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MEMORANDUM

To: Ron McLaughlin

From: John Faux

Date: March 20, 2012

Re: Revised Estimate of Runoff on Trout Creek

The proposed Trout Creek Reservoir (aka Energy Fuels Reservoir No. 2) was granted a conditional decree in Case No. W-1256-77. This reservoir is planned for construction on Trout Creek just upstream of its confluence with Fish Creek and about four miles upstream of the Yampa River. The Trout Creek watershed and the watershed above Trout Creek Reservoir are shown in Figure 1.

Flows on Trout Creek were estimated as part of the Yampa River Basin Water Resources Planning Model built using the StateMod program as part of the Colorado Decision Support Systems. This estimate of flows on Trout Creek was evaluated by TZA Water Engineers in June 2010 and a first approximation of expected Trout Creek flows available to Trout Creek Reservoir was made at that time. This memorandum presents a refinement of our earlier estimate of Trout Creek flows.

Correlation to Estimate Trout Creek Virgin Flows

StateMod uses the "neighboring gage" approach for estimating runoff at ungaged watersheds. For estimating virgin flow on Trout Creek, StateMod used the USGS gage Elk River at Clark (# 9241000) as the reference gage and the factor of 0.307 to convert from Elk River flow to Trout Creek flow. The ratio of 0.307 was determined based on area times precipitation (A * P). That is, the Yampa River Basin Model used 0.307 as the correlation factor based on the following.

	Area	Precip	A * P	$\frac{(A*P)_{Trout}}{(A*P)_{Elk}}$
Elk River at Clark	213	38.4	8164	
Trout Creek	102	24.5	2506	0.307

While the neighboring gage approach is often the best approach for estimating streamflow in ungaged watersheds, it is important to use the best available correlation factor. A correlation factor based on area and precipitation alone ignores the fact that percent runoff varies with depth of precipitation. That is, as precipitation increases, the percent of that precipitation that runs off increases.

The Elk River at Clark watershed receives far more precipitation than does the Trout Creek watershed, thus the percent runoff from the Trout Creek watershed can be expected to be less than the Elk River watershed and the correlation factor should reflect this difference.

Figure 2 illustrates the 14 USGS gaging stations in the vicinity of Trout Creek. Table 1 summarizes information about these watersheds, including mean annual precipitation which was developed from the Oregon State University PRISM Climate Group mapping of annual precipitation, shown in Figure 3. By comparison of precipitation to discharge, percent runoff is calculated, which is shown in the right-most column of Table 1. As can be seen, Elk River at Clark experiences 54% runoff, whereas Fish Creek near Milner, for example, experiences only 19% runoff.

Figure 4 provides a correlation of percent runoff as a function of mean annual precipitation for the 14 watersheds in the vicinity of Trout Creek Reservoir. Using this correlation and the mean annual precipitation for the watershed above Trout Creek Reservoir, a percent runoff of 18.1% is estimated for the Trout Creek Reservoir watershed. This is shown in Table 2, column e. The next step, shown in column f, is to combine the percent runoff information with the area and precipitation information. Table 2, column f shows the flow expected at Trout Creek at Trout Creek Reservoir to be 10.6% of the flow of Elk River at Clark.

Table 2 also provides a row for the other watershed modeled in StateMod that could affect operation of Trout Creek Reservoir, that is, Fish Creek plus Trout Creek below Fish Creek. The estimation procedure is similar to that discussed for Trout Creek at Trout Creek Reservoir. Because there are water rights on Trout Creek downstream of Fish Creek, the flow contribution from Fish Creek could affect the ability to store water in Trout Creek Reservoir.

Figure 5 provides another correlation of USGS gage data, in this case mean annual discharge depth as a function of mean annual precipitation. Again, a good correlation is found and the depth of runoff at Trout Creek Reservoir can be estimated to be 0.388 AF/acre/year (shown in column g of Table 2). Compared to Elk River with an average depth of runoff of 1.72 AF/acre/year, the flow at Trout Creek Reservoir can be expected to be 10.9% of the Elk River flow (column h of Table 2).

