APPENDIX B: Historic water-quality data.

Historic water-quality data is provided, for 1965 and 1966. Additional data is available upon request, in hard-copy format.

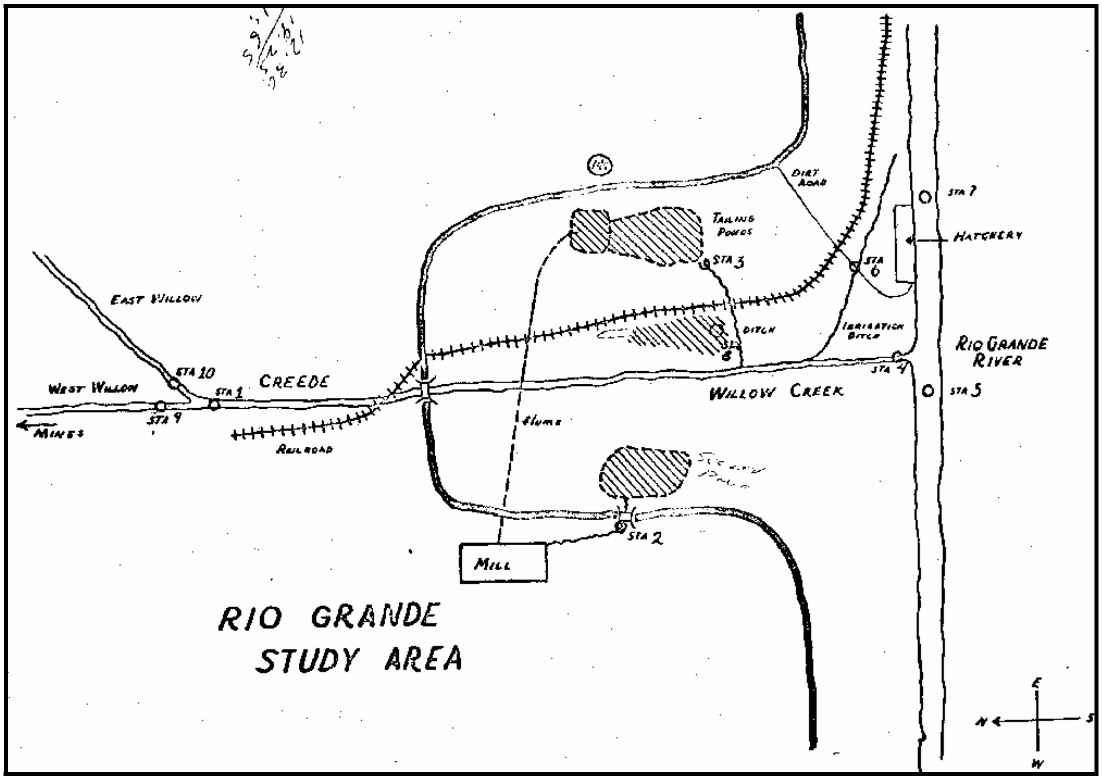

Figure B-1: Sampling location sketch, Tables A-?? through A-??.

Table B-1: Historic water-quality sampling, 7/7/1965. nd: not detected; blank: unavailable.

	Site ID										
	1	2	3	4	5	6	7	8	9	10	11
Temperature (F)	52		62				54	58	53	52	52
Dissolved Solids (mg/l)	52		2204	64	48	52	60	4312	72	44	140
pH	7.4		5.4	7.6	7.5	7.2	7.6	3.9	7.2	7.4	7.3
Alkalinity, M.O. (mg/l)	20		6	20	20	20	24	0	20	18	23
Chloride (mg/l)	0.5		17.5	0.5	0.5	0.5	0.5	8.5	0.5	0.5	0.5
Calcium (mg/l)	9.8		0	12	8.2	9.8	12.8	0	14.7	7	12
Copper (mg/l)	nd		3.15	nd	nd	nd	nd	78	nd	nd	nd
Free Cyanide (mg/l)			0.8					0.1			
Iron (mg/l)	0.08		0.19	0.1	0.13	0.1	0.12	0.07	0.12	0.08	0.11
Lead (mg/l)	0.05		3.2	nd	nd	nd	nd	2.1	nd	nd	nd
Magnesium (mg/l)	1.1		0.2	1.8	1.5	1.2	1.8	0.2	1.7	1.0	1.6
Manganese (mg/l)	0.15		28	0.52	0.04	0.9	0.32	56	0.3	0.04	0.04
Potassium (mg/l)	1		41.5	1	1	1	1	32	1	1	1
Sodium (mg/l)	3.1		27.2	2.7	2.6	2.7	3.5	20.7	3.5	2.1	2.6
Sulfate (mg/l)	6		1500	9	4	12	8	3000	17	2	7
Zinc (mg/l)	0.5			1.3	0.04	1.7	0.8	1.2	1.1	0.22	0.16

Table B-2: Historic water-quality sampling, 8/2/1965. nd: not detected; blank: unavailable.

	Site ID										
	1	2	3	4	5	6	7	8	9	10	11
Temperature (F)	52	68	64	56	54	64	55	60	43	53	
Dissolved Solids (mg/l)	48	272	2308	32	44	96	88	3012	92	92	
pH	7.8	9.0	5.35	6.4	6.7	6.2	6.6	4.0	7.65	7.7	
Alkalinity, M.O. (mg/l)	19	45	3	21	22	15	18	0	22	17	
Chloride (mg/l)	0.5	4.5	10	0.5	0.5	0.5	0.5	10	0.5	0.5	
Calcium (mg/l)						nd					
Copper (mg/l)	nd	nd	1.02	nd	nd	nd	nd	0.85	nd	nd	
Free Cyanide (mg/l)		0.55									
Iron (mg/l)	0.29	0.20	0.23	0.26	0.27	0.40	0.23	0.08	0.23	0.28	
Lead (mg/l)	0.09	0.05	3.6	0.29	0.12	nd	0.12	2.05	nd	nd	
Magnesium (mg/l)	1.8	2.3	17.5	21	2.1	1.9	2.2	nd	26	1.8	
Manganese (mg/l)	nd	0.4	42	0.46	nd	0.26	0.66	220	nd	nd	
Potassium (mg/l)											
Sodium (mg/l)	2.0	4.0	33.0	2.0	2.6	0.7	3.2	26.0	3.2	0.7	
Sulfate (mg/l)	11	180	1500	18	5	20	18	2000	17	8	
Zinc (mg/l)	0.34	0.34	415	1.12	0.05	0.57	1.23	385	0.56	0.15	

Table B-3: Historic water-quality sampling, 9/8/1965. nd: not detected; blank: unavailable.

	Site ID										
	1	2	3	4	5	6	7	8	9	10	11
Temperature (F)	52	68	64	62	59		59	61	52	51	
Dissolved Solids (mg/l)	76	268	2584	92	92		76	3308	108	56	
pH	7.1	6.9	5.2	5.9	6.2		6.45	4.2	7	7.25	
Alkalinity, M.O. (mg/l)	6	5	1	5	6		6	0	7	5	
Chloride (mg/l)	1	1	14.5	1	1		1	9.5	0.5	1	
Calcium (mg/l)	15.5	66.5	98	18.5	20		15.5	200	23.5	10	
Copper (mg/l)	nd	nd	2.3	nd	nd		nd	nd	nd	nd	
Cyanide (mg/l)		0.6	1.0					0.09			
Iron (mg/l)	0.37	1.20	0.19	0.34	0.08		0.22	0.10	0.10	0.04	
Lead (mg/l)	0.35	0.31	3.3	nd	nd		nd	1.75	0.15	0.26	
Magnesium (mg/l)	0.35	0.5	45	0.42	0.45		0.5	82	0.51	0.24	
Manganese (mg/l)	0.35	0.5	45	0.42	0.45		0.5	82	0.51	0.24	
Potassium (mg/l)	nd	1.2	35	nd	nd		nd	13.2	nd	nd	
Sodium (mg/l)	2.4	6.1	36.8	3.1	3.5		2.4	26.6	5.4	1.0	
Sulfate (mg/l)	13	300	1000	30	28		9	1500	38	3	
Zinc (mg/l)	0.74	3.6	400	2.1	1.55		0.55	400	1.9	0.25	

Table B-4: Historic water-quality sampling, 10/15/1965. nd: not detected; blank: unavailable.

	Site ID										
	1	2	3	4	5	6	7	8	9	10	11
Temperature (F)	39	67	43	43	42		42	54	42	37	
Dissolved Solids (mg/l)	84	356	320	104	84		84	4108	108	84	
pH	6.4	6.2	4	6.8	7.1		7.1	3.9	6.2	6.1	
Alkalinity, M.O. (mg/l)	1.2	1.4	0.8	1.2	1.2		1.4	0.8	1	0.8	
Chloride (mg/l)	3.49	0.49	14.49	4.99	9.99		6.99	8.99	0.49	4.99	
Calcium (mg/l)	15.5	92.5	100	18.5	13.5		16.5	210	24.5	14	
Copper (mg/l)	0.06	0.06	0.06	0.09	0.09		0.03	1.39	0.05	0.06	
Free Cyanide (mg/l)											
Iron (mg/l)	0.08	6.00	0.19	0.06	0.19		0.14	0.08	0.11	0.05	
Lead (mg/l)	nd	1.4	2.3	nd	nd		nd	2.18	nd	nd	
Magnesium (mg/l)	0.42	0.55	4.9	0.59	0.59		0.59	170.2	0.65	0.54	
Manganese (mg/l)	0.14	0.55	58	1.25	nd		0.35	1000	0.48	nd	
Potassium (mg/l)	0.5	1.8	36	nd	nd		nd	15.7	0.5	0.5	
Sodium (mg/l)	1.1	2.0	35.0	nd	nd		nd	33.0	4.1	nd	
Sulfate (mg/l)	11	200	1400	23	4		9	2100	32	4	
Zinc (mg/l)	1	2.2	15	3	0.1		0.8	15	1.7	1.4	

Table B-5: Historic water-quality sampling, 12/7/1965. nd: not detected; blank: unavailable.

	Site ID										
	1	2	3	4	5	6	7	8	9	10	11
Temperature (F)	33		frozen	3	33		33	frozen	34	32	
Dissolved Solids (mg/l)	88	1580		112	80		92		128	64	
pH	7.2	10.2		7.1	7.4		7.2		7.4	8.2	
Alkalinity, M.O. (mg/l)	7	17		6	8		8		7	6	
Chloride (mg/l)	10.5	12.5		1	1		1		0.5	1	
Calcium (mg/l)	17	296		22	18		23		25	14	
Copper (mg/l)	nd	1.3		nd	nd		nd		nd	nd	
Free Cyanide (mg/l)											
Iron (mg/l)	0.09	95.0		0.09	0.15		0.10		0.11	0.09	
Lead (mg/l)	nd	nd		nd	nd		nd		nd	nd	
Magnesium (mg/l)	4.5	1.6		6	6		7		5.7	4.5	
Manganese (mg/l)	0.7	0.1		1.6	nd		0.7		0.5	nd	
Potassium (mg/l)	nd	10		nd	nd		nd		1.2	nd	
Sodium (mg/l)	6.3	15.8		5.3	5.3		5.3		11.4	4.1	
Sulfate (mg/l)	21	750		43	5		24		48	5	
Zinc (mg/l)	1.5	nd		3.9	nd		3.9		2.8	0.36	

Table B-6: Historic water-quality sampling, 1/4/1966. nd: not detected; blank: unavailable.

	Site ID										
	1	2	3	4	5	6	7	8	9	10	11
Temperature (F)	32	40	frozen	32	32		32	frozen	32	32	
Dissolved Solids (mg/l)	116	788		148	108		128		156	84	
pH	7.3	7.5		6.5	7.4		7.4		7.4	7.6	
Alkalinity, M.O. (mg/l)	6	3		7	10		7		7	5	
Chloride (mg/l)	0.5	2.5		0.5	0.5		0.5		1	0.5	
Calcium (mg/l)	18	148		23	18		20		26	12	
Copper (mg/l)	nd	0.4		nd	nd		nd		nd	nd	
Free Cyanide (mg/l)											
Iron (mg/l)	0.03	54.0		0.04	0.13		0.08		0.03	0.03	
Lead (mg/l)	nd	nd		nd	nd		nd		nd	nd	
Magnesium (mg/l)	4.5	7.9		6.1	6.1		6.1		6	3.8	
Manganese (mg/l)	0.3	3.8		1.6	0.1		1		0.6	nd	
Potassium (mg/l)	5.5	19.5		6.7	7.9		5.5		6.7	5.5	
Sodium (mg/l)	5.8	15.2		5.8	4.2		5.8		10.9	2.1	
Sulfate (mg/l)	22	75		40	5		22		60	5	
Zinc (mg/l)	1.9	2.1		5.5	nd		2.4		3.4	0.53	

Table B-7: Historic water-quality sampling, 2/3/1966. nd: not detected; blank: unavailable.

