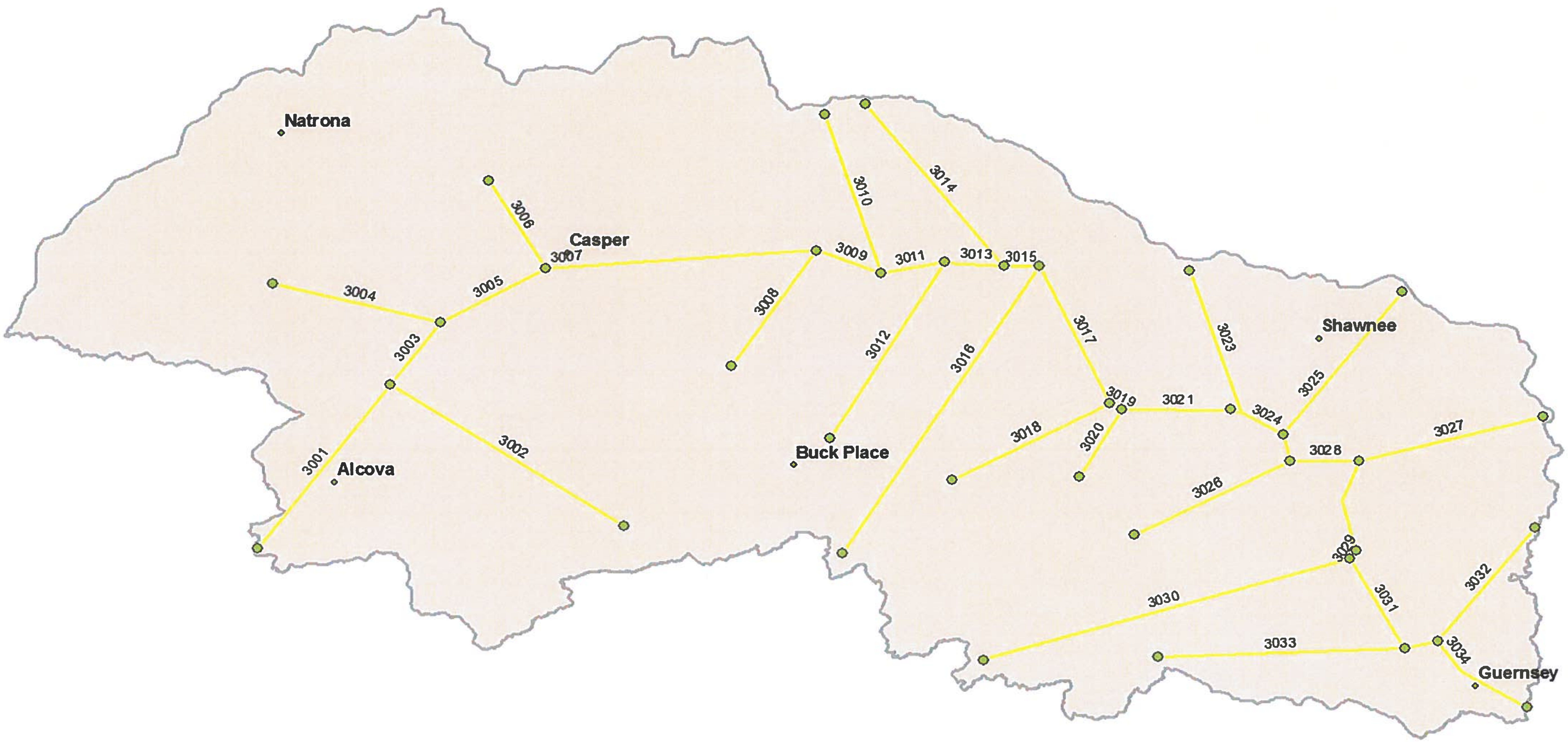

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Figure 2.4: Guernsey to State Line Reach and Node Map