Figure 6 provides another correlation with good fit, in this case percent runoff as a function of mean annual discharge depth. By using the estimated depth of discharge of 0.388 AF/acre for the Trout Creek Reservoir watershed (column g of Table 2), the percent runoff can be estimated to be 17.4% (column I of Table 2). Incorporating the area and precipitation ratios, the flow at Trout Creek Reservoir can be expected to be 10.2% of the flow at Elk River (column j of Table 2).

Finally, the three estimates of the ratio of flow at Trout Creek Reservoir versus flow at Elk River at Clark were averaged to arrive at an expected ratio of 10.5%. Similar calculations performed for the other watershed leads to the expectation that Fish Creek plus Trout Creek below Fish Creek discharges 5.9% of Elk River at Clark. The goodness-of-fit on the three correlations and the close agreement between the three methods for comparing Elk River to Trout Creek provides reason for confidence in these results.

Table 1 - USGS Gaged Watersheds in Vicinity of Proposed Trout Creek Reservoir

		Drainage Area	Gage Elevation	Mean Basin Elevation	Mean Annual Precipitation	Period of Record	Years of Data	Mean Annual Discharge	Mean Annual Discharge	Percent Runoff
		sq mi	feet	feet	inches			ac-ft	ac-ft/ac	
9237450	Yampa R ab Stagecoach Res	208	7235	9,000	28.5	1989-2010	22	49,932	0.38	16%
9237800	Service Cr nr Oak Creek CO	38.2	7000	9,302	36.3	1966-1973	8	32,763	1.34	44%
9238900	Fish Cr nr Steamboat Spr CO	25.8	7150	9,716	50.5	1967-2010	35	46,910	2.84	68%
9241000	Elk R at Clark CO	216	7268	9,104	38.3	1911-2003	74	237,759	1.72	54%
9243700	Middle Cr nr Oak Creek CO	23.5	6720	7,669	21.3	1976-2001	26	3,057	0.20	11%
9243800	Foidel Cr nr Oak Creek CO	8.61	6880	7,387	21.4	1976-2001	25	1,229	0.22	13%
9243900	Foidel Cr at mouth	17.5	6730	7,206	20.8	1976-2001	26	2,390	0.21	12%
9244100	Fish Cr nr Milner CO	34.5	6912	8,296	25.8	1956-1973	18	9,239	0.42	19%
9244300	Grassy Cr nr Mount Harris CO	25.8	6580	7,144	21.2	1959-1966	8	1,040	0.06	4%
9244500	Elkhead Cr nr Clark CO	45.4	7800	8,606	31.8	1943-1973	17	24,548	0.84	32%
9245000	Elkhead Cr nr Elkhead CO	64.2	6845	8,413	30.9	1953-1996	44	39,881	0.97	38%
9245500	NF Elkhead Cr nr Elkhead CO	21	7005	8,461	32.4	1959-1973	15	12,514	0.93	34%
9248600	EF Williams ab Willow Cr	108	7100	9,464	35.4	1957-1972	16	77,846	1.13	38%
9249000	EF Williams Fk nr Pagoda CO	150	6830	9,063	33.2	1954-1971	18	81,570	0.85	31%
	Trout Creek at Trout Cr Res	104		7,790	25.1					
	Trout Creek at mouth	198		8,088	23.9					

Table 2 – Evaluation of Flow Correlation for Ungaged Watersheds

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)
	Area	Mean Precip Depth	Precip Volume	Percent Runoff	Flow Comparison to Elk River	Mean Annual Discharge Depth	Flow Comparison to Elk River	Percent Runoff	Flow Comparison to Elk River	Average of Three Flow Comparisons
	sqmi	inch				AF/ac				
	A	P	$A*P$	$\%RO$	$\frac{(A*P*\%RO)_i}{(A*P*\%RO)_{ELK}}$	$P*\%RO$	$\frac{(A*P*\%RO)_i}{(A*P*\%RO)_{ELK}}$	$\%RO$	$\frac{(A*P*\%RO)_i}{(A*P*\%RO)_{ELK}}$	$\frac{(A*P*\%RO)_i}{(A*P*\%RO)_{ELK}}$
Elk R at Clark	216	38.3	8273	53.9%		1.72		53.9%		
Trout Cr at Trout Cr Res	104	25.1	2610	18.1%[1]	10.6%	0.388[2]	10.9%	17.4%[3]	10.2%	10.5%
Fish Cr & Trout Cr below Fish Cr	94	22.6	2122	12.8%[4]	6.1%	0.232[5]	5.9%	11.9%[6]	5.6%	5.9%