	Site ID										
	1	2	3	4	5	6	7	8	9	10	11
Temperature (F)	33	43	frozen					frozen	33	33	
Dissolved Solids (mg/l)	132	812		176	136		148		216	104	132
pH	7.3	7.5		6.5	7.4		7.4		7.4	7.6	7.4
Alkalinity, M.O. (mg/l)	6	3		7	10		7		7	5	7
Chloride (mg/l)	1	6		2.5	0.5		0.5		5	0.5	1
Calcium (mg/l)	20.5	144		24.5	19		22		32.5	13.5	20.5
Copper (mg/l)	nd	1.1		nd	nd		nd		nd	nd	nd
Free Cyanide (mg/l)											
Iron (mg/l)	0.09	2.2		0.11	0.19		0.17		0.10	0.09	0.19
Lead (mg/l)	nd	nd		nd	nd		nd		nd	nd	nd
Magnesium (mg/l)	3.4	6.4		4.3	4.3		4.4		4.9	2.2	4.6
Manganese (mg/l)	nd	3		1.7	nd		1.3		nd	nd	16
Potassium (mg/l)	13.2	18		10.8	12		12		13.2	13.2	12
Sodium (mg/l)	6.5	18.7		5.8	3.1		3.1		15.2	2.1	3.1
Sulfate (mg/l)	25	420		48	7		18		70	5	7
Zinc (mg/l)	1.6	0.2		7.2	0.08		1.38		3.6	0.7	0.48

Table B-8: Historic water-quality sampling, 3/4/1966. nd: not detected; blank: unavailable.

	Site ID										
	1	2	3	4	5	6	7	8	9	10	11
Temperature (F)	32	44		33	33		33		32	32	
Dissolved Solids (mg/l)	96	656		128	84		104		168	20	
pH	7.2	4.2		6.5	7.2		7		7.1	7.5	
Alkalinity, M.O. (mg/l)	0	0		0	0		5		0	0	
Chloride (mg/l)	28.5	5		3	0.5		1		10	0.5	
Calcium (mg/l)	1.8	5		1.9	15		1.8		2.6	0.8	
Copper (mg/l)	nd	0.4		nd	nd		nd		nd	nd	
Free Cyanide (mg/l)											
Iron (mg/l)	0.10	72.0		0.80	0.32		0.21		0.10	0.08	
Lead (mg/l)	nd	3.75		nd	nd		nd		nd	nd	
Magnesium (mg/l)	0.3	0.5		0.42	0.42		0.43		0.43	0.2	
Manganese (mg/l)	0.1	3.3		2.5	nd		nd		0.3	nd	
Potassium (mg/l)	0.8	5		1.5	1.5		1.5		1.5	0.8	
Sodium (mg/l)	10.2	13.2		9.6	5.5		7.8		21.5	6.0	
Sulfate (mg/l)	28	950		62	5		22		72	2	
Zinc (mg/l)	1.5	1.5		5.9	0.1		1.5		2.9	0.3	

Table B-9: Historic water-quality sampling, 4/14/1966. nd: not detected; blank: unavailable.

	Site ID										
	1	2	3	4	5	6	7	8	9	10	11
Temperature (F)	48	46	54	55	52		54		44	42	
Dissolved Solids (mg/l)	68	1052	2856	112	96		88		68	80	
pH	7.4	5.0	5	6.9	7.2		7.2		7.4	7.3	
Alkalinity, M.O. (mg/l)	24	0	7	22	39		32		21	22	
Chloride (mg/l)	0.5	7.5	13.5	1	0.5		0.5		0.5	0.5	
Calcium (mg/l)	8	48	112	10	9.5		8		7	1	
Copper (mg/l)	nd	0.42	1.42	nd	nd		nd		nd	nd	
Free Cyanide (mg/l)		0.58	0.9								
Iron (mg/l)	0.26	200.0	42.0	0.20	0.38		0.28		0.15	0.42	
Lead (mg/l)	nd	nd	2.1	nd	nd		nd		nd	nd	
Magnesium (mg/l)	2.5	6.2	6	5.8	4.6		4.1		2	3.4	
Manganese (mg/l)	nd	3.3	29	1.1	nd		0.5		nd	0.19	
Potassium (mg/l)	0.8	8.5	46.2	1	1.8		1.5		0.8	1.6	
Sodium (mg/l)	4.0	13.0	42.5	6.0	5.0		5.8		4.5	6.0	
Sulfate (mg/l)	12	400	15	32	10		20		5	20	
Zinc (mg/l)	0.42	47	153	4	0.05		1.53		0.28	0.82	

Table B-10: Historic water-quality sampling, 5/3/1966. nd: not detected; blank: unavailable.

	Site ID										
	1	2	3	4	5	6	7	8	9	10	11
Temperature (F)											
Dissolved Solids (mg/l)				72	80		68	56			
pH				7.5	7.2		7.6	7.7			
Alkalinity, M.O. (mg/l)				24	24		13	16			
Chloride (mg/l)				0.5	0.5		0.5	0.5			
Calcium (mg/l)				7	8		7	7			
Copper (mg/l)				nd	nd		nd	nd			
Free Cyanide (mg/l)				nd	nd		0.02	0.04			
Iron (mg/l)				0.28	0.20		0.28	0.38			
Lead (mg/l)				nd	nd		nd	nd			
Magnesium (mg/l)				1.32	1.96		1.58	1.85			
Manganese (mg/l)				0.4	nd		0.18	0.08			
Potassium (mg/l)				0.5	0.5		0.5	0.8			
Sodium (mg/l)				2.3	4.5		2.3	4.0			
Sulfate (mg/l)				5	150		11	8			
Zinc (mg/l)				1.95	0.05		1.18	0.8			

Table B-11: Historic water-quality sampling, 5/10/1966. nd: not detected; blank: unavailable.

	Site ID										
	1	2	3	4	5	6	7	8	9	10	11
Temperature (F)											
Dissolved Solids (mg/l)	48	692	2456	56	112	52	84	2652	48	60	
pH	7.3	4.7	5.5	6.6	7	6.9	7	3.2	6.5	6.7	
Alkalinity, M.O. (mg/l)	37	14	6	22	32	21	31	0	21	23	
Chloride (mg/l)	0.5	0.5	13	0.5	0.5	0.5	0.5	0.5	0.5	0.5	
Calcium (mg/l)	11	56	92	10	9.7	9.8	10.2	166	8	10.2	
Copper (mg/l)	nd	0.44	2.22	nd	nd	nd	nd	0.49	nd	nd	
Free Cyanide (mg/l)											
Iron (mg/l)	0.42	86.0	0.22	0.20	0.30	0.20	0.34	0.22	0.22	0.32	
Lead (mg/l)	nd	nd	1.7	nd	nd	nd	nd	1.5	nd	nd	
Magnesium (mg/l)	1.06	1	14.7	1.12	1.42	1.16	1.33	63	0.76	1.3	
Manganese (mg/l)	nd	3.2	24	0.6	nd	4.6	nd	210	nd	nd	
Potassium (mg/l)	1.8	5.2	1.2	1.2	1.8	1.2	1.2	13	1.2	1.2	
Sodium (mg/l)	3.0	8.0	0.8	3.0	2.5	2.5	2.5	26.5	2.0	3.0	
Sulfate (mg/l)	8	500	1500	10	5	13	5	5	5	13	
Zinc (mg/l)	0.44	12.1	>140	1.38	0.12	1.5	0.63	>140	0.26	0.76	

Table B-12: Historic water-quality sampling, 7/1/1966. nd: not detected; blank: unavailable.

	Site ID										
	1	2	3	4	5	6	7	8	9	10	11
Temperature (F)	58	64	71	65	58	65	60	68	58	57	
Dissolved Solids (mg/l)	68	1412	2356	108	8	32	16	2272	76	24	
pH	7.1	3.6	4.1	7.4	7.5	7.5	7.6	3.8	7	6.7	
Alkalinity, M.O. (mg/l)	34	0	0	34	46	30	37	0	36	32	
Chloride (mg/l)	1	4	15	0.5	0.5	0.5	0.5	5	1	1	
Calcium (mg/l)	23	9.3	12	2.9	2.9	1.8	1.2	12.6	4.2	2	
Copper (mg/l)	nd	nd	3.1	nd	nd	nd	nd	1	nd	nd	
Free Cyanide (mg/l)											
Iron (mg/l)	0.05	0.65	0.14	0.03	0.08	0.02	0.10	0.02	0.08	0.01	
Lead (mg/l)	0.34	3.51	3.25	0.14	nd	0.35	0.2	1.8	0.34	0.25	
Magnesium (mg/l)	1.6	4.35	504	1.66	1.92	1.7	1.51	162.5	1.76	1.0	
Manganese (mg/l)	nd	8.4	42	0.54	0.14	0.72	0.14	168	0.14	0.02	
Potassium (mg/l)	nd	9.3	68	nd	1	nd	0.5	16.2	nd	nd	
Sodium (mg/l)	5.3	13.0	55.8	3.7	3.7	3.7	2.4	2.4	5.3	2.4	
Sulfate (mg/l)	15	750	5	19	5	100	17	1250	9	16	
Zinc (mg/l)	0.27	67	500	1.18	0.03	1.03	0.25	361.5	0.56	0.24	

Table B-13: Historic water-quality sampling, 8/3/1966. nd: not detected; blank: unavailable.

	Site ID										
	1	2	3	4	5	6	7	8	9	10	11
Temperature (F)	50	58	64	53	58	53	55	62	52	50	
Dissolved Solids (mg/l)	56	388	2864	52	64	64	68	3512	68	48	
pH	6.7	5.9	4.0	6.4	6.5	6.1	6.4	3.3	6.9	7.1	
Alkalinity, M.O. (mg/l)	31	0	16	33	32	33	33	0	32	23	
Chloride (mg/l)	0.5	2.5	4.5	0.5	0.5	3	0.5	2	0.5	0.5	
Calcium (mg/l)	55	136	164	28	32	28	31	105	40	20	
Copper (mg/l)	0.077	0.084	1.81	0.1	0.046	0.11	0.11	0.65	0.12	0.09	
Free Cyanide (mg/l)											
Iron (mg/l)	0.14	34.0	0.22	0.11	0.3	0.13	0.21	0.08	0.12	0.10	
Lead (mg/l)	nd	nd	2.6	nd	nd	nd	nd	1.4	nd	nd	
Magnesium (mg/l)	1.7	1.9	24	1.3	2.4	1.4	1.8	47.5	1.9	0.9	
Manganese (mg/l)	nd	2.1	21	0.52	nd	0.55	0.26	4.3	nd	nd	
Potassium (mg/l)	0.5	4	41.9	0.5	1.2	8.6	0.9	15.5	0.5	nd	
Sodium (mg/l)	2.0	4.5	21.0	2.5	2.5	2.0	2.7	18.1	3.0	1.7	
Sulfate (mg/l)	17	150	155	18	12	19	18	2100	23	8	
Zinc (mg/l)	0.25	2.98	620	1.3	0.06	1.61	0.62	540.0	0.43	0.18	

Table B-14: Historic water-quality sampling, 8/29/1966. nd: not detected; blank: unavailable.

	Site ID										
	1	2	3	4	5	6	7	8	9	10	11
Temperature (F)	54	56	67	64	66	dry	64	65	54	55	
Dissolved Solids (mg/l)	64	4.2	2584	76	72		76	4588	92	52	
pH	7.1	4.8	5.0	7.4	7.4		7.6	3.6	6.8	7.1	
Alkalinity, M.O. (mg/l)	27	0	15	38	52		44	0	35	30	
Chloride (mg/l)	0.5	5.5	17.5	0.5	0.5		0.5	4.5	0.5	0.5	
Calcium (mg/l)	19	59	161	22	22		22	305	25	14	
Copper (mg/l)	nd	1.0	1.7	nd	nd		nd	1.1	nd	nd	
Free Cyanide (mg/l)											
Iron (mg/l)	0.09	44.0	0.14	0.05	0.15		0.10	0.06	0.09	0.07	
Lead (mg/l)	nd	nd	2.7	nd	nd		nd	2.6	nd	nd	
Magnesium (mg/l)	1.5	1.7	9.9	1.7	2.3		2.1	45.0	1.9	1.2	
Manganese (mg/l)	nd	2.6	21	nd	nd		nd	105	0.18	nd	
Potassium (mg/l)	1	3.3	47.3	1	2.3		1.3	18.5	1	0.7	
Sodium (mg/l)	2.7	5.0	25.0	3.0	4.6		3.0	22.5	4.0	2.0	
Sulfate (mg/l)	17	300	1450	20	8		17	2550	28	7	
Zinc (mg/l)	0.6	3.18	475	0.96	0.04		0.12	490.0	1.25	0.16	

Table B-15: Historic water-quality sampling, 10/17/1966. nd: not detected; blank: unavailable.

	Site ID										
	1	2	3	4	5	6	7	8	9	10	11
Temperature (F)	48		52	51	54		52		44	48	
Dissolved Solids (mg/l)	108		2744	120	24		100		160	56	
pH	7.5		4.9	6.6	6.4		6.9		7.2	7.5	
Alkalinity, M.O. (mg/l)	31		21	22	42		42		40	32	
Chloride (mg/l)	0.5		12.5	0.5	1.5		0.5		0.5	0.5	
Calcium (mg/l)	17		30	20	17		18		26	10	
Copper (mg/l)	nd		1.9	nd	nd		nd		nd	nd	
Free Cyanide (mg/l)											
Iron (mg/l)	0.02		0.12	0.02	0.31		0.06		0.02	0.04	
Lead (mg/l)	nd		2	nd	nd		nd		nd	nd	
Magnesium (mg/l)	1.2		10.6	1.6	1.6		1.7		1.7	0.9	
Manganese (mg/l)	0.14		21	1.4	0.36		0.41		0.31	nd	
Potassium (mg/l)											
Sodium (mg/l)											
Sulfate (mg/l)	23.0		30.0	48.0	25.0		21.0		48.0	4.0	
Zinc (mg/l)	1.55		10.5	2.9	2.6		2.4		2.75	0.37	

Table B-16: Historic water-quality sampling, 11/4/1966. nd: not detected; blank: unavailable.