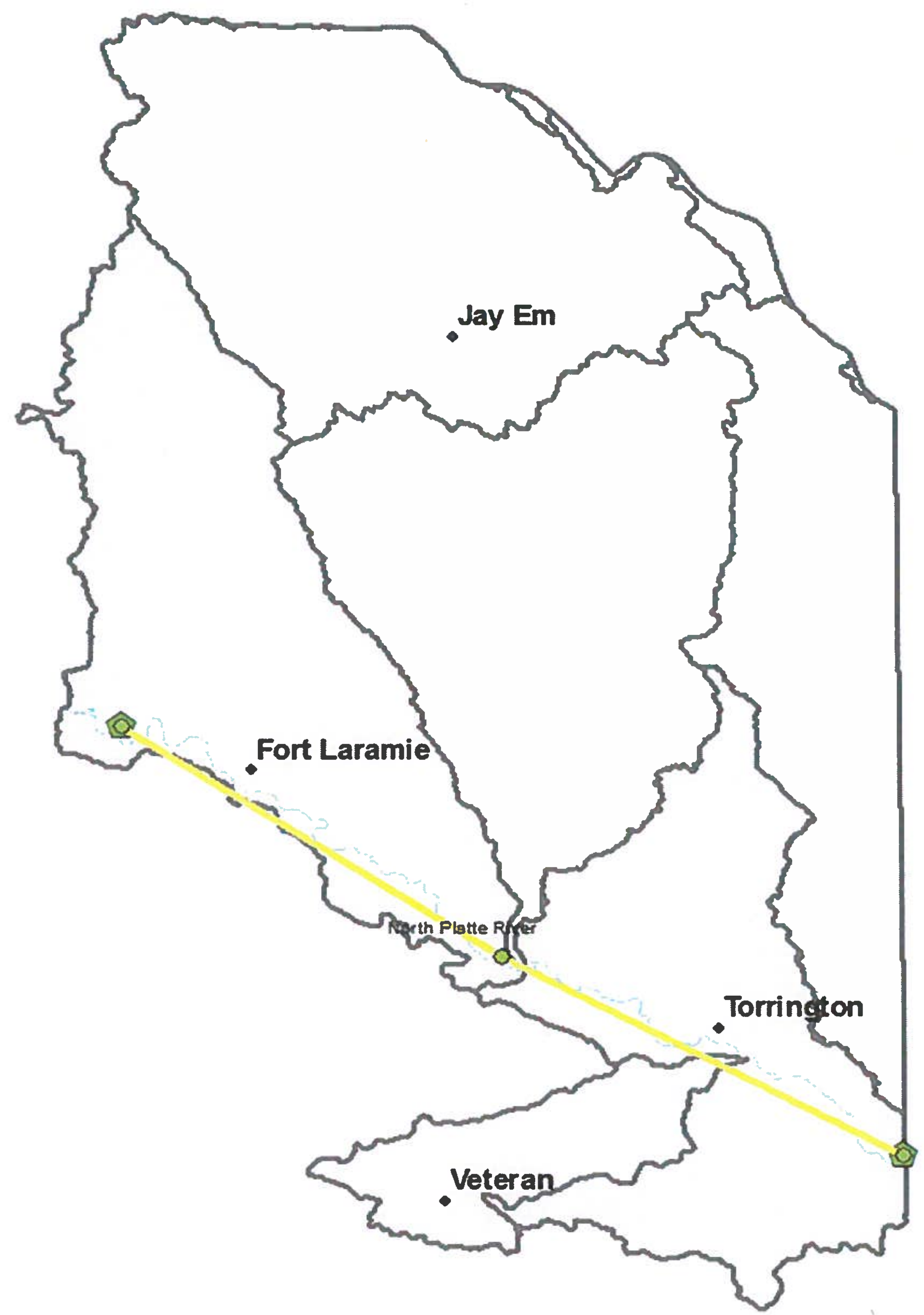


Figure 2.5: Lower Laramie Reach and Node Map

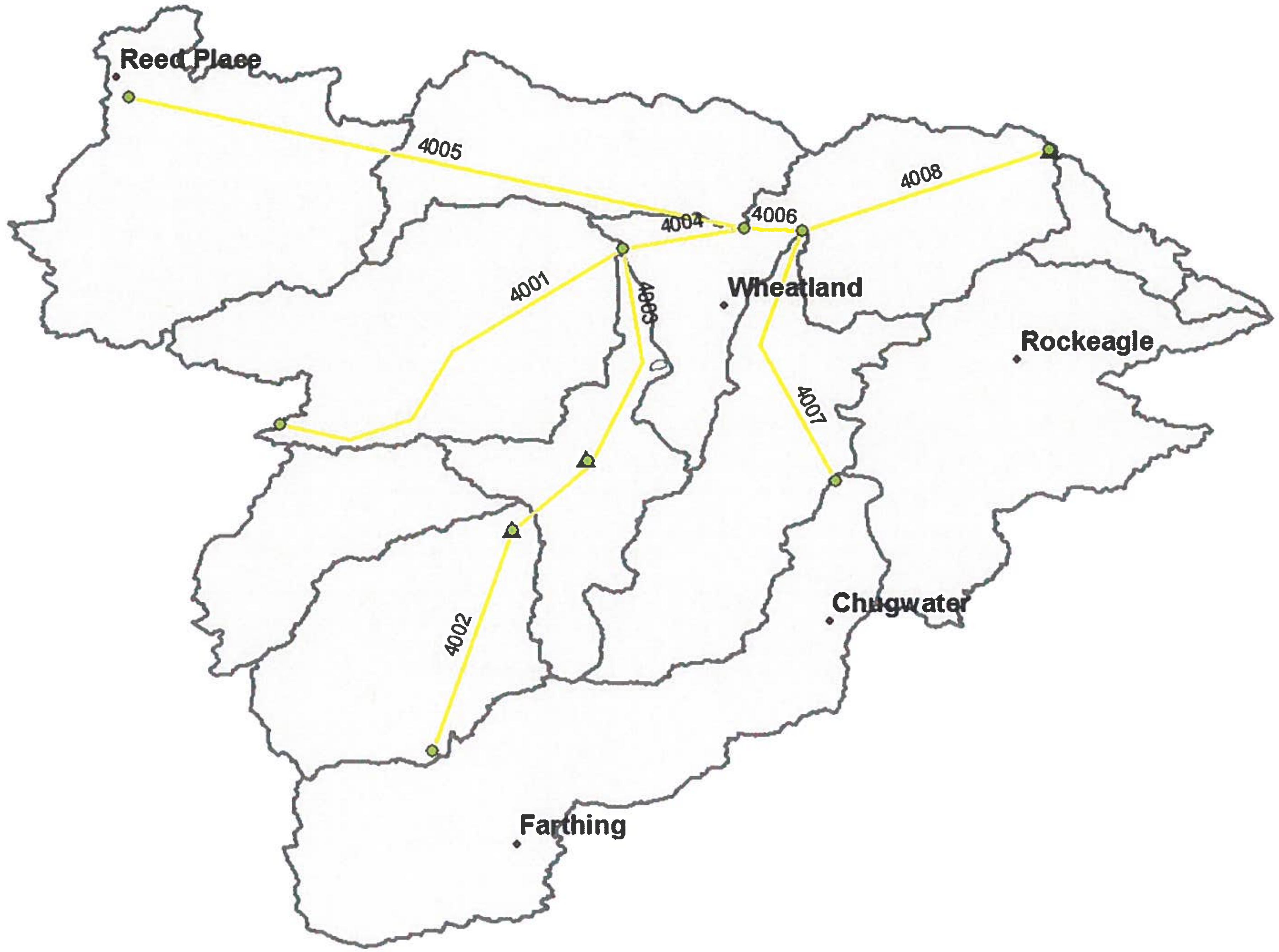


Figure 2.6: Horse Creek Reach and Node Map

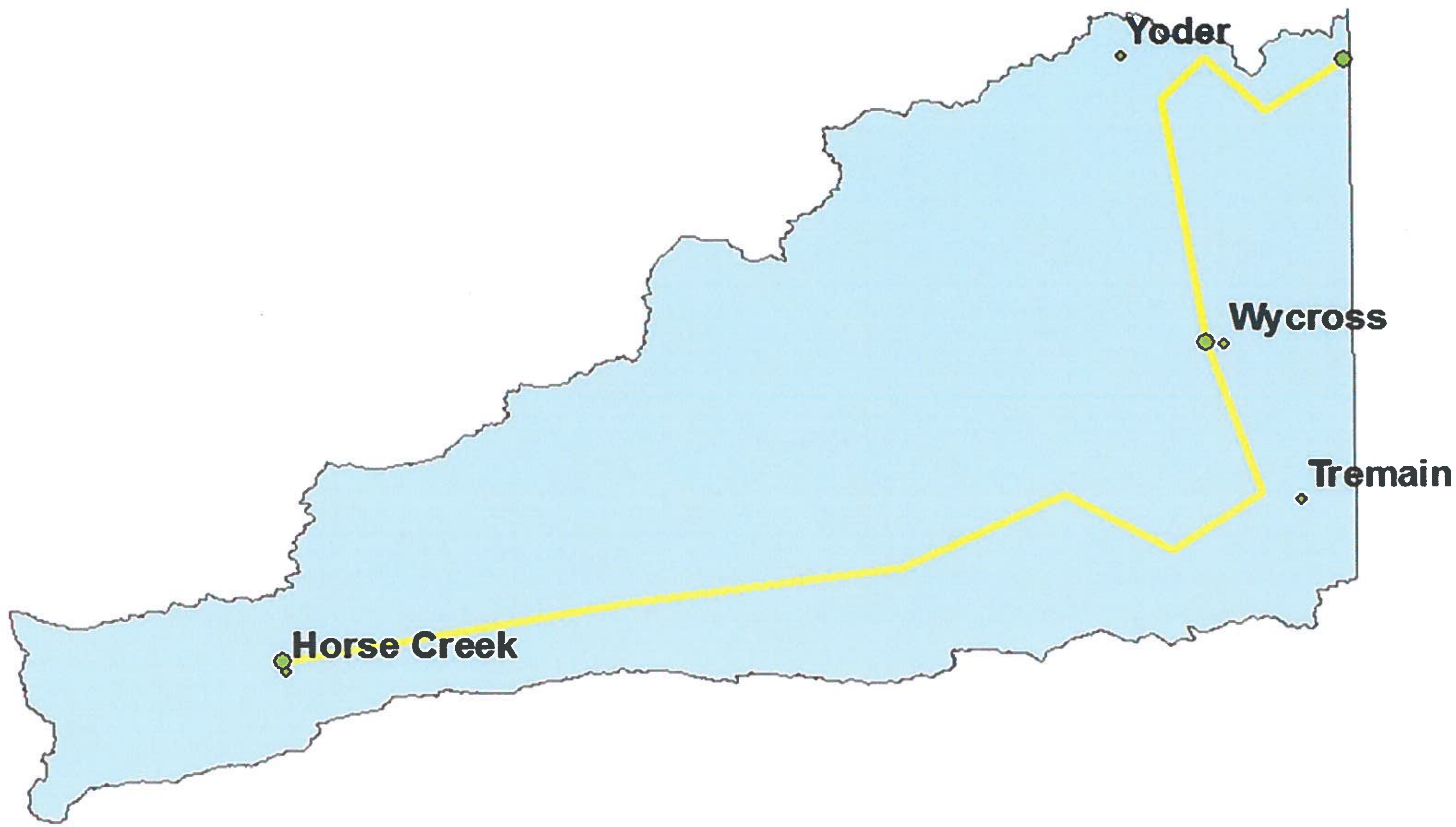
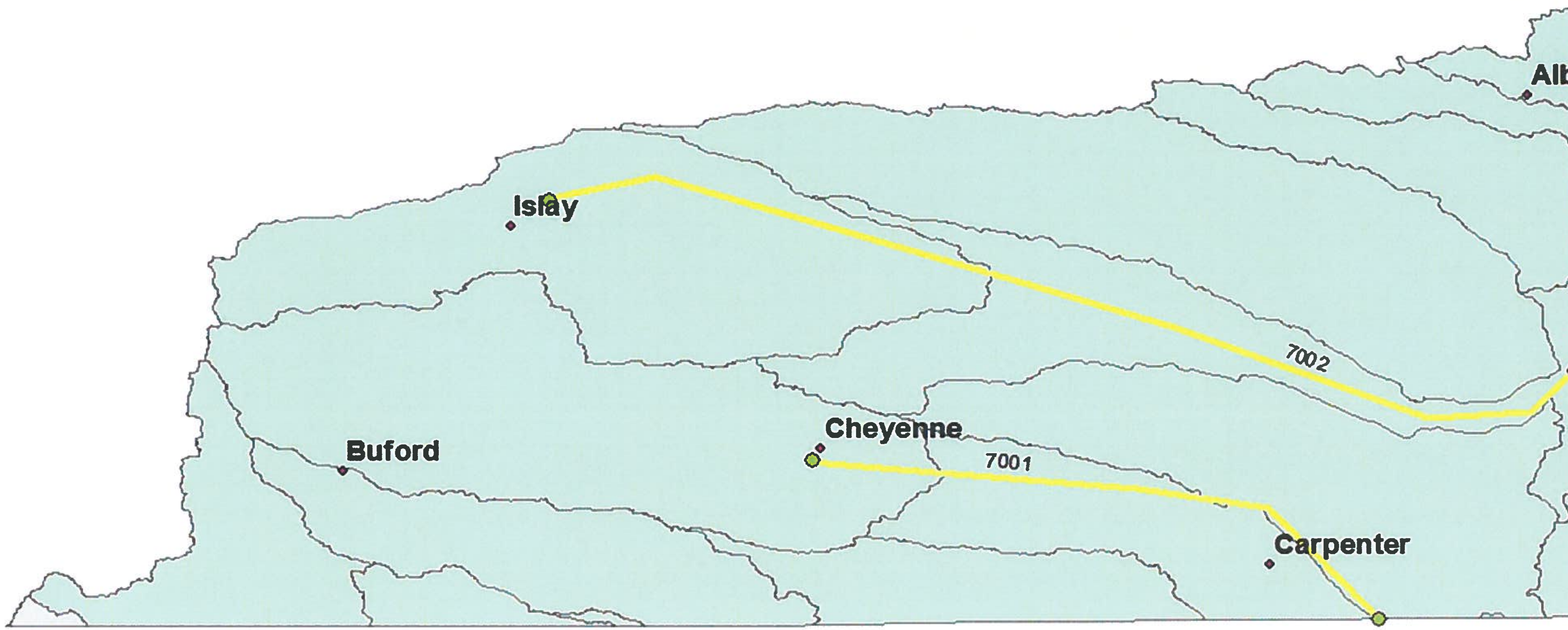


Figure 2.7: South Platte Reach and Node Map



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2.7 RESULTS

The purpose of the model development for this Platte Basin Plan Update was to develop water balance within each of the seven subbasins to help determine how much flow each of the subbasins contributes to the North and South Platte River basins. Seven spreadsheet models were developed, one for each of the seven subbasins. A summary was developed within each of the spreadsheet models to illustrate the results of the water balance. The summaries contain information for a dry, average and wet year scenario.