[1] From correlation, see Figure 4
[2] From correlation, see Figure 5
[3] From correlation, see Figure 6
[4] From correlation, see Figure 4
[5] From correlation, see Figure 5
[6] From correlation, see Figure 6

Figure 4 - USGS Gages Near Proposed Trout Creek Reservoir

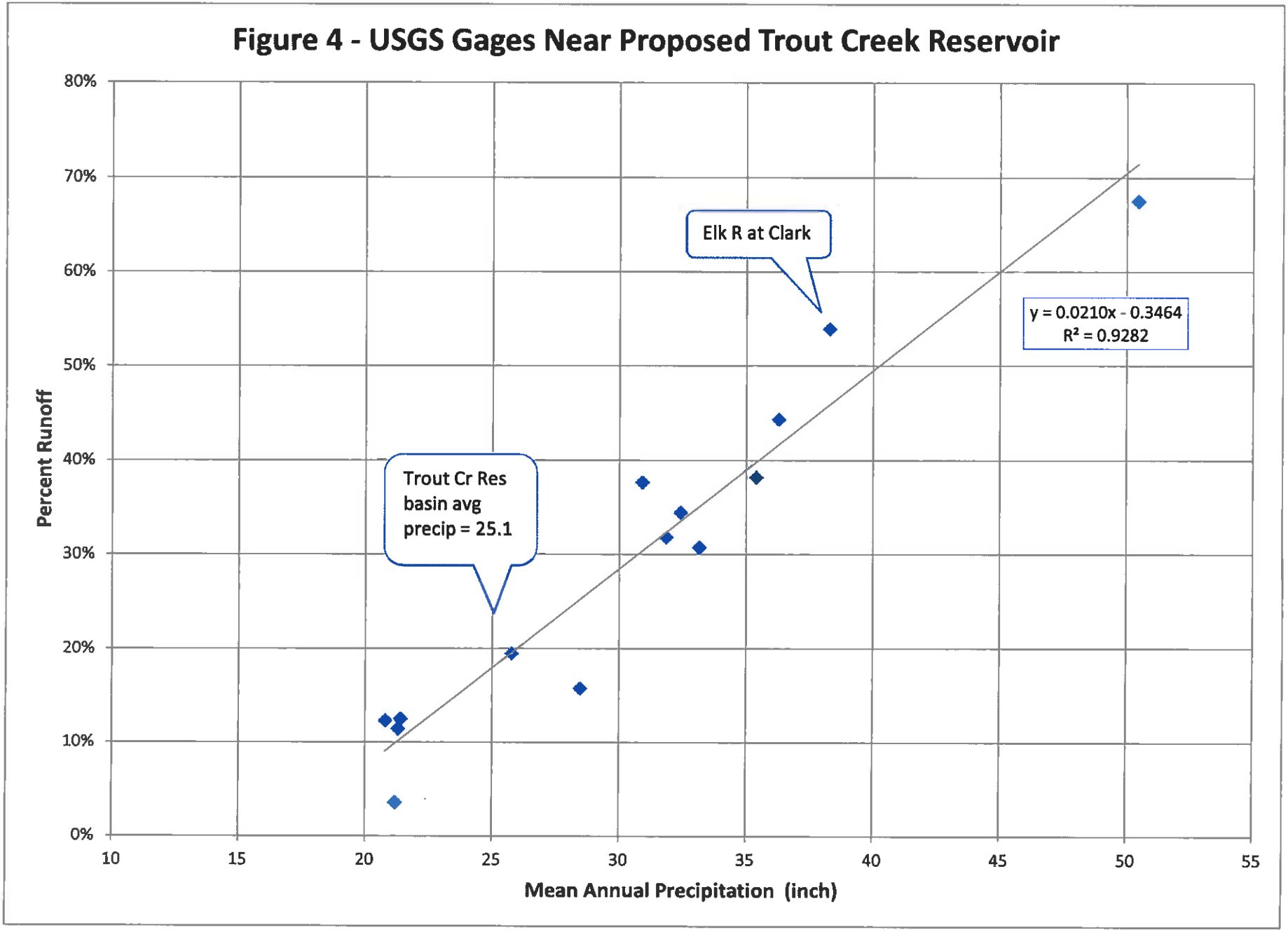


Figure 5 - USGS Gages Near Proposed Trout Creek Reservoir