	Site ID										
	1	2	3	4	5	6	7	8	9	10	11
Temperature (F)	37	50	40	44	33		39		41	33	
Dissolved Solids (mg/l)	76	660	2308	120	84		108		148	88	
pH	7.1	4.6	5.6	7	7.2		7.2		7.1	7.3	
Alkalinity, M.O. (mg/l)	15	17	35	40	41		41		36	35	
Chloride (mg/l)	0.5	1.5	9.0	0.5	0.5		0.5		0.5	0.5	
Calcium (mg/l)	20	56	112	28	18		24		36	12	
Copper (mg/l)	nd	3.6	2.3	0.1	0.1		nd		nd	0.2	
Free Cyanide (mg/l)											
Iron (mg/l)	0.46	162.0	1.18	0.86	0.57		1.05		0.50	0.09	
Lead (mg/l)	nd	nd	1.7	nd	nd		nd		nd	nd	
Magnesium (mg/l)	2.1	3.9	13.9	3.1	3.1		3.0		3.3	1.7	
Manganese (mg/l)	0.14	4.7	17	1.2	nd		0.62		0.38	nd	
Potassium (mg/l)	1.4	7	43	1.7	2		1.7		1.7	2.8	
Sodium (mg/l)	4.2	6.3	22.0	3.7	3.1		4.8		8.5	1.6	
Sulfate (mg/l)	25.0	350.0	1350	38.0	7.0		30.0		52.0	6.0	
Zinc (mg/l)	1.29	13.1	650	4.5	nd		1.75		2.1	0.17	

Table B-17: Historic water-quality sampling, 12/14/1966. nd: not detected; blank: unavailable.

	Site ID										
	1	2	3	4	5	6	7	8	9	10	11
Temperature (F)	34	40	35	37	33		34		37	33	
Dissolved Solids (mg/l)	84	624	3856	156	92		120		136	40	
pH	7.0	6.1	5.7	6.3	6.4		6.6		7.2	7.5	
Alkalinity, M.O. (mg/l)	34	0	17	40	60		50		36	31	
Chloride (mg/l)	0.5	4.5	25.0	0.5	0.5		0.5		0.5	0.5	
Calcium (mg/l)	46	172	485	70	46		50		60	28	
Copper (mg/l)	0.10	0.78	13.00	0.25	0.18		0.25		0.10	0.18	
Free Cyanide (mg/l)											
Iron (mg/l)	0.64	48.5	1.05	0.60	0.82		0.76		0.73	0.56	
Lead (mg/l)	nd	24	7.2	nd	nd		nd		nd	nd	
Magnesium (mg/l)	3.9	5.6	46.5	6.1	4.9		5.2		4.4	2.2	
Manganese (mg/l)	0.07	2.3	17	1.6	nd		0.47		0.12	nd	
Potassium (mg/l)	0.7	6.4	66	1.4	1.4		1.4		1.4	0.7	
Sodium (mg/l)	2.7	8.7	25.0	3.1	4.5		3.1		5.0	1.5	
Sulfate (mg/l)	28.0	400.0	2000	51.0	6.0		24.0		50.0	8.0	
Zinc (mg/l)	0.33	0.24	1200	1.86	nd		0.31		1.16	0.1	

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APPENDIX C: Monitoring well level measurements.

Table C-1: Monitoring well level measurements, April 2005 through May 2006.

Well ID	4/7/05	5/7/05	6/7/05	7/8/05	8/4/05	8/8/05	8/10/05	9/12/05	10/12/05	11/8/05	12/9/05	1/6/06	2/14/06	3/28/06	4/25/06	5/23/06
1	21.05	18.84	18.05	16.24	16.97	14.49		14.88	18.50	19.61	20.43	20.82	21.31	21.55	20.44	17.55
2	11.34	9.65	13.27	9.58	11.79		12.15	13.17	13.15	12.69	9.20	12.93	13.92	11.42	8.68	8.25
3	4.99	4.91	4.64	5.00	5.02	5.03		5.05	4.88	4.95	4.92	5.11			4.90	4.78
5	5.63	6.02	5.67	5.82	6.44		6.52	7.24	6.75	7.11	6.10	6.22	6.72	6.16	5.60	5.40
7	7.99	16.04	7.31	7.52	8.10		8.18	8.53	9.32	8.44	7.75	8.42	8.88	8.85	8.15	7.95
8	3.00	4.09	3.67	4.09	4.14		4.18	4.40	3.62	4.38	4.46	4.60	4.62	4.12	4.45	4.12
12	2.35	2.42														
13	3.31	3.22	3.06	3.32	3.49	3.50		3.68	3.44	3.54	3.16	3.38	3.32	3.33	3.20	3.07
14	2.59	2.80	2.35	2.79	3.25	3.35		3.78	2.80	3.48	3.58	3.02		2.83	2.70	2.08
15	6.16	6.20	5.26	5.94	6.47	6.62		7.35	6.14	7.12	7.25	6.70	6.59	6.35	6.10	5.11
16	8.21	8.08	8.21	8.31	8.02	8.49		8.60	7.45	8.43	8.22	8.26	8.25	8.36	8.25	8.16
17	10.72	10.99	11.02	10.09	11.05			11.86	11.81	12.07	11.25	11.72	12.02	11.52	10.40	9.90
18	6.20	7.08	6.66	7.03	7.46		7.59	7.90	7.77	7.86	7.75	7.62	7.90	7.82	7.70	7.45
19	7.12	7.33	7.06	7.32	7.64		7.73	7.87	7.55	7.81	7.42	7.85	7.85	7.85	7.42	7.21
20	7.59	7.78	7.47	7.98	8.14	8.19		8.29	8.09	7.20	7.98	7.99	7.95	7.92	7.95	7.72

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APPENDIX D: Revegetation Species

Table D-1: Revegetation Species List

Scientific Name	Common Name	Family/Tribe	A/P	N/I	pH range	Saline Tolerance
Graminoids						
Agropyron trachycaulum	slender wheatgrass	*Triticeae*	P	N	*6.0 - 7.2*	*high*
Deschampsia caespitosa	tufted hairgrass	*Aveneae*	P	N	*3.3 - 7.2*	*low*
Elymus canadensis	Canada wildrye	*Triticeae*	P	N		
Leymus cinereus	Basin wildrye	*Triticeae*	P	N		*high*
Phleum alpinum	alpine timothy	*Meliceae*	P	N		
Agrostis scabra	ticklegrass	*Aveneae*	P	N		
Calamagrostis canadensis	bluejoint reedgrass	*Aveneae*	P	N	*4.5 - 8.0*	*moderate*
Calamagrostis inexpansa	northern reedgrass	*Aveneae*	P	N	*5.5 - 8.0*	*moderate*
Calamagrostis neglecta	slimstem reedgrass	*Aveneae*	P	N		
Carex aquatilis	water sedge	*Cyperaceae*	P	N	*4.0 - 7.5*	*none*
Carex nebrascensis	Nebraska sedge	*Cyperaceae*	P	N	*5.7 - 7.4*	*moderate*
Glyceria striata	fowl mannagrass	*Meliceae*	P	N	*4.0 - 8.0*	*moderate*
Agropyron smithii	western wheatgrass	*Triticeae*	P	N	*4.5 - 9.0*	*high*
Bouteloua gracilis	blue grama	*Chlorideae*	P	N	*6.6 - 8.4*	*high*
Festuca arizonica	Arizona fescue	*Poeae*	P	N	*6.3 - 7.7*	*none*
Oryzopsis hymenoides	Indian ricegrass	*Stipeae*	P	N	*6.6 - 8.6*	*high*
Poa secunda	Sandberg's bluegrass	*Poeae*	P	N	*6.5 - 8.2*	*high*
Shrubs						
Chrysothamnus viscidiflorus va	lanceleaf rabbitbrush	*Asteraceae*	P	N	*6.0 - 8.4*	*med*
Cornus sericea	red-osier dogwood	*Cornaceae*	P	N	*5.5 - 7.5*	
Potentilla fruticosa	shrubby cinquefoil	*Rosaceae*	P	N	*5.0 - 8.0*	*none*
Prunus virginiana	chokecherry	*Rosaceae*	P	N	*5.2 - 8.4*	*none*
Ribes inerme	white-stemmed gooseberry	*Grossulariaceae*	P	N	*6.0 - 7.5*	*none*
Ribes wolfii	Wolf's currant	*Grossulariaceae*	P	N	*NA*	*NA*
Rosa woodsii	Woods' rose	*Rosaceae*	P	N	*5.0 - 8.0*	*none*
Salix bebbiana	Bebb willow	*Salicaceae*	P	N	*5.5 - 7.5*	*none*
Salix drummondiana	Drummond's willow	*Salicaceae*	P	N	*5.2 - 7.4*	*none*
Salix exigua	narrowleaf willow	*Salicaceae*	P	N	*6.0 - 8.5*	*low*
Salix geyeriana	Geyer's willow	*Salicaceae*	P	N	*6.5 - 7.5*	*none*
Salix interior	sandbar willow	*Salicaceae*	P	N	*NA*	*NA*
Salix ligulifolia	strapleaf willow	*Salicaceae*	P	N	*5.5 - 7.5*	*none*
Salix monticola	mountain willow	*Salicaceae*	P	N	*5.0 - 7.0*	*none*
Salix planifolia	planeleaf willow	*Salicaceae*	P	N	*4.5 - 6.0*	*none*
Cercocarpus montanus	mountain-mahogany	*Rosaceae*	P	N	*6.0 - 8.0*	*none*
Rhus aromatica	skunkbrush	*Anacardiaceae*	P	N	*NA*	*NA*
Ribes cereum	wax currant	*Grossulariaceae*	P	N	*6.5 - 7.5*	*none*
Trees						
Alnus tenuifolia	thinleaf alder	*Betulaceae*	P	N	*NA*	*none*
Picea pungens	Colorado blue spruce	*Pinaceae*	P	N	*5.5 - 7.8*	*none*
Populus angustifolia	narrowleaf cottonwood	*Salicaceae*	P	N	*6.0 - 7.5*	*low*
Populus trichocarpa	black cottonwood	*Salicaceae*	P	N	*5.0 - 7.0*	*low*
Salix amygdaloides	peachleaf willow	*Salicaceae*	P	N	*6.0 - 8.0*	*none*
Picea engelmannii	Engelmann spruce	*Pinaceae*	P	N	*6.0 - 8.0*	*none*
Pinus contorta	lodgepole pine	*Pinaceae*	P	N	*6.2 - 7.5*	*none*
Pinus ponderosa	ponderosa pine	*Pinaceae*	P	N	*5.0 - 9.0*	*none*
Populus tremuloides	quaking aspen	*Salicaceae*	P	N		
Pseudotsuga menziesii	Douglas-fir	*Pinaceae*	P	N	*5.0 - 7.5*	*none*

A- Annual, P- Perennial
N- Native, I- Introduced

Table D-1: Revegetation Species List (continued)

Scientific Name	Habitat	Seasonal Growth	Synonyms
Graminoids			
Agropyron trachycaulum	floodplain	C	*Elymus trachycaulus*
Deschampsia caespitosa	floodplain	C	*Aira caespitosa*
Elymus canadensis	floodplain	C	
Leymus cinereus	floodplain	C	
Phleum alpinum	floodplain	C	
Agrostis scabra	wetland	C	
Calamagrostis canadensis	wetland	C	
Calamagrostis inexpansa	wetland	C	*C. stricta* ssp. *inexpansa*
Calamagrostis neglecta	wetland	C	*C. stricta* ssp. *stricta* var. *stricta*
Carex aquatilis	wetland	C	
Carex nebrascensis	wetland	C	
Glyceria striata	wetland	W	*G. elata*
Agropyron smithii	upland	C	*Pascopyrum smithii*
Bouteloua gracilis	upland	W	*Chondrosum gracile*
Festuca arizonica	upland	C	
Oryzopsis hymenoides	upland	C	*Achnatherum hymenoides*
Poa secunda	upland	C	*P. ampla*
Shrubs			
Chrysothamnus viscidiflorus var. *lanceolatus*	floodplain	W	*Ericameria viscidiflora* ssp. *lanceolata*
Cornus sericea	floodplain	C	
Potentilla fruticosa	floodplain	C	*Pentaphylloides floribunda*; *Dasiphora floribunda*
Prunus virginiana	floodplain	C	*P.virginiana* var. *melanocarpa*
Ribes inerme	floodplain	C	
Ribes wolfii	floodplain	C	*R. mogollonicum*
Rosa woodsii	floodplain	C	
Salix bebbiana	floodplain	C	*S. bebbiana* var. *capreifolia*
Salix drummondiana	floodplain	C	*S. bella*
Salix exigua	floodplain	C	*S. argophylla*
Salix geyeriana	floodplain	C	*S. geyeriana* ssp. *argentea*
Salix interior	floodplain	C	*S. exigua* ssp. *Interior*
Salix ligulifolia	floodplain	C	*S. eriocephala* var. *ligulifolia*
Salix monticola	floodplain	C	*S. amelanchieroides*
Salix planifolia	floodplain	C	*S. chlorophylla*
Cercocarpus montanus	upland	C	
Rhus aromatica	upland	C	*R. trilobata*
Ribes cereum	upland	C	
Trees			
Alnus tenuifolia	floodplain	C	
Picea pungens	floodplain	E	
Populus angustifolia	floodplain	C	*P. balsamifera* var. *angustifolia*
Populus trichocarpa	floodplain	C	*P. balsamifera* ssp. *trichocarpa*
Salix amygdaloides	floodplain	C	*S. wrightii*
Picea engelmannii	upland	E	*P. glauca* ssp. *engelmannii*
Pinus contorta	upland	E	
Pinus ponderosa	upland	E	
Populus tremuloides	upland	C	
Pseudotsuga menziesii	upland	E	

C- Cool season, E- Evergreen, W- Warm season

Table D-2: Seed recommendations, with costs per acre.