The summaries show the amount of contributing water supply as "Gains" and consumptive water use in each subbasin or "Losses" for each dry, average and wet year scenarios. The summaries also show the average amount of reservoir storage and total subbasin outflow for each of the scenarios as well.

Gains, or water supply, in each basin consists of the following:

- Flow from Regression – calculated ungaged streamflow contributing to the subbasin.
- Return Flows – The amount of flow returned to the stream from municipal and industrial diversions.
- Import – the amount of water imported through a transbasin diversion between different subbasins or transbasin diversions imported into the Platte River Basin.

Losses, or consumptive uses, in the sub basin consist of the following:

- Agricultural Consumptive Use – the amount of depleted water for irrigation and other agricultural uses.
- Municipal Diversions – Total surface water diverted for municipal uses. (Note: the consumptive use component of the municipal diversions is accounted for as the difference between diversions and return flows discussed above.)
- Industrial uses – Total amount of surface water for industrial diversions. (Note: the consumptive use component of the industrial diversions is accounted for as the difference between diversions and return flows discussed above.)
- Instream Flows – Instream flows reduce the amount of water available for consumptive use. The flows are protected through the designated river reach and no losses or depletions occur in the model.
- Reservoir Evaporative Losses – water lost (consumptive use) due to evaporation of reservoir storage water.
- Export – amount of water exported as a transbasin diversion between subbasins or to basins outside the Platte River Basin.
- Federal Canal Diversion Out-of-State Delivery – amount of water diverted within Wyoming from the Platte River and delivered to Federal Contractors in Nebraska. (This water is delivered to Nebraska via canal, and is in addition to water in the Platte River passing the Stateline.)

The modeled outflow for each of the subbasins is the result of the model analyses tracked and reported at the most downstream node in each of the subbasin nodes. A summary of these results for dry, average and wet years is presented in **Table 2.11**. The results are summarized for the entire Platte River Basin within **Table 2.12** with a breakout of North Platte and South Platte subbasins.

Hydrographs were developed within the spreadsheet models to compare the depleted flow to undepleted flow. Undepleted flows represent the amount of water that could be expected in the tributary if water was not diverted from the stream. Depleted flows reflect actual water flow within the stream. The graphs plot the total monthly volume of water in the stream for the average year water condition. The major tributaries, subbasin and reach number tab where the hydrographs are presented are listed below:

Tributary Name	Subbasin Model	Reach Number
Little Laramie River	Upper Laramie	1012
Brush Creek	Above Pathfinder	2006
Encampment River	Above Pathfinder	2010
Spring Creek	Above Pathfinder	2016
Medicine Bow River	Above Pathfinder	2027
Sweetwater River	Above Pathfinder	2032
Bates Creek	Pathfinder to Guernsey	3002
Deer Creek	Pathfinder to Guernsey	3008
Box Elder Creek	Pathfinder to Guernsey	3012
LaPrele Creek	Pathfinder to Guernsey	3016
La Bonte Creek	Pathfinder to Guernsey	3020
Laramie River	Lower Laramie	4008
Horseshoe Creek	Horse Creek	6002
Note: Graph is located in Tab – Depl vs Undepl Laramie Total		