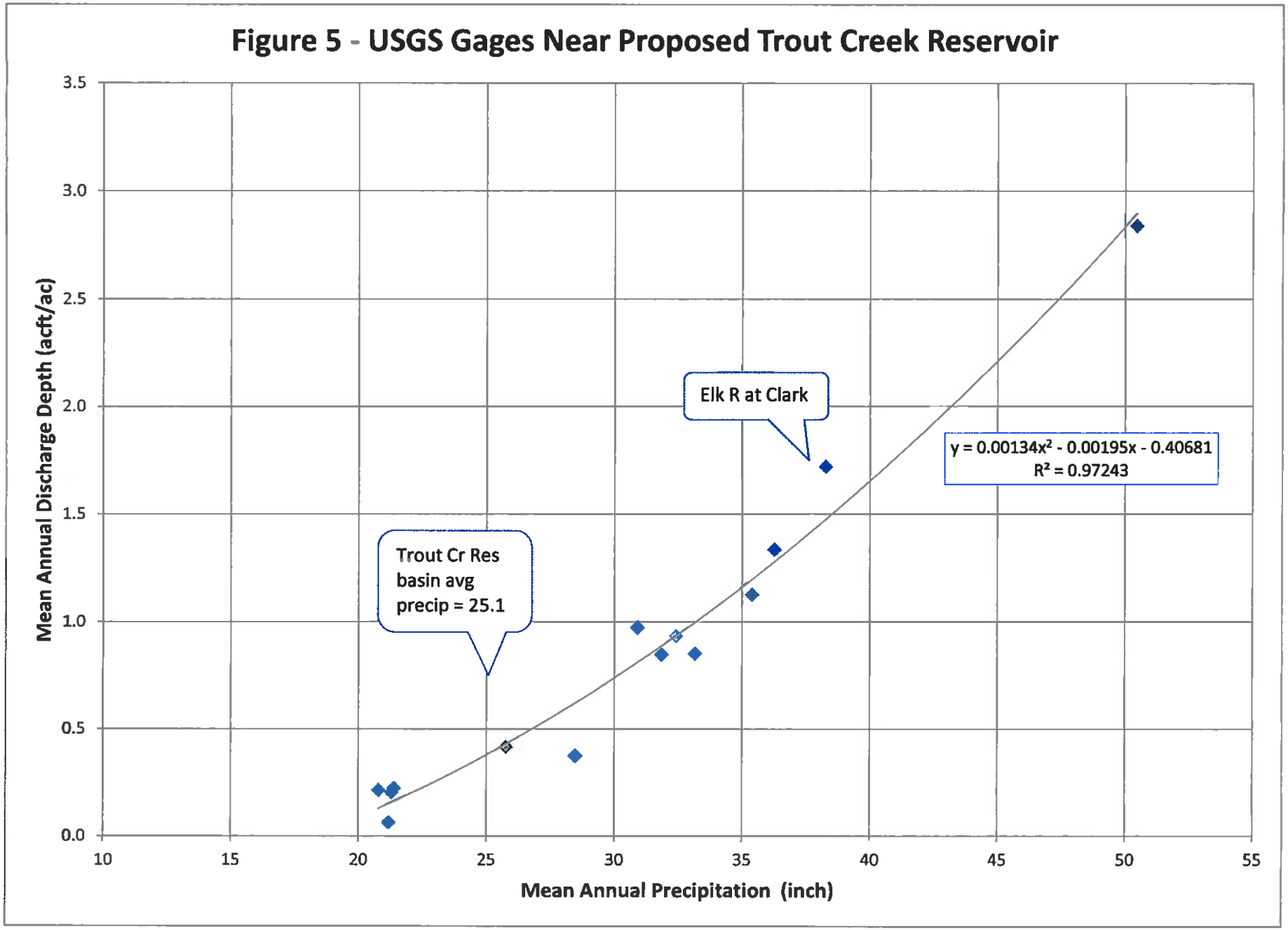
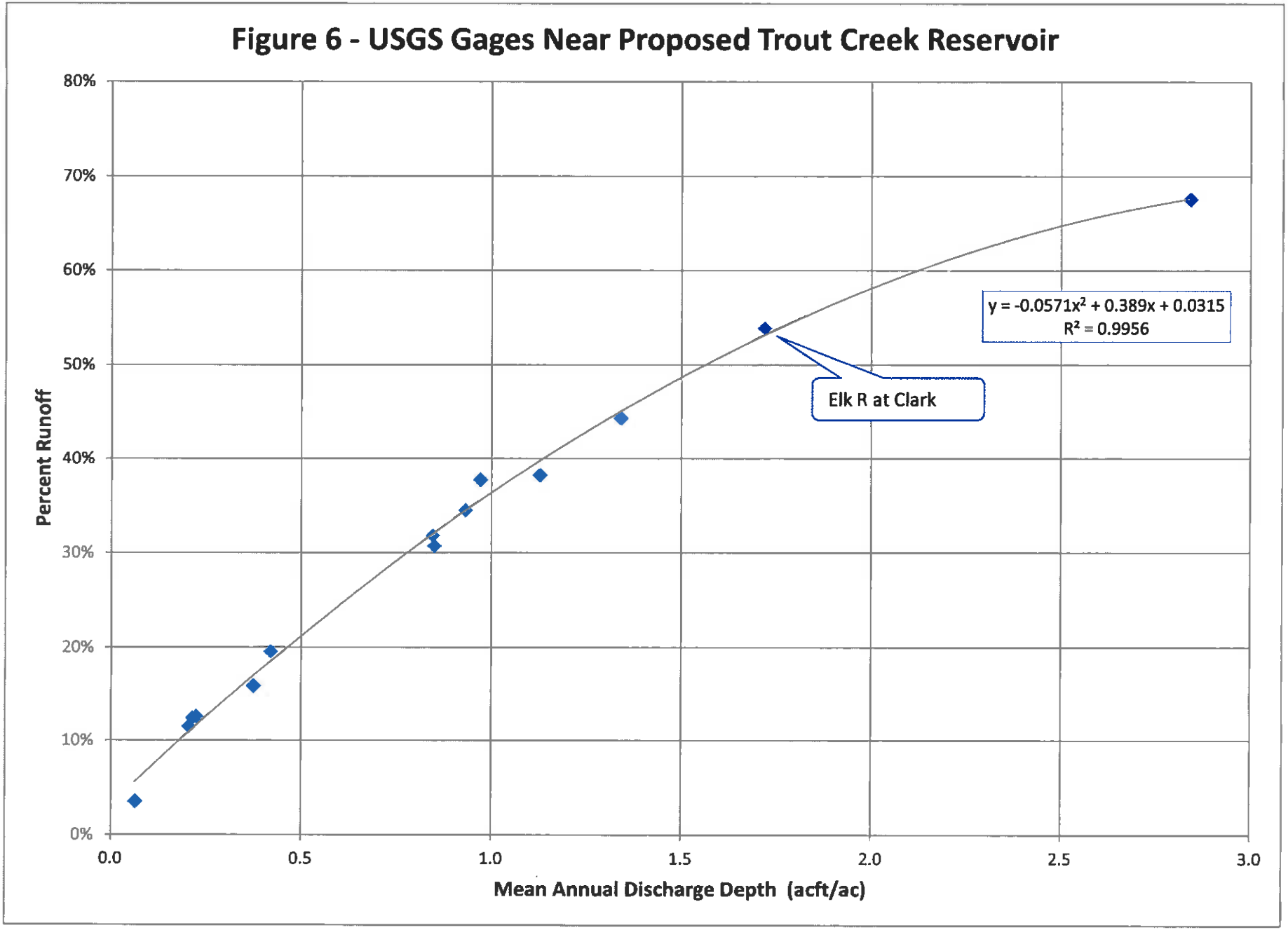
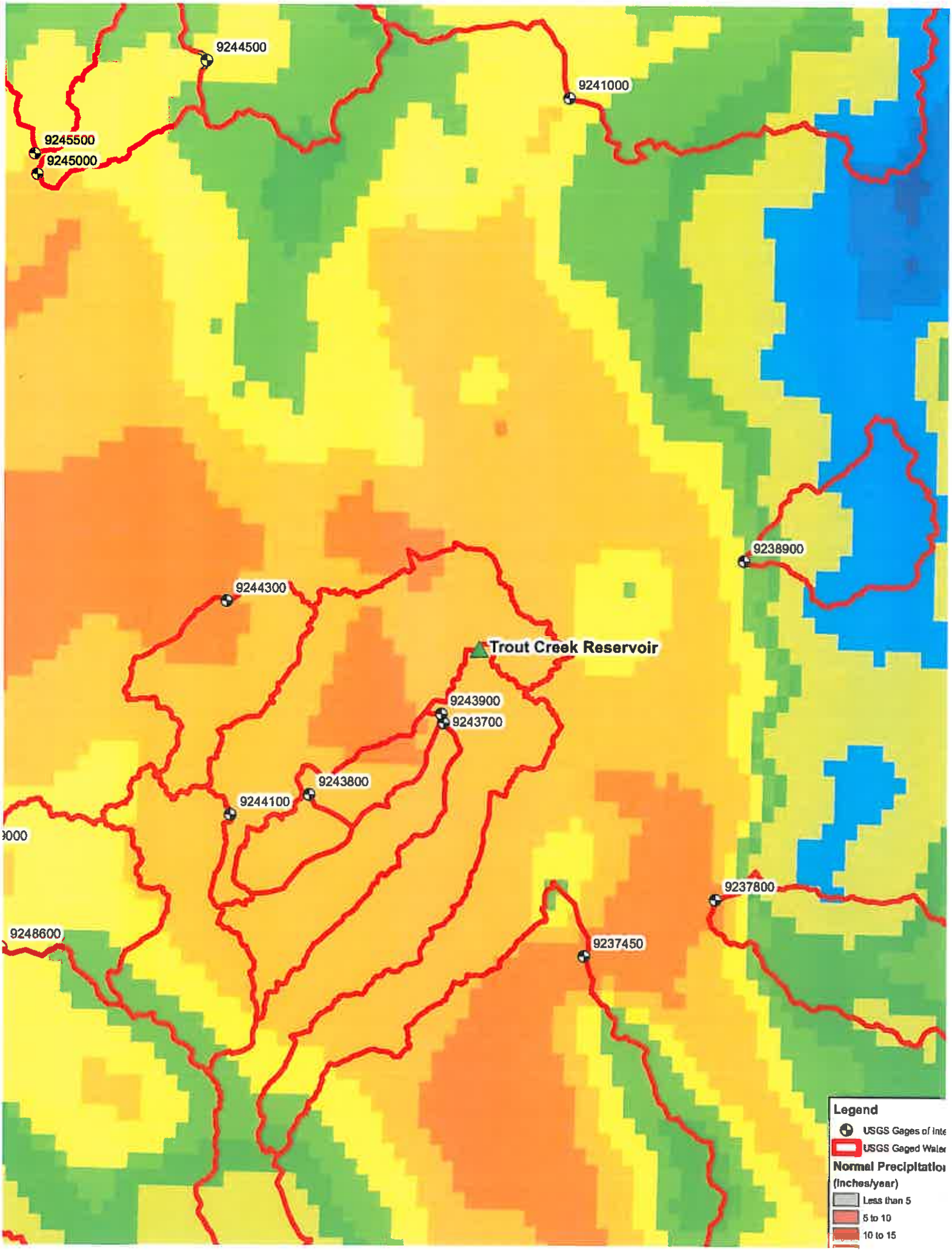