Upland Seed Recommendations:								
Species	**Variety (table 6: PMTN 59)**	**PLS Rates Irr/Non-Irr**	**PLS/Ac to use (100%)**	**% in mix**	**Rate (PLS lb/ac)**	**Total PLS**	**Price/#**	**Total Cost**
Blue grama	Hachita	3.0 / 1.5	3.0	15	0.5	0.45	$7.00	$3.15
Western wheatgrass	Arriba or Barton	16.0 / 8.0	16.0	15	2.4	2.40	$10.50	$25.20
Arizona fescue	Redondo	4.5 / 2.5	4.5	20	0.9	0.90	$14.00	$12.60
Indian ricegrass	Rimrock or Paloma	.0-12.0 / 4.0-6	10.0	20	2.0	2.00	$7.00	$14.00
Sandberg bluegrass		2.0 / 1.5	2.0	20	0.4	0.40	$6.00	$2.40
Totals:			**35.5**	**90.0**	**6.2**	**6.15**	**$44.50**	**$57.35**

Floodplain Seed Recommendations:								
Species	**Variety (table 6: PMTN 59)**	**PLS Rates Irr/Non-Irr**	**PLS/Ac to use (100%)**	**% in mix**	**Rate (PLS lb/ac)**	**Total PLS**	**Price/#**	**Total Cost**
Western wheatgrass	Arriba or Barton	16.0 / 8.0	16.0	15	2.4	2.40	$10.50	$25.20
Slender wheatgrass	Pryor or San Luis	11.0 / 5.5	11.0	15	1.7	1.65	$5.00	$8.25
Alpine timothy		2.0 / 1.0	2.0	15	0.3	0.30	$14.00	$4.20
Tufted hairgrass	Peru Creek	1.5 / 1.0	1.5	20	0.3	0.30	$8.00	$2.40
Canada wildrye		10.0 / 5.0	10.0	20	2.0	2.00	$3.00	$6.00
Basin wildrye		10.0 / 5.0	10.0	15	1.5	1.50	$3.00	$4.50
Totals:			**50.5**	**100.0**	**8.2**	**8.15**	**$43.50**	**$50.55**

Wetland Seed Recommendations:								
Species	**Variety (table 6: PMTN 59)**	**PLS Rates Irr/Non-Irr**	**PLS/Ac to use (100%)**	**% in mix**	**Rate (PLS lb/ac)**	**Total PLS**	**Price/#**	**Total Cost**
Water sedge		3.0 / 1.5	3.0	10	0.3	0.30	$400.00	$120.00
Nebraska sedge		3.8 / 1.9	3.8	15	0.6	0.57	$100.00	$57.00
Slender sedge		3.6 / 1.8	3.6	15	0.5	0.54	$100.00	$54.00
Creeping bentgrass		0.5 / 0.3	0.5	10	0.1	0.05	$7.00	$0.35
Bluejoint reedgrass		1.0 / 0.5	1.0	15	0.2	0.15	$250.00	$37.50
Tufted hairgrass		1.5 / 1.0	1.5	15	0.2	0.23	$8.00	$1.84
Fowl mannagrass		20.0 / 10.0	20.0	5	1.0	1.00	$250.00	$250.00
Ticklegrass		0.5 / 0.3	0.5	15	0.1	0.08	$36.00	$2.88
Totals:			**33.9**	**100.0**	**2.9**	**2.92**	**$1,151.00**	**$523.57**

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APPENDIX E: Vegetation Species Descriptions

Note: Unless otherwise noted, all information provided in the following narratives was taken from Fire Effects Information System (FEIS).

GRAMINOIDS

Slender wheatgrass (*Agropyron trachycaulum*) Slender wheatgrass is a perennial, cool-season, tufted bunchgrass. The root system is dense, consisting of coarse and fine fibrous roots which extend beyond 12 inches (30 cm) in depth. The dense root system makes this species moderately drought tolerant. It requires a moderately moist bare mineral or lightly mulched seedbed. It is a good competitor on disturbed sites for the first 2 to 3 years. Seedling establishment is often poor in older communities because seedlings to not grow well in thatch or other heavy litter.

Slender wheatgrass is found on semiarid ranges, in temperate and boreal forests, and in subalpine, alpine, and subarctic habitats. It grows in dry to moist, medium-textured soil. It tolerates silt and clay but does best on sandy loam. This species has a high salt tolerance. Soil pH usually ranges from moderately acid to moderately alkaline, although it has been reported growing in soils with a pH as high as 8.8.

Slender wheatgrass is grazed by sage grouse, deer, elk, moose, bighorn sheep, mountain goat, pronghorn, various rodents, and all classes of livestock. It is among the preferred foods of elk and bighorn sheep and is palatable to all classes of livestock.

Ticklegrass (*Agrostis scabra*) is a short-lived, perennial bunchgrass with a fibrous root system but is not rhizomatous. It reproduces primarily by seed but can spread laterally by stolons. Seeds colonize recently disturbed sites with exposed mineral soil seedbeds. It is tolerant of a wide range of moisture regimes; it thrives in wet or moist soils and can survive seasonal stem submergence and is also found in dry habitats and is a common component of semiarid grasslands and sagebrush communities. It grows well on sandy loam, loam, and clay loam soil textures. It is adapted to soils that are low in nutrients and is tolerant of low pH levels.

Ticklegrass is generally a pioneer or invader species. Seed is widely dispersed by wind and requires bare mineral soil for establishment; seedlings are common on recently disturbed sites, which make it a suitable candidate for revegetation programs. It has been used successfully in seeding experiments on alpine sites, where areas disturbed by grazing, recreation, and mining or mineral exploration are common. It is one of the most successful native grasses in the revegetation programs in which it has been included. It shows good potential for both short-term and long-term revegetation, and has low establishment requirements. Ticklegrass seed is not available commercially, but it is produced at the Plant Materials Center in Bridger, Montana.

Ticklegrass is occasionally eaten by elk, mule deer, white-tail deer, pronghorn, small mammals, upland gamebirds, and waterfowl. Moose may also graze on ticklegrass throughout the year. It provides moderate cover for white-tail deer, pronghorn, small mammals, upland gamebirds, and small nongame birds. It may also provide good cover for waterfowl.

Creeping bentgrass (*Agrostis stolonifera*) is a cool season, stoloniferous perennial, and is sometimes mat-forming or tufted. It is most commonly found in moist places such as recently exposed sand and gravel bars, wet meadows, and along streams. Creeping bentgrass grows on disturbed sites such as in ditches or along roadsides, and in pastures and hayfields. It grows best on moist to semi-wet soils, but is tolerant of poorly drained and subirrigated conditions, submergence, and frequent flooding and is moderately tolerant of drought. It grows best on loam, clay-loam, and sandy soils, but occurs on gravelly and rocky substrates as well.

Creeping bentgrass is moderately effective in stabilizing streambanks due to its typically dense network of intertwining roots and rhizomes. Erosion control, short-term revegetation potential, and long-term revegetation potential are rated high for creeping bentgrass. In subalpine and spruce-fir (*Picea-Abies*) habitats of the Intermountain West, creeping bentgrass is recommended for direct seeding and transplanting on riparian sites. Transplant capability is good, growth rate is moderate, and flooding tolerance is moderate. An abandoned tailings pond from a zinc-lead mill near Pecos, New Mexico, was sampled after 50 years of mining. An ephemeral stream ran through the tailings pond and had resulted in extensive flooding and deposition of sediment on top of original tailings. A distinct vegetational community had developed and creeping bentgrass was found in the mesic meadow site. High levels of zinc and lead were found in vegetation being grazed by cattle.

Creeping bentgrass is rated good in nutritional value for elk and mule deer, poor for pronghorn, and fair for white-tailed deer, small mammals, small nongame birds, upland game birds, and waterfowl. Cover value of creeping bentgrass is rated good for upland game birds and waterfowl and fair for small mammals and small nongame birds.

Bluejoint reedgrass (*Calamagrostis canadensis*) is a sod-forming, native, perennial, cool-season grass with extensive creeping underground rhizomes and shallow fibrous roots. Bluejoint reedgrass can also reproduce vegetatively by rhizomes. This grass is capable of producing an extensive network of rhizomes during a single growing season. Small sections of several rhizomes can produce shoots and establish new clones. It prefers moist sites but can survive in a wide range of moisture regimes, however, cannot germinate under drought conditions, although it is very drought resistant once established. It is an aggressive ground residual colonizer and initial off-site colonizer in early seral communities. Once established, a very dense stand of bluejoint reedgrass may persist almost indefinitely, severely limiting the invasion of woody species.

Bluejoint reedgrass occupies sites with imperfectly to moderately well-drained soils. It is found on both peat and mineral soils and is adapted to a wide range of soil textures. This grass is tolerant of extremely acidic soils, with pH values as low as 3.5, and is moderately tolerant of saline soils. Bluejoint reedgrass is a serious competitor of regeneration of conifer seedlings on disturbed moist sites.

The rhizomatous nature of bluejoint reedgrass helps provide streambank stability. This is particularly important on higher gradient streams where scouring by seasonal flooding is possible. This grass is a vigorous invader of oil spill sites in the Northwest Territories, Canada, and recovers rapidly after spills.

Water sedge (*Carex aquatica*) is a native, water-obligate, cool season, long-lived perennial. Water sedge is sod-forming with an extensive network of vertical and horizontal long, stout rhizomes interspersed with expansive meshes of fine roots. These plants are capable of extensive belowground production in low oxygen and anoxic environments. It thrives on disturbed sites, is shade intolerant, and occurs in several stages of succession.

On the upper Mackenzie Delta, Northwest Territories, seedlings of water sedge produced rhizomes and tillers during their 1st year of growth. Water sedge reproduces asexually from rhizomes. On cryic soils, vegetative reproduction rates of water sedge are slow, resulting in limited expansion. A low rate of expansion is also often associated with deficient soil phosphorus levels.

Water sedge is an excellent species for stabilizing streambanks due to its strong rhizomatous growth. In the southern Rocky Mountains of Colorado, water sedge was used to revegetate mined peatlands. Water sedge seedlings were collected from the field in late fall 1991 and early spring 1992, and germinated in a greenhouse in April 1992. While the seeds were germinating, rhizome cuttings from a healthy population of water sedge were collected from High Creek fen. In June 1992, 270 water sedge seedlings and rhizome cuttings were planted in 27 study plots. Water sedge seedling and transplanted rhizome survival rate was greatest where the water table was within 4 inches (10 cm) from the soil surface or where there was shallow standing water.

Tufted hairgrass (*Deschampsia caespitosa*) is a densely caespitose, cool-season, native perennial bunchgrass. It is found in very moist to saturated habitats at the margins of bogs and marshes and in sloughs, moist areas along shores, drainage ditches, and moist draws, and in moderately dry to very dry locations on slopes. It is frequently found on disturbed sites, especially at higher elevations and moist habitats. In Colorado tufted hairgrass grows best in moist habitats, wet meadows, and bogs, and often occurs in nearly pure stands in moist, favorable sites.

Tufted hairgrass grows on a variety of soil types and textures. It is found on sandy loam, sandy clayey loam, silty loam, loam, loamy clay, and clay. It is adapted to cool, acid locations but it also grows on somewhat alkaline soils. It has been found on soils varying from pH 3.3 on mine tailings in Ontario to pH 8.4 in central Idaho. Some tufted hairgrass populations are adapted to growing on spoils with elevated levels of heavy metals. It can be an aggressive colonizer on disturbed sites, particularly in alpine and subalpine regions and occurs on acidic or pyritic mine spoils at high elevations throughout the western United States. Tufted hairgrass has good competitive ability compared to other plants evaluated for high latitude revegetation. It has low to medium potential for short-term revegetation; it has medium to high potential for long-term revegetation. It is a valuable soil stabilizer especially in wet, acid locations.

Tufted hairgrass has been successfully established by seeding on alpine disturbances. Seeds from locally adapted populations have been most successful. For disturbances on well-developed soils that contain minimum amounts of toxic substances, seeds can be selected from a broad range of relatively well-adapted populations. On sites with limiting spoil characteristics, selection from metal and/or acid tolerant populations is more successful. Some tufted hairgrass populations are highly tolerant of lead, zinc, copper, or manganese contaminated tailings. Late fall seeding is most successful; seedling establishment is improved if seeds are exposed to cold dormancy over winter.