Table 2.11: Subbasin Water Balance Results Summary

		Gains				Losses									
		Gaged Inflows	Ungaged Inflows	Return Flows (Municipal, Industrial)	Import	Agricultural Consumptive Use	Municipal Diversions	Industrial Diversions	Reservoir Evaporative Losses	Federal Canal Diversion Out-of-State Delivery	Export	Total Gains	Total Losses	Average Reservoir Storage	Modelled Outflow
Dry	Upper Laramie	43,126	230,000	3,400	355	81,432	3,091	0	34,521			280,000	119,044	150,646	102,147
	Above Pathfinder	339,837	470,000	617	9,142	98,592	2,872	3,113	99,992		8,669	820,000	213,239	1,091,785	1,920,700
	Pathfinder to Guernsey	870,141	220,000	64,568	0	70,503	4,517	64,587	51,120			1,150,000	190,727	649,253	916,223
	Lower Laramie	13,116	120,000	57	0	93,895	0	0	10,698			130,000	104,593	79,616	33,985
	Guernsey to State Line	1,045,705	13,000	231	0	109,823	0	509	1,391	734,831		1,060,000	846,554	5,043	125,205
	Horse Creek	0	16,000	0	0	47,090	0	0	3,077			20,000	50,167	11,910	0
	South Platte	1,260	13,000	7,789	8,314	40,807	9,755	0	611			30,000	41,418	25,508	0
Average	Upper Laramie	72,299	460,000	3,479	812	70,113	3,163	0	34,521			540,000	107,797	140,237	39,433
	Above Pathfinder	669,792	910,000	664	10,089	100,130	2,678	2,852	111,342		9,126	1,590,000	226,128	1,237,419	1,959,951
	Pathfinder to Guernsey	1,032,741	430,000	61,499	0	71,602	4,157	62,183	52,553			1,500,000	190,495	697,821	1,139,540
	Lower Laramie	19,811	190,000	57	0	97,743	0	0	10,698			210,000	108,441	68,881	44,750
	Guernsey to State Line	1,257,054	20,000	231	0	107,069	0	519	1,391	655,851		1,280,000	764,830	5,043	270,037
	Horse Creek	0	50,000	0	0	43,379	0	0	3,077			50,000	46,456	11,329	2,093
	South Platte	4,149	40,000	9,344	8,314	37,592	9,755	0	611			60,000	38,203	21,744	16,735
Wet	Upper Laramie	116,670	850,000	3,136	3,633	96,089	2,850	0	34,521			970,000	133,460	156,092	237,129
	Above Pathfinder	1,112,111	1,490,000	577	9,895	118,735	2,816	2,595	117,118		11,947	2,610,000	253,211	1,476,844	2,483,717
	Pathfinder to Guernsey	1,437,579	780,000	60,283	0	84,904	3,758	60,566	53,436			2,280,000	202,664	733,470	1,599,702
	Lower Laramie	49,625	370,000	57	0	114,917	0	0	10,698			420,000	125,615	88,813	160,202
	Guernsey to State Line	1,922,752	70,000	231	0	109,622	0	407	1,391	611,625		1,990,000	723,045	5,043	1,148,027
	Horse Creek	0	200,000	0	0	47,004	0	0	3,077			200,000	50,081	19,289	148,080
	South Platte	16,178	170,000	10,469	8,314	40,733	9,755	0	611			200,000	41,344	37,305	151,109

Table 2.12: Basin Water Balance Results Summary

		Gains				Losses										
		Gaged Inflows	Ungaged Inflows	Return Flows (Municipal, Industrial)	Import[1]	Agricultural Consumptive Use	Municipal Diversions	Industrial Diversions	Reservoir Evaporative Losses	Federal Canal Diversion Out-of-State Delivery[2]	Export	Total Gains	Total Losses	Average Reservoir Storage	Depleted Flows Leaving Wyoming[3]	State Line Outflow-Natural Conditions[4]
North Platte	Dry	410,000	1,070,000	68,873	9,142	501,335	10,480	68,209	201,000	730,000	0	1,560,000	1,524,323	1,988,000	260,000	1,700,000
	Average	830,000	2,060,000	65,930	10,089	490,036	9,998	65,554	214,000	660,000	0	2,970,000	1,444,147	2,161,000	420,000	1,790,000
	Wet	1,415,000	3,760,000	64,284	9,895	571,271	9,425	63,567	220,000	610,000	0	5,250,000	1,488,076	2,480,000	1,530,000	2,940,000
South Platte	Average	4,000	40,000	9,344	8,314	37,592	9,755	0	611		0	62,000	38,203	22,000	16,000	0
Platte River Basin	Average	830,000	2,100,000	75,000	10,089	530,000	20,000	66,000	215,000	660,000	0	3,030,000	1,480,000	2,180,000	420,000	1,790,000