Figure 6 - USGS Gages Near Proposed Trout Creek Reservoir

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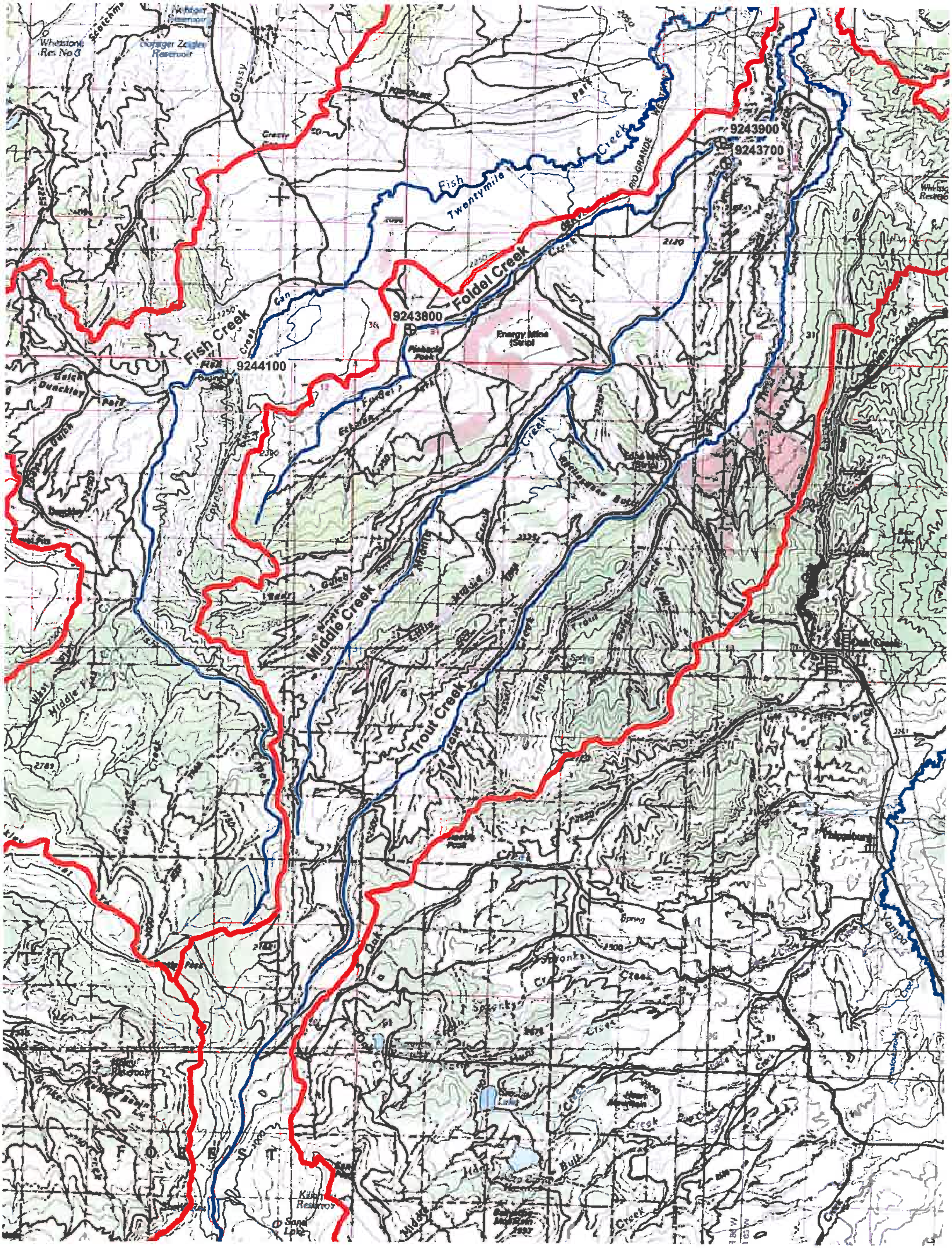