Tufted hairgrass can be established by transplanting soil plugs or sod in which it is established. In Nevada in the Lake Tahoe Basin, tufted hairgrass seeds and vegetation were part of wetland plugs which were cut from a mature wet meadow, allowed to grow out, recut, and successfully transplanted. Tufted hairgrass plugs were planted on spoils of an open-pit copper, gold, and silver mine at 9,800 feet (3,000 m) elevation in the Beartooth Mountains of Montana. Tufted hairgrass survival after 1 year was 72 percent. At the site of a backfilled gas pipeline trench at Rollins Pass, Colorado, tufted hairgrass sod was removed during plant dormancy, stored for 2 weeks during construction, and replaced. Tufted hairgrass sod recovery after 18 years was excellent; it was the most successful of the native sods used. High seeding rates of tufted hairgrass may inhibit succession and the establishment of greater species diversity. If the objective of revegetation is to provide immediate surface protection with long-term successional development of a diverse community, then low seeding rates are recommended.

Broadleaf cattail (*Typha latifolia*) is an erect, rhizomatous, semi-aquatic or aquatic, perennial.

Vegetative reproduction occurs through an extensive rhizome system and is responsible for the maintenance and expansion of existing stands. Sexual reproduction via seed dispersal and seedling establishment is responsible for invasion of new areas. Once established, a single seedling spreads rapidly by rhizomes. In Montana, a single seed planted in a stock tank on April 1, grew into a massive network of clones with 98 aerial shoots and 104 lateral buds by November 1. It has been reported that 2 years after germination, cattail may spread over an area of 624 square feet (58 sq m).

Broadleaf cattail grows just about anywhere that soil remains wet, saturated, or flooded most of the growing season. Common habitats include wet meadows, marshes, fens, pond and lake margins, floating bog mats, seacoast estuaries, roadside ditches, irrigation canals, oxbow lakes, and backwater areas of rivers and streams. It is tolerant of continuous inundation and seasonal drawdowns but is generally restricted to areas where the water depth never exceeds about 2.6 feet (80 cm). It is often a dominant component of early successional stages in wetlands. It rapidly colonizes exposed wet mineral soils, as it produces an extremely high number of seeds, which are dispersed by wind and water.

Broadleaf cattail rhizomes and basal portions are an important food of muskrat, nutria, and geese. It is considered an undesirable weed in marshes managed primarily for ducks. The seeds are too small to be an important bird food source, but are eaten by a few species, mainly the green-winged teal, semipalmated sandpiper, Canada goose, snow goose, and tule goose.

Western wheatgrass (*Agropyron smithii*) is a long-lived, native perennial, cool-season grass. It is an aggressive sod-forming grass characterized by an abundance of long, branched rhizomes. Rhizomes allow plants to survive moderately severe drought and act as soil binders. Western wheatgrass regenerates vegetatively through rhizomes to form uniform stands, although will also form from seed. Stands are slow to develop from seed, but once established are vigorous, hardy, and drought resistant. Seeds germinate slowly, but a fairly uniform sod is usually obtained within 2-3 years. Seasonal growth initiates around the 3rd week in April and flowering begins by the 1st week in June with maximum flowering by the 3rd week in June. A short fall regrowth period may occur if adequate precipitation is available.

It is well suited for reclamation of disturbed sites such as surface coal mines, erosion control, and soil stabilization. Western wheatgrass provides good forage value for wildlife; cures well, making good winter forage.

Blue grama (*Bouteloua gracilis*) is a densely tufted, native, warm season, perennial grass. It may grow as a bunchgrass and form thick mats by tillering, frequently resulting in an open sod character. Where it forms a dense cover, blue grama is an important soil-building grass. It is cold and drought tolerant and well adapted to xeric conditions. Growth typically begins from mid April through October; flowering generally occurs from July to August, with seeds ripening and dispersing from August to October.

Blue grama provides important winter forage for elk and deer, good forage for pronghorn during all seasons, and good summer forage for bighorn sheep. Seed is an important food source for small mammals.

Arizona fescue (*Festuca arizonica*) is a cool-season, perennial bunchgrass with deep, dense, fibrous root systems which allows it to tolerate dry conditions, bind soil, and withstand some trampling. Arizona fescue is common on sites with dry, shallow, clay loam soils but tolerates gravelly, sandy, or rocky soils as well. The level of salt and acid tolerance is low. While clay loam to sandy loam soils that are moderately well to well drained are preferred, Arizona fescue persists on shallow soils, tolerates slightly acid or slightly alkaline conditions, and has low fertility requirements.

Arizona fescue provides forage for livestock, elk, deer, and mountain goats and important habitat for birds, mammals, and native grazers in the southwest. Deer, elk, and bighorn sheep utilize Douglas-fir/Arizona fescue habitats for winter cover and forage in northern New Mexico and southern Colorado.

Indian ricegrass (*Oryzopsis hymenoides*) is a hardy, cool-season, densely tufted, native perennial bunchgrass, which has deep, fibrous, extensive roots and is one of the most drought tolerant of the native range grasses. Indian ricegrass grows on dry foothills, rocky valley or upper slopes, plains, and ridges. It is moderately tolerant of both alkali and salt, and is adapted to soils of low fertility. This species is particularly well adapted to sand and attains greatest abundance on loose sandy soils where it forms almost pure stands. Soils supporting Indian ricegrass range in texture from coarse sand to heavy clay. It is also found on shallow shale soils.

Indian ricegrass is well-suited for surface erosion control and desert revegetation although it is not highly effective in controlling sand movement. Certain native ecotypes exhibit desirable characteristics such as drought and salinity tolerance, low seed dormancy, and good nutritional qualities. Indian ricegrass can be useful in the reclamation of many arid and semiarid areas in the western United States. It can be used for revegetating degraded rangelands in areas of low precipitation and has naturally revegetated overgrazed ranges in parts of Utah.

Sandberg's bluegrass (*Poa secunda*) is a shallow-rooted, cool-season perennial bunchgrass. Growth form ranges from small tufts with only one or two culms to large tussocks up to 1 foot in diameter. Sandberg bluegrass is relatively short lived and its populations tend to fluctuate with annual weather conditions. It regenerates by tillering and by seed; it produces significant amounts of seed in most years.

Sandberg bluegrass occurs on flats and ridgetops, slopes, meadows, and open timberline. It grows well in rich clay loam soils but most often inhabits shallow, rocky, or sandy soils. It is fairly shallow-rooted and is favored over deeper-rooted perennials in areas receiving frequent light rains or where soil moisture is otherwise limited. It is a widespread and highly drought-resistant forage grass. It is one of the earliest grasses to green up in spring and is sought by all classes of livestock.

Sandberg bluegrass was included in an herbaceous seed mix used on coal spoils in northwestern Colorado. Sandberg bluegrass established successfully and remained an important component of the vegetation for at least 7 years after seeding.

SHRUBS

Yellow rabbitbrush (*Chrysothamnus viscidiflorus*) is a low shrub growing from 1 to 3.6 feet (0.3-1.1 m) with many brittle, erect stems branching from a compact base. It is well adapted to drought and occurs in desert or semi-desert environments. Yellow rabbitbrush grows on open ridges, on slopes, and along drainageways. It grows on dry, well-drained medium to coarse-textured soils and exhibits fair salt tolerance. Yellow rabbitbrush grows on alkaline soils and exhibits an affinity for calcium.

Yellow rabbitbrush is well suited for revegetating disturbed sites such as road cuts, strip mines, and depleted rangelands due to its prolific seed production and relatively high germination rates. It can be used for erosion control and to stabilize mass soil slippage and increase surface stability. Once plants are established, growth is rapid; subsequent spread is by seed. Two years of rest from grazing is recommended after seeding.

Yellow rabbitbrush provides an important source of browse for livestock and wildlife, particularly in the late fall and early winter after more palatable species have been depleted. Livestock and wild ungulates show varying preference for yellow rabbitbrush depending on season, locality, and subspecies; mature or partially mature plants are generally preferred to green, immature ones. Yellow rabbitbrush provides important cover for pronghorn fawns. It also provides nesting cover for some species of songbirds including the Brewer's sparrow and sage sparrow.

Red-osier dogwood (*Cornus sericea*) is a deciduous, many-stemmed shrub which varies in height from 3 to 19 feet (1-6 m). Red-osier dogwood is a characteristic species of swamps, low meadows, and riparian zones; it is also found in forest openings, open forest understories, and along forest margins. It is a facultative wetland plant. Although red-osier dogwood grows on a variety of soils, it prefers rich, moist soils.

Red-osier dogwood can tolerate flooding and, consequently, is found on floodplains and wetlands and is often one of the first shrubs to invade wet meadows. Its seeds germinate above water level, but after several years' growth, the plants can live with the roots submerged in water for most of the growing season. On good sites red-osier dogwood can form dense thickets through vegetative reproduction. It spreads by layering when the lower stems touch or lie along the ground and root at the nodes. Plants may also produce new shoots from the roots and new branches from the bases of dying branches. If 27% or more of the stem is girdled by small rodents, the stem will die back to the injury, and new growth begins below that point on the stem.

Red-osier dogwood is recommended for rehabilitating moist sites within its range. It is well adapted to disturbed sites, excellent at stabilizing soil, easy to establish, and grows rapidly. Rooted cuttings or nursery-grown seedlings are easily established on moist, well-drained soils and grow rapidly.

Natural regeneration of red-osier dogwood is both sexual and asexual. Pollinators include the honey bee, bumble bee, solitary bee and possibly beetles, flies, and butterflies. Seeds are dispersed primarily by songbirds, although other animals including bears, mice, grouse, quail, partridges, and even ducks and cutthroat trout may eat the fruit and disperse seeds. The seeds may be stored in seedbanks. Individual plants generally first bear fruit at 3 to 4 years of age, but older plants are more prolific.

Chokecherry (*Prunus virginiana*) is a native, deciduous, thicket-forming erect shrub. It has a network of rhizomes and a deep root system established at intervals along the rhizomes. Roots may extend laterally more than 35 feet (10.6 m) and vertically more than 6 feet (1.8 m). Rhizomes range from 0.4 to 0.8 inch (1-2 cm) in diameter.

In the western United States, chokecherry grows at low to mid-elevations in positions in the landscape where combinations of soil and topography permit greater than average accumulation of moisture. These sites include riparian areas, wooded draws, and steep ravines. Chokecherry can tolerate weakly saline soils but is intolerant of poor drainage and prolonged flooding. It grows in very acid to moderately alkaline soils.

Chokecherry has been selected as a revegetation species for wildlife habitat, shelterbelts, mine spoils, and soil stabilization. Chokecherry exhibited salt tolerance in a greenhouse study.

Chokecherry can be propagated from seed or rhizome cuttings. Nursery-grown seedlings of chokecherry establish satisfactorily if planted free of competition on sites with at least 15 inches (38 cm) of annual precipitation. Young plants are not tolerant of competing vegetation for 2 to 3 years following planting.

Chokecherry is widely regarded as an important wildlife food plant and provides habitat, watershed protection, and species diversity. Fruits, leaves, and twigs are all utilized. Large mammals including bears, moose, coyotes, bighorn sheep, pronghorn, elk, and deer use chokecherry as browse. It is also a food source for small mammals and the fruits are important food for many birds. Chokecherry also provides important cover and habitat for many bird species, small mammals, large mammals, and livestock. It is an excellent shrub for providing thermal cover and erosion control in fisheries.

Wood's rose (*Rosa woodsii*) is a native perennial shrub, which grows to a height of 3 to 10 feet (1-3 m) and attains maximum height within 10 years from initiation of growth. In western U.S. arid and semiarid riparian areas, rose is intermediately tolerant of seasonal flooding. Intermediately tolerant is defined as species which are able to survive flooding for periods between 1 to 3 months during the growing season. The root systems of these plants may produce few new roots or will be dormant during the flooded period.

Woods rose regenerates via seeds and vegetatively from the root crown, by root suckering, and layering. It first flowers and produce seeds when they are 2 to 5 years old.

Good seed crops generally occur every 1 to 2 years. The seeds of Wood's rose are primarily dispersed by birds and mammals.

Wood's rose prefers south-facing slopes, although it occurs on dry slopes, streambanks, open woods, hillsides, washes, waterways, irrigation canals, marshlands, lakeshores, hillsides, rocky prairie ravines, open woodlands, roadsides, and canyons. It is adapted to a wide range of soil types. It generally grows best on moderately fertile, well-drained clay loam, sandy loam, or sandy soil. Wood's rose is tolerant of moderately acid to weakly basic soils, preferring soils with a pH of 5.6 to 7.0. Within the broader site characteristics, Wood's rose infrataxa have individual preferences: *Rosa woodsii* var. *woodsii* occurs in plains and prairie ecotypes; interior rose occurs primarily in the cordilleran ecotype; *Rosa woodsii* var. *glabrata* is found in moist places, generally about springs.

Wood's rose is an excellent species for revegetation of disturbed sites because it is an excellent soil stabilizing species and a valuable species for revegetating disturbed sites along streambanks and seeps. Spring planting of 1-year old Wood's rose bare-rooted plants on road cuts in northwestern Montana was more successful than fall planting. Four years following planting, spring-planted Wood's rose had a survival rate of 93% compared to 62% for fall-planted Wood's rose.