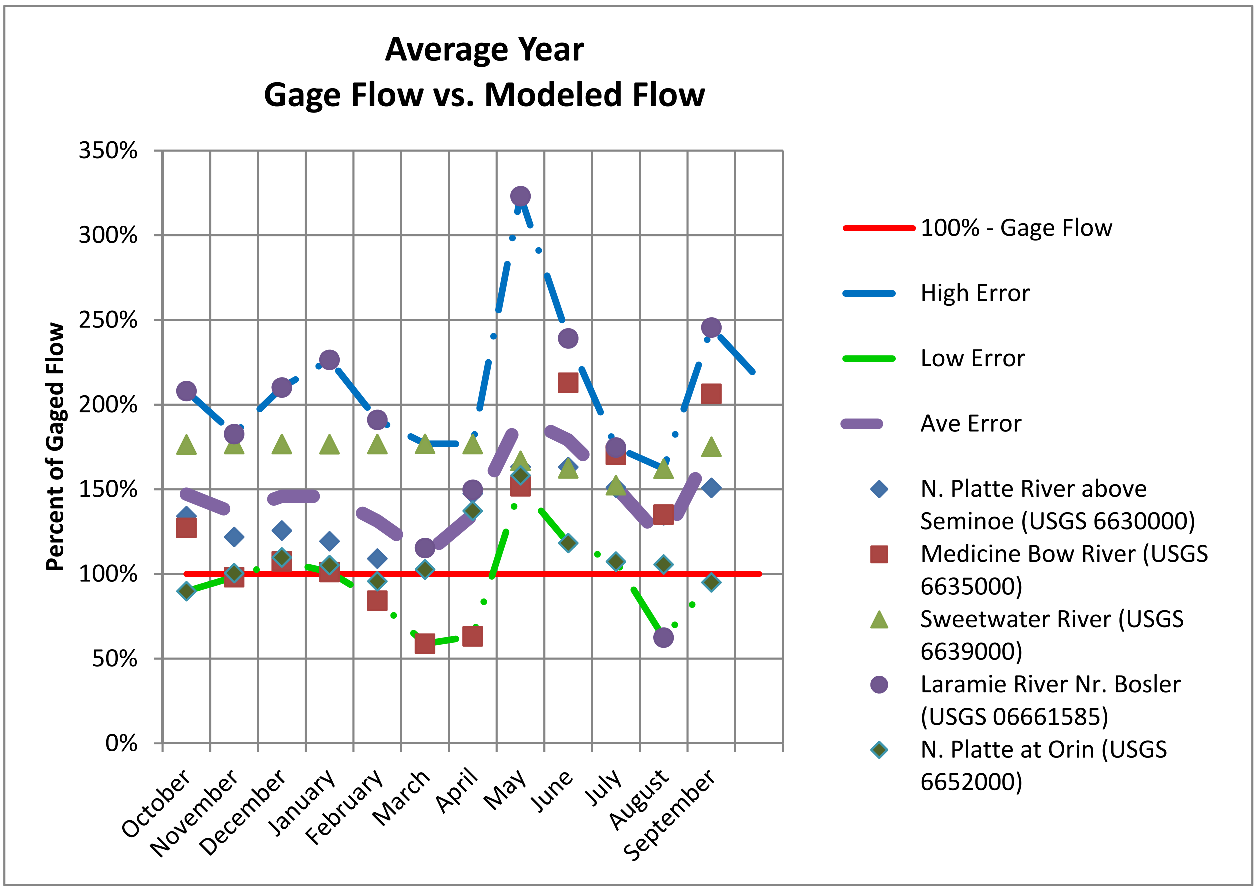
Notes:

1. For North Platte, quantity is water imports by City of Cheyenne from Little Snake River Basin. For South Platte, quantity is water imported to South Platte from North Platte Basin. For Platte River Basin, quantity is the Little Snake River Basin import.
2. Water diverted from the North Platte in Wyoming and delivered to Nebraska for use by out-of-state Federal contractors.
3. Outflows based on 1973-2013 period of record at USGS State Line Gage.
4. Estimate based on depleted outflow plus depletions in Wyoming.

2.7.1 Comparison of Modeled Flow to Gage Data

A comparison was developed to graphical compare stream flow calculated within the model to the actual flow realized at several gages. Modeled flow was calculated in the spreadsheet models. At locations in the model where a node represented an actual gage with sufficient data for the period of record selected for the study, the modeled flow was compared to the gaged flow. The modeled flow was calculated as a percentage of the gaged flow at each of the representative gaged nodes for each month of an average year condition. For example, a modeled flow of 150% means that the modeled flow at a gaged node is 50% higher than the gage flow at that node. Each modeled flow percentage was plotted to the corresponding month, so that each month had five modeled flow percentages plotted. The 100% line on the chart represents the gage flow. The "High Error" line in the chart plots a line between the highest flow percentages of all the data points. The "Low Error" line plots the lowest percentage of compared flow. The "Ave Error" line plots the average of all the data points within the chart.

Figure 2.8 Average Year Gage Flow vs. Modeled Flow comparison.



The largest differences between modeled flow and gaged records are major ungaged tributaries dominated by plains and high deserts regions; i.e., Sweetwater, Medicine Bow, South Platte, Horse Creek and Laramie River drainages. The overall trend throughout is that modelled flows primarily exceed the gaged flows with exceedance over 300% measured in the Laramie River drainage. On an average error basis, the errors are approximately 150% of gaged flow and the error excursions vary on a monthly basis with the smallest errors occurring in March and the largest exceedances in May, June, and September which correlate to the higher monthly flow periods.