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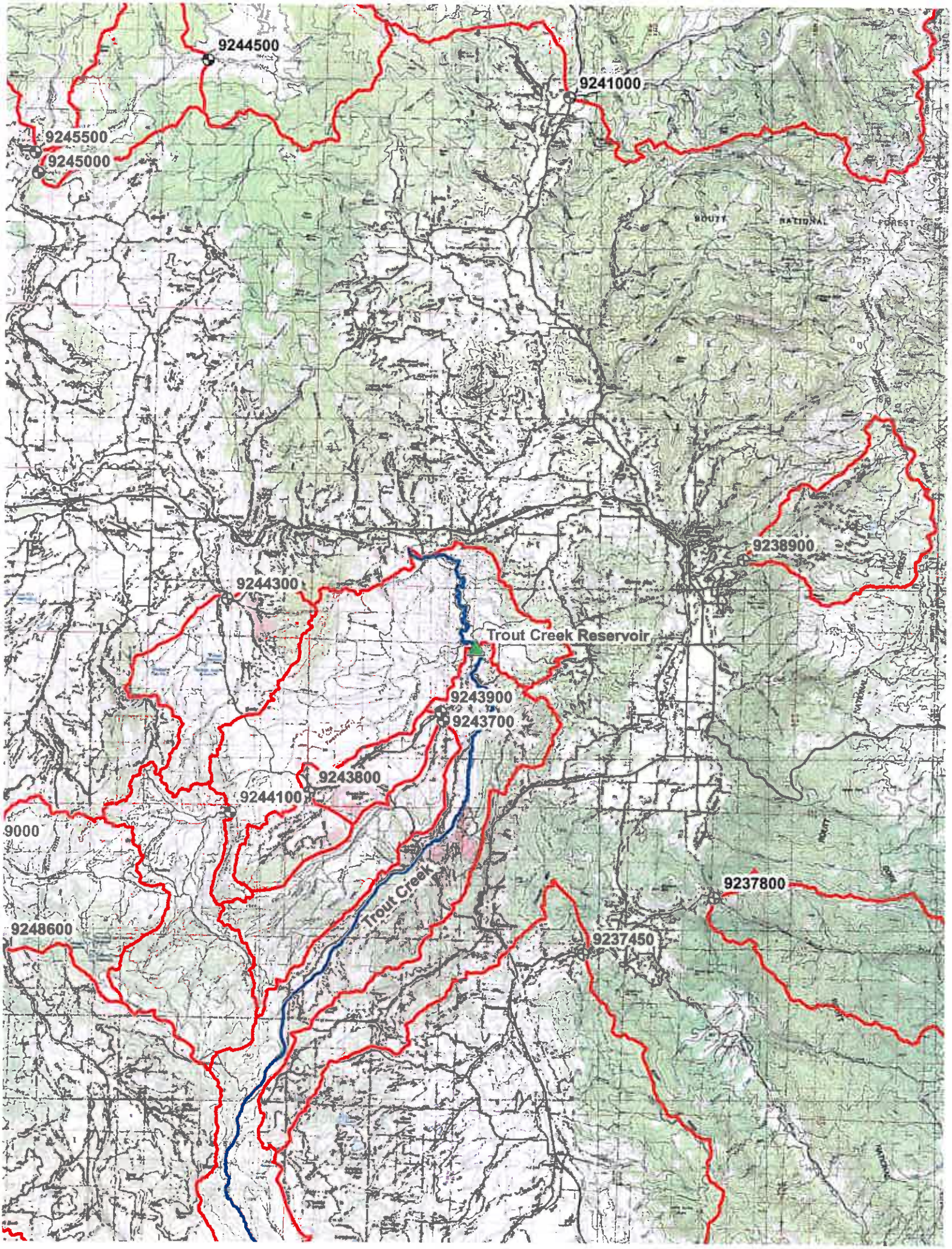
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