Wood's rose provides forage for small and large mammals, birds, and ungulates. It has good food value for upland game birds, nongame birds, and small mammals, but poor food value for waterfowl. It provides good cover for birds, small mammals, fish, and ungulates. It is an essential cover species for a variety of nongame birds in the Great Plains and the western U.S.

Bebb willow (*Salix bebbiana*) is a large shrub 10 feet (3 m) tall or a small multi-stemmed tree with a bushy top 15 to 25 feet (4.6-7.6 m). Roots of Bebb willow are shallow and dense.

Male and female flowers of Bebb willow are borne on separate individuals. Bebb willow starts flowering from 2 to 10 years of age, with optimum seed-producing years from 10 to 30. Bees are the chief pollinating agents. Bebb willow will also establish by root shoots and basal stem sprouting. Stem and root fragments root naturally if buried in moist soil. Damaged and cut stems produce prolific sprouts from the stem base or root collar. Layering also occurs readily if branches become buried.

Bebb willow is usually found on moist sandy or gravelly soils but is adapted to a wide variety of soil textures. It will tolerate moderately alkaline soils but does poorly in extremely acidic or alkaline conditions. The general pH range for willows is 5.5 to 7.5. Bebb willow can survive short periods of standing water, but growth rates decline sharply if water persists above the root collar. This willow is not drought tolerant, however, and prefers sites with adequate moisture. It is also shade intolerant and grows best in full sunlight.

Bebb willow is a pioneer species and once established may persist in areas with moist site conditions or frequent disturbance such as fire or flooding. Channel changes that reduce the availability of water may prevent successful germination and establishment of Bebb willow within established stands. This willow is a relatively good soil stabilizer and is valuable for revegetating streambanks and other disturbed sites. It readily invades mine spoil piles and has been observed invading barren acid soils near Sudbury, Ontario, particularly after such soils were treated with lime and phosphate.

Bebb willow cuttings should be planted on sites that have sufficient moisture to start and carry the cuttings through the growing season. Cuttings are best taken in the spring from dormant 2- to 4-year-old wood. Cuttings 12 to 20 inches (30-50 cm) long and greater than 0.4 inch (1 cm) in diameter produce best results, with the cuttings rooting freely along the entire length of the stem. Roots and shoots from cuttings can be expected to appear 10 to 20 days after planting. Using root cuttings and nursery-grown stock will produce the best results. Bebb willow seed is not available from commercial sources because it is generally viable for only a few days. The maximum period of storage is 4 to 6 weeks, but viability is markedly reduced after 10 days for seed stored at room temperature.

Bebb willow is a major source of browse for moose, elk, and deer. In winter, heavy snows tend to bend the branches down so that they are in reach of both moose and snowshoe hares. R esults of a southwestern Montana food habit study showed that Bebb willow became increasingly important browse for moose during late winter, making up 15.4 percent of the total forage taken. Bebb willow shoots, buds, and catkins are eaten by many small mammals, birds, and beaver. It has been rated as highly palatable to livestock, big game, and beaver. Willow palatability increases as the season progresses. Bebb willow provides cover and protection for many birds and mammals. It also provides shade for fish in streams and ponds.

Drummond's willow (*Salix drummondiana*) is a deciduous shrub generally between 6.5 and 13 feet (2-4 m) tall, but occasionally up to 20 feet (6 m) tall. Male and female flowers occur on separate plants in erect, nearly sessile catkin.

Drummond willow's primary mode of reproduction is sexual. It produces an abundance of small, light-weight seeds. Like most willows, it begins seed production at an early age (between 2 and 10 years). At maturity, the fruit splits open and releases the seed. Each seed has a cottony down that aids in dispersal by wind and water. Seeds are dispersed during the growing season and remain viable for only about 1 week. The seeds contain significant amounts of chlorophyll and photosynthesis generally begins as soon as the seed is moistened. Germination occurs within 24 hours of dispersal if a moist seedbed is reached. Exposed mineral soils are the best seedbed.

Drummond willow sprouts from the root crown or stem base if aboveground stems are broken or destroyed by cutting, flooding, or fire. Detached stem fragments will root if they are buried in moist soil. This occurs when stem fragments are transported by floodwaters and deposited on fresh alluvium.

Drummond willow occurs along the borders of streams, rivers, beaver ponds, and lakes, and in wet meadows and marshes. It grows at moderate elevations from lower forested and non-forested foothills to subalpine habitats. At montane elevations it is usually confined to the edges of streams. Drummond willow tends to form relatively stable, long-lived seral communities that are maintained by seasonal flooding or high water tables.

Drummond willow is recommended for use in revegetating disturbed riparian areas and is especially useful for streambank stabilization. It is usually planted as rooted or unrooted stem cuttings. Drummond willow stems contain pre-developed root primordia. Stem cuttings develop roots along the entire length of the buried portion within about 10 days of planting. Because it roots quickly, unrooted Drummond willow cuttings may be planted on sites with sufficient moisture throughout the growing season to start and maintain growth. Rooted cuttings have higher survival rates than unrooted cuttings.

Drummond willow thickets that provide good cover for a variety of wildlife species, especially moose, and excellent nesting and foraging habitat for ducks, shore birds, vireos, warblers, and sparrows. Moose consume large amounts of Drummond willow during the winter, but use by other ungulates is generally moderate to light. Willows are a preferred food and building material of beaver. Willow catkins, shoots, buds, and leaves are eaten by ducks and grouse, other birds, and small mammals. In Colorado, red-naped sapsuckers drill wells in the stems and feed on the sap of Drummond willow. Heavy drilling can occur, with up to 90 percent of a single plant's branches containing wells. These wells serve as feeding sites for other animals such as warblers, hummingbirds, chipmunks, and red squirrels. Dense overhanging branches provide shade for salmonids.

Narrowleaf willow (Salix exigua) is a native, winter-deciduous shrub that grows up to 33 feet (10 m) tall. More commonly, narrowleaf willow is 6.5 to 20 feet (2-6 m) tall with many erect shoots. Individual stems arise singly or a few together and form large colonies from spreading roots. Lateral roots of narrowleaf willow produce root sprouts in profusion, often in long rows. These shoots elongate rapidly in spring. Narrowleaf willow also resprouts from the root crown. Individual stems often only live 10 years, though some may reach 20 years. Roots are woody and spreading, forming an extensive root system, especially with the development of large clones.

Narrowleaf willow is both drought resistant and very tolerant of flooding; it can withstand flooding for periods of 2 or more growing seasons. "Very tolerant" species usually exhibit good adventitious or secondary root growth during periods of flooding. The ability to generate new roots on the original root or submerged stem is important to willows. Elevated soil-water tables result in severely restricted root development and eventual death of the root system. However, adventitious rooting above the flooded soil is abundant in many species of willow and a new root system develops above the soil-water table, which likely contributes to narrowleaf willow's flood tolerance.

Narrowleaf willow is generally dioecious; however, monoecious individuals have also been described. This willow produces many small seeds with morphological adaptations to enhance dispersal. Flowering and seed production may begin as early as age 2 to 3 years. In general, willow seeds are dispersed primarily via wind and water. Narrowleaf willow seeds usually germinate with 24 hours of landing on a suitable substrate (freshly deposited, wet alluvium in full sunlight). Because narrowleaf willow requires moist exposed surfaces for germination, there may be a period of only a few days where suitable substrate is available due to the rapid recession of water in riparian zones.

Though neutral pH (7.2 to 7.6) is optimal, narrowleaf willow also grows outside that narrow range. It is more often found on alkaline soils, though it may also be found on slightly acid soils. Narrowleaf willow is tolerant of low nutrient levels. In general, willows have poor height growth on sites with low pH and low nutrient availability. However, they will tolerate low nitrogen levels and sustain healthy, if dwarfed, shoots.

Due to it's proliferation of seeds, ability to resprout, tolerance of low nutrient levels, and tolerance of disturbance, narrowleaf willow is a pioneer species that rapidly colonizes fresh alluvial deposits. I t typically forms narrow bands along streams, rivers, lakes, and ponds. Narrowleaf willow colonizes rocky, gravelly, and sandy stream and lake edges, moist, well-drained alluvial terraces and bottomlands, and recently deposited sand and gravel bars that are below the high-water mark, where it is subject to annual flooding, ice jams, and associated scouring and deposition. Narrowleaf willow is shade intolerant; other willows (Geyer willow, yellow willow, and Drummond willow may become the climax vegetation as narrowleaf willow communities promote bank building and soil development, preparing hospitable sites for other species.

Narrowleaf willow is recommended for riparian revegetation projects. Propagation studies in Ontario have achieved 90% rooting success in bareroot plantings of narrowleaf willow. Narrowleaf willow propagates well from stem cuttings. Dormant willow stem cuttings strike root easily in moist sand or soil, and direct planting of cuttings is commonly used for revegetation and restoration of riparian areas. Unrooted cuttings may be used successfully on low-elevation sites where the water table remains high throughout the growing season. Rooted stock should be used on sites with fluctuating water tables, high flooding potential, or short growing seasons. Cuttings develop roots along the entire length of the stem; roots and shoots appear in 10 to 15 days.

Narrowleaf willow is browsed by moose, elk, and to a limited extent, mule deer. Where abundant, it may be important late summer and winter browse for elk. Narrowleaf willow is important and heavily-used browse for beaver. It provides important nesting and cover sites for nongame birds; fair cover for elk; fair to good cover for antelope, waterfowl, and small mammals; and good cover for mule deer, white-tailed deer, and upland game birds.

Geyer's willow (*Salix geyeriana*) is larger than many associated shrub willows. It grows as a large deciduous shrub or small tree sometimes up to 20 feet (6 m) tall. Male and female flowers occur on separate plants in erect catkins. Geyer willow's primary mode of reproduction is sexual, producing an abundance of small, light-weight seeds. Like most willows, it probably begins seed production at an early age (between 2 and 10 years). At maturity, the fruit splits open, releasing the seed. Each seed has a cottony down that aids in dispersal by wind and water. Seeds are dispersed during the growing season and remain viable for only about 1 week. The seeds contain significant amounts of chlorophyll, and photosynthesis generally begins as soon as the seed is moistened. Germination occurs within 24 hours of dispersal if a moist seedbed is reached. Exposed mineral soils are the best seedbed. Germination and/or seedling establishment is generally inhibited by litter.

Geyer willow sprouts from the root crown or stembase if aboveground stems are broken or destroyed by cutting, flooding, or fire. Detached stem fragments form adventitious roots if they remain moist. Thus portions of stems will root if buried in moist soil. This can occur when stem fragments are transported by floodwaters and deposited on fresh alluvium. It occupies sites that range from wet to relatively dry, but it rarely grows on sites where the water table is deeper than 39 inches (1 m).

Geyer willow is recommended for use in revegetating disturbed riparian areas. It is especially useful for streambank stabilization where it is usually planted as rooted or unrooted stem cuttings. Geyer willow stems contain predeveloped root primordia. Stem cuttings develop roots along the entire length of the buried portion about 10 to 15 days after planting. Because it roots quickly, it may be planted as unrooted cuttings on sites with sufficient moisture throughout the growing season to start and maintain growth. Rooted cuttings have higher survival rates than unrooted cuttings. Procedures and techniques for collecting, preparing, and planting willow cuttings are described by and McClusky and others.

Elk and moose eat Geyer willow, especially in winter. Willow catkins, shoots, buds, and leaves are eaten by ducks and grouse, other birds, and small mammals. Livestock and wild ungulates apparently prefer Geyer willow over Drummond willow, Wolf willow (*Salix wolfii*), and Booth willow (*Salix boothii*). Geyer willow often occurs in widely spaced clumps, allowing for easy access and movement of livestock and large wildlife species. Geyer willow communities can provide excellent habitat for deer and excellent nesting and foraging habitat for a variety of birds, such as ducks and shorebirds, blackbirds, warblers, vireos, and sparrows.

Mountain willow (*Salix monticola*) is a native, erect shrub 3 to 12 feet (1.5-4 m) tall, and usually forming dense clumps. It can be found in floodplain thickets on rivers and grows on recent alluvial deposits characterized by exposed mineral soil, low moisture content, and absence of permafrost. In temperate climates, mountain willow occurs at middle to rather high elevations (6,000 to 10,500 feet [1,800-3,100 m]) in the mountains along riparian zones. It is usually found on moist sandy or gravelly soils but is adaptable to a wide variety of soils. It will tolerate moderately alkaline soils but does poorly in extremely acidic of alkaline conditions. The general pH range for willows is 5.5 to 7.5. Growth of mountain willow is severely reduced when water levels are maintained at or above the root collar for extended periods.

Mountain willow is dioecious. The fruit is contained in a dehiscent capsule that releases many seeds that are then dispersed by wind or water. Optimum seed production occurs between 2 and 10 years. The flowers of mountain willow are mostly, but not exclusively, insect-pollinated. Bees are the chief pollinating agents. It flowers in May, before the leaves appear, through July. The fruit ripens soon after flowering, followed by seed dispersal in early to midsummer. It readily sprouts from the root crown or basal stem. It will root from stem cuttings or root fragments on moist to wet sites and will sprout vigorously following cutting regardless of cutting season, but vigor is more pronounced if cutting occurs during the dormant season.

Mountain willow is useful in stabilizing streambanks and providing erosion control on severely disturbed sites. It is an important invader of sites disturbed by man or natural phenomena because of its ability to produce roots and root crown shoots, which provide for quick recovery. The utilization of willows for riparian habitat improvement is widespread because they are easy to obtain, inexpensive, usually locally acclimated, and provide a good benefit/cost ratio.