Two USGS reports performing flood frequency analysis in Wyoming according to regression methods concluded a number of causes of errors within the statistical analysis of the data. The overriding concern was the lack of available gage records within the plains and high desert regions. The most recent peak-flow analysis study in Wyoming completed in 2003 (WRIR 03-4107), cited that flows within these regions are impacted by intense localized convective rainstorms. The intense rainstorms that occur in the eastern portion of the state receive moisture from summer monsoonal flow from the Gulf of Mexico or from east-moving storms. The distribution and occurrence of the events vary considerably from year-to-year having a significant and variable impact on actual flows measured at gaging stations. Particularly when the period of record is short, the large runoff events have a substantial affect on the statistical regression analysis of the available flow records. The large dispersions of the flow record data are reflected in the magnitude of standard errors associated with the regression analysis. The standard error is a measure of how much the existing flow data varied from the predicted flow calculated from the derived regression equation. Another significant problem is that the few gages that are available within these regions are typically operated on a seasonal basis.

The standard errors and predictive estimate intervals reported within the USGS studies portray the high uncertainty of the derived regression equations. The average standard error cited within the USGS Lowham report (WRIR 88-4045) for the plains and high desert regression equation was 96% for mean annual flow estimates. A lower average standard error of 57% was reported for the mountainous region regression equation. In specific instances, the standard errors in the more recent 2003 USGS report increased in comparison to the 1988 report. The standard error for the flow regression equation derived for peak flows with a 1.5 year return period was 122% for the eastern basins and plains region which encompasses much of the major tributary drainages within the Platte River Basin. This high standard error quantity indicates that actual peak flow records can have high errors that exceed flows by 2.2 times as calculated with the regression equation based on the significant dispersions of the analyzed regression data. Conversely, when the standard errors exceed 100% the actual records can drop to zero so no flows are generated within the subbasin based on the significant low error dispersions of analyzed regression data. The error analysis of modeled flow versus gaged flow demonstrates that the regression derived flows typically over predict actual flows so actual data is associated with low errors. The level of low errors indicate that much of the plains and high desert subbasins may not yield any actual flows that reach a defined drainage that would be measurable with a gage. Both reports relied on the more extensive network of gaging stations existing in many of the mountainous areas of the State but there were large data gaps in much of the State because of the lack of gages within plains and high desert basin regions throughout Wyoming.

2.8 SUMMARY

As described in the previous section, for the results of the spreadsheet model and individual reaches within, it was difficult to correlate modeled results with available gage data. When comparing modeled flow in many of the reaches to gage flow, the modeled flow often differed from the gage data considerably. Throughout the entire basin, complete records of gage data were very scarce, particularly within the plains and high desert regions. The compilation of all gage data developed in the previous master plan produced a large number of gages. However, many of the gages identified did not contain significant amounts of data, if any, pertaining to the study years. To further compound this problem, gage data that did coincide with the study period years was largely in the form of seasonal data, not representing an entire year of record. This likely produced inaccuracies with data filling and estimations of data during non-irrigation seasons for many of the gages. **Of the gages representing an entire period of record, very few were located on tributaries where needed to determine the amount of stream flow contributing to the basin. Most of the gages with complete records were located downstream of reservoirs, making is difficult to estimate virgin flows entering the system.**

With the lack of gage data, much of the basin inflow was calculated using regression flood frequency prediction equations. As described previously the regression method relied upon for ungaged flow estimates had a 57% average standard error in the mountainous regions and as much as a 96% average standard error in the high plains regions (WRIR 88-4045). For comparison between gaged data and modeled data in the previous section of the report, the flow estimates in arid ungaged regions exceeded gaged flows by approximately 150% percent on average with excursions up to 300%. Given the large amount of data that were generated with these equations, it is possible that flow estimations could produce large errors in data for the model.

Another likely problem with the data is the manner in which consumptive use for agriculture was determined. The consumptive use data for irrigated lands was provided for each of the subbasins to reflect the Wyoming's Depletion Plan. It is unsure that the depletion numbers used to calculate the consumptive use reflect actual consumptive use values within the basin and the timing of return flows from irrigation was not considered.

In addition, much of the precipitation falling on specific watersheds may be evaporated or transpired, or being lost to infiltration, and may never show as surface water flow. These undetermined losses likely result in modeled overestimates of runoff from most of the ungaged watersheds.

Because of these issues, the accuracy of the models developed for this update was very questionable.

The following research and monitoring studies may address some of the deficiencies in the data and modeling discussed above:

1) Collect precipitation, weather and streamflow data on specific watersheds within the subbasins where the modeling results did not correlate well with the gage data.

2) Expand the gage network in subbasins where the modeling results did not correlate well with the gage data.

3) Collect temporary gage data in watersheds where the modeling results did not correlate well with the gage data. This may be necessary if impoundments (large or small) or wetland enhancements are being contemplated.

4) Utilize actual consumptive use values for agricultural depletions and address the timing of return flows.

"Clean water and access to food are some of the simplest things that we take for granted each and every day."

- Marcus Samuelsson

2.9 REFERENCES

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