<u>Planeleaf willow (*Salix planifolia*)</u> is a small- to medium-sized deciduous shrub. Planeleaf willow's primary mode of reproduction is sexual, although it also sprouts from the root crown or stem base if aboveground stems are broken or destroyed by cutting, flooding, or fire. Detached stem fragments form adventitious roots if they remain moist; portions of stems will root naturally if buried in moist soil.

Planeleaf willow occupies different habitats, commonly forming thickets along stream and lake margins, in wet meadows and seep areas, and on slopes kept moist by melting snow. These sites are usually wet, with water tables at or near the surface. Soils may be mineral or organic and overlain by a shallow, organic surface layer. It generally occurs scattered in other willow-dominated communities along the banks of streams, ponds, and lakes and in wet meadows and marshes.

Planeleaf willow is recommended for use in revegetating disturbed riparian areas, and is especially useful for streambank stabilization. It is usually planted as rooted or unrooted stem cuttings. Planeleaf willow stems contain predeveloped root primordia. Stem cuttings develop roots along the entire length of the buried portion within about 10 to 15 days after planting. Because it roots quickly, unrooted planeleaf willow cuttings may be planted on sites sufficiently moist to start and maintain growth. Rooted cuttings have higher survival rates than unrooted cuttings.

Planeleaf willow occurring in montane and subalpine riparian communities provides excellent nesting and foraging habitat for a variety of birds, such as ducks, shorebirds, warblers, vireos, and sparrows. Nesting sandhill cranes frequently used low-stature planeleaf willow cover in Idaho. Planeleaf willow branches overhanging streambanks provide cover and shade for salmonids.

<u>Mountain-mahogany (*Cercocarpus montanus*)</u> is a native, xerophytic, deciduous shrub growing up to 19.8 feet (6 m) tall. The stout, lateral roots arise from a large root crown. In alluvial soils, they descend downward to depths of 3.3 feet (1 m) or more. Mountain-mahogany roots may have associations of nitrogen-fixing endomycorrhizae.

Mountain-mahogany reproduces vegetatively and sexually. It sprouts from the root crown following disturbance and in favorable years, produces a good crop of seedlings; however, seedling establishment can be very sporadic. It commonly grows on plains, foothills, moderately steep slopes, ridges, and bluffs in coarse, shallow, well-drained residual soils on sunny sites, and it sometimes grows in the moist, fertile, relatively deep soil of canyon bottoms.

Mountain-mahogany can be used to improve ranges or rehabilitate mountain shrub and pinyon-juniper communities, although it may be difficult to establish. It should be transplanted in the fall. Protection from the effects of browsing may be necessary.

Mountain-mahogany provides highly palatable forage for all classes of browsing animals in both summer and winter. New spring foliage is preferred by livestock and wildlife and remains palatable until late fall. Deer and elk consume the leaves and twigs in the summer and browse the twigs in winter. Because mountain-mahogany grows more slowly than many of its associates, it continues to provide succulent forage after other species become unpalatable.

Skunkbrush (*Rhus aromatica*) is a deciduous, flowering native shrub. It grows 2 to 12 feet (0.6-3.6 m) tall, averaging 4 feet (1.2 m) tall. It has a taproot and a fibrous root system which support roots that are deep and extensively branched with somewhat shallow, spreading woody rhizomes. Individual shrubs and patches of skunkbrush sumac may be connected by underground structures that can exceed 20 feet (6 m) in length and 30 years in age.

Skunkbrush propagates by seed and root sprouts, although reproduces only rarely from seed. It sprouts readily from the root crown after severe disturbance but is unlikely to reproduce vegetatively in the absence of disturbance. Skunkbrush grows on dry, rocky hillsides and sandhills, as well as along streams, canyon bottoms, and wetlands. It is found in grassy flats and openings in woodland areas. It may grow to 2 to 3 feet (0.6-0.9 m) on dry sites, and 10 to 12 feet (3-3.6 m) with more favorable moisture availability. Skunkbrush is tolerant of most soil textures but prefers well-drained sites; it may be found in higher density at mid-slope positions than at the bottom of slopes. It prefers deep soil or thin soils with a gravel base. Extensive stands have been reported on steep slopes where topsoils were thin or absent. Skunkbrush is intolerant of flooding and high water tables.

Skunkbrush is useful for reclamation of disturbed areas. It is excellent for erosion control and survives on untreated mine spoils. Skunkbrush is commercially available (e.g. cultivar "Autumn Amber") and grows well from seed (especially when planted in fall and winter) or transplants.

Skunkbrush is browsed by big game, including elk, bighorn sheep, pronghorn, mule deer, and white-tailed deer. It is occasionally browsed by cattle and domestic sheep and goats. Porcupines utilize it, and it is also browsed, sometimes heavily, by jackrabbits and cottontail, particularly after heavy snow when branches extend above drifts. Its fruit is an important winter food source for birds, including songbirds, prairie chickens, Merriam turkeys, ring-necked pheasants, sage-grouse, ruffed grouse, sharp-tailed grouse, and bobwhite, valley, Gambel, and scaled quail. Fruit is also eaten by black bears, and occasionally, white-tailed deer. Skunkbrush also provides useful cover and nesting sites for birds; poor to fair cover for elk; fair to good cover for white-tailed deer, mule deer, and pronghorn; good cover for upland game birds, nongame birds, and small mammals; and poor cover for waterfowl.

Wax currant (*Ribes cereum*) is a native, deciduous, non-rhizomatous shrub growing from 1.65 to 4.95 feet (0.5-1.5 m) tall. It reproduces mainly by seed. Its ability to sprout from the root crown is described in the literature as "weak". Shrubs of *Ribes* spp. begin fruiting after 3 years. Many seeds fall beneath the parent plant; they are also dispersed by birds and mammals. Fallen seeds remain viable in the soil and duff for many years

Wax currant commonly occurs on dry, open slopes, ridges, and rock outcrops at elevations from 4,950 to 13,200 feet (1,500-4,000 m). It is one of the first shrubs to dominate well-scarified sites but declines when a canopy taller than its own develops and their roots stabilize the soil.

Wax currant provides food and cover for wildlife. It is only fair to poor browse for deer, but it is important on ranges where little else is available. It provides important cover for small mammals and song birds.

TREES

<u>Thinleaf alder (*Alnus tenuifolia*)</u> is a deciduous multi-stemmed shrub or small tree which tends to form thickets and may grow up to 40 feet (12 m) tall. More typically, mature plants are 6 to 15 feet (2-5 m) tall, with 4 to 8 inch (10-20 cm) diameter trunks.

Thinleaf alder is recommended for use in revegetating disturbed riparian areas. It is easy to establish on disturbed sites and has a rapid growth rate, it can quickly stabilize disturbed streambanks. Plants can be established along streambanks from direct seeding, container-grown seedlings, or bareroot stock, but propagation from stem cuttings is not recommended. Once established, plants spread well vegetatively and by natural seeding. Streambanks anchored by thinleaf alder are stable and can withstand relatively severe spring runoff. Thinleaf alder also improves soil fertility through the addition of nitrogen to the soil from nitrogen-fixing root nodules and a nitrogen-rich leaf litter.

<u>Blue spruce (*Picea pungens*)</u> is a native evergreen tree with a dense, pyramidal to spire-shaped crown. The shallow roots of blue spruce restrict it to moist sites where water is close to the surface. Blue spruce occurs on montane streambanks; well-drained floodplains or cobble flats; first-level terraces; ravines; intermittent streams; or subirrigated, gentle slopes. It is a pioneer species in riparian communities that are subject to periodic disturbances, such as scouring and flooding.

Throughout much of its range, blue spruce grows in cool climates that are characterized by low summer temperatures and low winter precipitation. In the southern end of its range, it may be restricted to riparian areas in arid and semiarid climates. Blue spruce grows on a variety of soil types. Usually, soils are young and undeveloped; however, soil textures may be deep sandy to gravelly loams that are well drained. Soils are commonly derived from fluvium, alluvium, and colluvium. Soil temperature regimes are frigid in montane canyons to cryic at higher elevations. Blue spruce stands are often associated with areas of cold air drainage.

Blue spruce provides cover for a variety of bird and animal species. Big game forage is good throughout blue spruce habitat types in northern New Mexico and southern Colorado. Numerous birds eat blue spruce seeds. It also provides good environmental protection for elk, mule deer, white-tailed deer, small mammals, and small nongame and upland game birds in Colorado, Utah, and Wyoming.

<u>Narrowleaf cottonwood (*Populus angustifolia*)</u> Narrowleaf cottonwood is a native deciduous tree with a slender crown. Narrowleaf cottonwood is reported as a facultative wetland species tolerant of frequent and prolonged flooding. It is not drought resistant and is extremely vulnerable to drought induced xylem cavitation. A life span of 100 to 200 years is not uncommon. Narrowleaf cottonwood is a rapidly growing pioneer species, showing natural stand replacement adjacent to riparian systems with undisturbed hydrology. However, narrowleaf cottonwood shows slower growth rates than the majority of cottonwood species, requiring a longer time for adequate establishment.

Narrowleaf cottonwood shows both asexual and sexual regeneration. Channel narrowing and redistribution of sediment are the 2 main fluvial processes providing suitable narrowleaf cottonwood establishment sites. Pollen is wind dispersed with fertilization occurring within 24 hours of pollination. Subsequent seed maturation is temperature dependent, generally requiring 3 to 6 weeks. Seed dispersal through wind and water is aided by fluffy cotton-like hairs. Seeds possess a small window of viability, generally 2 days. They readily germinate when deposited in favorable environments. Successful germination and establishment is dependent upon a suite of abiotic and biotic conditions, with insulation and moisture availability the most limiting factors. Seedlings require wet alluvium in full sunlight. Narrowleaf cottonwood seedlings are poor competitors in vegetated sites because lack of endosperm food reserves limits successful establishment in shaded areas.

Narrowleaf cottonwood sprouts from the root crown and roots. Sprouting is often linked to disturbance that scarifies stems and/or roots. Narrowleaf cottonwood also sprouts from branch and root fragments when adequate sediment deposition is present. Vegetative propagation is a dominant mode of reproduction within foothill rivers and relatively clear streams with coarse substrates, promoting colonization of bare gravel bars. Steep gradients, coarse streambeds, and constrained channels also promote clonal regeneration. Cloning is important in narrowleaf cottonwood gallery maintenance. Male and female trees have similar clonal abilities. Shoot sprouting produced tightly clustered clones around buried root crowns. Root suckers produced wider spacing than shoot sprouting. Beavers influenced clonal propagation, perpetuating clonal expansion and encouraging regeneration near stream channels.

Branch fragments provide an important mode of asexual propagation. Beavers, high winds, heavy rain, hail, snow, and flooding all produce branch fragments capable of regeneration. Branches have the ability to impede stream flow and trap sediment for localized deposition, and may promote narrowleaf cottonwood establishment in areas lacking unvegetated sediment deposits.

Although successional events in communities dominated by narrowleaf cottonwood are different between sites, common attributes are shared. Narrowleaf cottonwood colonizes moist, barren, newly deposited alluvium exposed to full sunlight. Shade intolerance, and lack of successful sexual regeneration under its own canopy prevent narrowleaf cottonwood communities from achieving climax status.

Narrowleaf cottonwood provides erosion control and streambank stabilization. It is well adapted to planting on disturbed sites. Rooted cuttings and nursery grown seedlings are easily established. Propagated cuttings of narrowleaf cottonwood are readily available. Water availability, vegetative cutting length, and phenological status all limit artificial regeneration of narrowleaf cottonwood. Pole-sized narrowleaf cottonwoods generally have lower survival rates when planted in areas with fluctuating water table levels than in areas with constant water levels. Dormant poles show better establishment and survival than actively growing poles. Pole cuttings up to 20 feet (6.1 m) are useful in difficult revegetation projects. Long poles can better access deep water tables to enhance rooting and are also more resistant to bank slough.

Annual spring flooding is a controlling factor behind species composition and population dynamics of narrowleaf cottonwood communities. Annual floods usually coincide with seed dissemination. Damming generally reduces the number and quality of narrowleaf cottonwood regeneration sites. Recent studies have focused on dam-related decreases in summer water tables. Many dams do not alter spring discharge. Dams that have no effect on spring discharge rates may not affect the production of alluvial deposits for narrowleaf cottonwood regeneration. However, seedling establishment is generally adversely affected by exposing seedlings to artificial drought. Summer water table levels are a critical component of narrowleaf cottonwood establishment. In Alberta narrowleaf cottonwood abundance declined from 1951 to 1994. Ground surveys conducted over 9 years (1985-1994) recorded an absence of seedlings and saplings. Declines were drought induced, through insufficient flow rates during summer months together with the abrupt reductions following high spring flow rates. Narrowleaf cottonwood seedlings are not tolerant of abrupt declines in water table levels. Slow daily declines of 1.6 inches per day (4.0 cm/day) in water table levels over a 28-day period were found to stimulate root growth without causing profound decreases in shoot height. Larger declines of 4 inches per day (10 cm/day) drastically slowed shoot height.

Quaking aspen (*Populus tremuloides*) is a native deciduous tree. The root system is relatively shallow, with wide spreading lateral roots and vertical sinker roots descending from the laterals. Laterals may extend over 100 feet (30 m) into open areas. Quaking aspen form clones connected by a common parent root system. It is typically dioecious, with a given clone being either male or female. Clones can be distinguished by differences in phenology, leaf size and shape, branching habit, bark character, and by electrophoresis. A male clone in the Wasatch Mountains of Utah occupies 17.2 acres (43 ha) and has more than 47,000 stems; to date, it is the world's most massive known organism. Clone age can be great; the large Utah clone is estimated to be 1 million years old.

Quaking aspen is not shade tolerant; neither does it tolerate long-term flooding nor waterlogged soils. Even if quaking aspen survives flooding in the short term, stems subjected to prolonged flooding usually develop a fungus infection that greatly reduces stem life.

Quaking aspen regenerate from seed and by sprouting from the roots. Root sprouting is the most common method of regeneration. Root suckers originate from meristems in the root's cork cambium and can develop anytime during secondary growth. Saplings may begin producing root sprouts at 1 year of age. Sprout development is largely suppressed by apical dominance. Closed stands produce a few inconspicuous sprouts each growing season; the sprouts usually die unless they occur in a canopy gap. Best sucker production follows either a fire that kills all parent trees and brush or other complete clearing.

Quaking aspen commonly establishes from seed in Alaska, northern Canada, and eastern North America. Seedling establishment is less common in the West, where rainfall is often followed by dry periods that kill newly germinated seedlings. Seedlings may reach 6 to 24 inches (15-61 cm) in height by the end of their first year, and roots may extend 6 to 10 inches (15-25 cm) in depth and up to 16 inches (41 cm) laterally. Roots grow more rapidly than shoots; some seedlings show little top-growth until about their third year. During the first several years, natural seedlings grow faster than planted seedlings but not as fast as sprouts. High mortality characterizes young quaking aspen stands regardless of origin. In both seedling and sprout stands natural thinning is rapid. Stems that occur below a canopy die within a few years.

Quaking aspen occur on a wide variety of sites. It grows on moist upland woods, dry mountainsides, high plateaus, mesas, avalanche chutes, talus, parklands, gentle slopes near valley bottoms, alluvial terraces, and along watercourses. It also grows on a variety soils ranging from shallow and rocky to deep loamy sands and heavy clays. The best stands in the Rocky Mountains and Great Basin are on soils derived from basic igneous rock such as basalt, and from neutral or calcareous shales and limestones. The poorest stands are on soils derived from granite.

Aspens are unique in their ability to stabilize soil and watersheds. The trees produce abundant litter that contains more nitrogen, phosphorus, potash, and calcium than leaf litter of most other hardwoods. The litter decays rapidly, forming nutrient-rich humus that may amount to 25 tons per acre (oven-dry basis). The humus reduces runoff and aids in percolation and recharge of ground water. Litter and humus layers reduce evaporation from the soil surface. Compared to conifers, more snow accumulates under quaking aspen and snowmelt begins earlier in the spring. Soil under quaking aspen thaws faster and infiltrates snow more rapidly than soil under conifers.

Wide adaptability of quaking aspen makes it well-suited for restoration and rehabilitation projects on a wide range of sites. Seedlings transplanted onto disturbed sites have shown good establishment. Seedlings have some advantages over vegetative cuttings. In large-scale greenhouse production, quaking aspen seedlings are more economical to establish and grow. Seedlings grow a taproot and secondary roots quickly, while quaking aspen cuttings can be slow to establish an adequate root system. Also, genetic diversity is greater among seedlings than cuttings. The major advantage of using quaking aspen cuttings is that clones with desirable traits can be selected as parent stock; however, quaking aspen vegetative cuttings are difficult to root.

Quaking aspen forests provide important breeding, foraging, and resting habitat for a variety of birds and mammals. Wildlife and livestock utilization of quaking aspen communities varies with species composition of the understory and relative age of the quaking aspen stand. Young stands generally provide the most browse. Although many animals browse quaking aspen year-round, it is especially valuable during fall and winter, when protein levels are high relative to other browse species.

Black cottonwood (*Populus trichocarpa*) is a fast growing, native deciduous tree, growing to 100 feet (30 m) high though occasionally as high as 160 feet (50 m). Black cottonwood grows on alluvial sites, riparian habitats, and moist woods on mountain slopes, at elevations up to 9,000’ (2750m) meters.

Black cottonwood is a pioneer species that grows best in full sunlight and commonly establishes on recently disturbed alluvium. Seeds are numerous and widely dispersed because of their cottony tufts, enabling the species to colonize even burn sites, if conditions for establishment are met. Seral communities dominated or co-dominated by cottonwood are maintained by periodic flooding or other types of soil disturbance. Black cottonwood has low drought tolerance; it is flood-tolerant but cannot tolerate brackish water or stagnant pools.

The aggressive root systems of black cottonwood are effective soil stabilizers and make the species useful in restoration of riparian areas, where it also provides protection for the aquatic environment, especially in helping to maintain low water temperatures through shading. The high nitrate uptake and extensive rooting of these trees make them useful for buffer or "filter" planting along streams in agricultural areas.

Black cottonwood provides food and cover for a variety of wildlife species, including deer, elk, and beaver. Large birds use the crowns for nesting sites and various animals rely on the trunk cavities, which commonly result from heart rot in most stands nearing maturity.

Variation within the species: black cottonwood is most commonly and widely known as the distinct species *Populus trichocarpa* but is sometimes treated as *P. balsamifera* var. *trichocarpa*, the western North American segment of the broader species *P. balsamifera*. Black cottonwood and balsam cottonwood have similar appearances, biological features, and ecology, and they hybridize and introgress where their ranges overlap. Still, they have essentially separate geographic ranges, and, like various other species of *Populus* that are separated by relatively small differences, black cottonwood and balsam poplar differ in a number of technical features.

Note: Species information for black cottonwood was derived from the USDA-NRCS PLANTS Database.

Peachleaf willow (*Salix amygdaloides*) is a rapidly growing, short-lived, small- to medium-sized deciduous tree with one to several trunks that is typically from 20 to 40 feet (6-12 m) tall but occasionally reaches 65 to 80 feet (20-24 m). Peachleaf willow regenerates primarily through the dispersal of thousands of small seeds. It is unable to produce suckers from lateral roots but will resprout from its root crown or stem base following fire or cutting. Peachleaf willows rely heavily on insect pollination, especially from bees. Seeds have a cottony down which allows them to float long distances in wind or on water. Seeds are non-dormant remaining viable for only a few days. They germinate rapidly, usually within 12 to 24 hours of dispersal if a moist seedbed is reached. The seeds contain significant amounts of chlorophyll, and photosynthesis generally occurs as soon as the seed is moistened. Regeneration may also occur through broken pieces of stems or roots, which are transported and deposited by floodwaters, and later sprout.

Peachleaf willow is found along stream and river banks, pond and lake borders, moist ravines and ditches, oxbows, roadside gullies, and prairie sloughs. It is shade intolerant and requires canopy openings to survive. I t is tolerant of poor drainage and prolonged flooding but extended immersion in water for a year or longer will cause most plants to die.

Peachleaf willow is an early successional species which pioneers floodplain alluvium. In Kansas, it occurs only as a pioneer on newly deposited alluvium; stands maintain themselves for about 30 years, until other riparian forest trees shade them out. It is shade intolerant and can therefore persist along a river's edge, where repeated flooding prevents other species from becoming established.

Cuttings of peachleaf willow can be used to revegetate disturbed riparian areas. Cuttings quickly stabilize disturbed alluvium, allowing other plants to become established. Unrooted willow stem cuttings (slips) should be planted on sites that provide sufficient moisture to start and maintain growth throughout the growing season. Since willows are sensitive to both competition and shading, dense tall grasses will reduce transplant survival and may need to be removed by cutting or by herbicide application. Although harder to plant, rooted stock is recommended for use because it has higher survival rates. A 20-inch (50 cm) cutting should be planted to a depth of 12 inches (30 cm), with 8 inches (20 cm) left aboveground. This deep planting allows for more rooting surface to extract soil moisture and higher amounts of carbohydrates as stored food reserves. Peachleaf willow cuttings root at the base of the cut; roots appear in about 10 to 20 days, and stems in about 10 days. If serious streambank erosion has resulted in a nearly vertical cut bank, slope reshaping may be necessary to enhance success of transplants. Reshaping may not be necessary if, through protective measures, existing vegetation is able to stabilize the site. With any method of revegetation, sites may need to be fenced to protect them from grazing and trampling.

Engelmann spruce (*Picea engelmannii*) is a long-lived, native, coniferous, evergreen tree. It grows best on moderately deep, well-drained, loamy sands and silts, and silt and clay loam soils developed from volcanic lava flows and sedimentary rock. It also grows well on alluvial soils where the underlying water table is readily accessible.

Engelmann spruce can be planted on disturbed sites within forest vegetation types where it naturally occurs. Planting nursery stock is more successful than direct seeding. Most commonly, 2- or 3-year-old bareroot or container-grown stock is planted following snowmelt. Since seedlings are sensitive to direct sunlight, they should be planted in the protective shade of stumps, logs, or vegetation. Artificial shade also is effective in protecting seedlings from wind and sun. Two- to 4-foot tall (0.6-1.5 m), open-grown Engelmann spruce seedlings dug from the wild before breaking dormancy have shown good survival when transplanted.

Ponderosa pine (*Pinus ponderosa*) is a native coniferous, evergreen tree. A deep, extensive root system, high sapwood:heartwood ratio, and sunken stomata make ponderosa pine highly drought tolerant throughout its range. In the northern and central portions of ponderosa pine's distribution, only limber pine and Rocky Mountain bristlecone pine (*Pinus aristida*) better withstand extended drought.

Ponderosa pine occupies relatively dry, nutrient-poor sites compared to other montane conifers but shows wide ecological amplitude throughout its distribution. Ponderosa pine in the Sangre de Cristo Mountains of Colorado is associated with dry sites.

Some exotic herbs that are commonly planted for rehabilitation may interfere with growth of ponderosa pine seedlings. Artificial ponderosa pine regeneration planted north of Flagstaff showed no significant difference ($p < 0.05$) in height and stem diameter on plots seeded to native blue grama or bottlebrush squirreltail and then weeded of other species compared to control plots kept free of all species but ponderosa pine; however, ponderosa pine seedlings on plots seeded with the exotics small burnet (*Sanguisorba minor*), yellow sweetclover (*Melilotus officinalis*), orchardgrass (*Dactylis glomerata*), or desert wheatgrass (*Agropyron desertorum*) were significantly shorter than seedlings on control plots or plots planted to the native grasses. Seedlings planted with yellow sweetclover or desert wheatgrass were significantly smaller in girth compared to those on weeded plots or plots seeded to other herbaceous species.

Ponderosa pine communities are important wildlife habitat. The forest understory provides valuable browsing and grazing for wildlife and livestock. These pine communities are critical habitat for a wide variety of birds including owls, other cavity nesters, and wild turkey. Cavity-nesting birds use ponderosa pine snags for foraging and roosting as well as nesting. Ponderosa pine also provides habitat for many rodent species, and the seeds are an important food source for some rodents and shrews. Tree squirrels (*Sciurus* and *Tamiasciurus* spp.) use ponderosa pine for nesting, and the seeds are among their most important foods. Abert's squirrel is ecologically dependent upon southwestern ponderosa pine. Red squirrels beyond the range of Abert's squirrel use ponderosa pine heavily for food and nesting. Where ranges of the 2 squirrels overlap, Abert's squirrels tend to displace red squirrels to higher-elevation forests.

Douglas-fir (*Pseudotsuga menziesii*) is a native coniferous, evergreen tree. The oldest accurately-dated Rocky Mountain Douglas-fir, 930 years old, is on the El Malpais National Monument in New Mexico. This longevity is apparently an anomaly; growing on a relatively barren lava field has protected it from fire, animals, and humans. Growth typically slows dramatically between 90 and 140 years of age.

Root morphology is variable, but when unimpeded, a taproot forms within several years. The most prominent lateral roots begin in the 1st or 2nd year of growth. Fine root production is episodic in response to changing environmental conditions; average lifespan of fine roots is usually between several days and several weeks. Rocky Mountain Douglas-fir in Colorado that were 22 to 24 feet (6.7 to 7.3 m) tall and 60 to 80 years old had root systems that extended 2.7 to 5 feet (0.82 to 1.52 m) vertically and 10 to 21 feet (3 to 6.4 m) laterally. In a 27 to 53 inch- (69 to 135 cm) deep soil taproots were 50% of final depth in 3 to 5 years and 90% in 6 to 8 years.

Rocky Mountain Douglas-fir grows on a wide variety of soils and parent materials. Substrates may be of igneous, sedimentary, or metamorphic origin. In some areas, particularly near the Great Plains, Rocky Mountain Douglas-fir is more common on basic parent materials such as limestone, andesite, and basalt. In the Sangre de Cristo Range, Colorado, acidic soils on north-facing slopes are dominated by lodgepole pine and/or Rocky Mountain Douglas-fir; more basic soils on southern aspects are dominated by quaking aspen or white fir.

Rocky Mountain Douglas-fir habitat types provide excellent hiding and thermal cover for deer, elk, bighorn sheep, small mammals, small nongame birds, and upland game birds in Colorado, Montana, Utah, and Wyoming.