adsorb readily onto soil colloids and does this affect chemical activity? If adsorbed, what are its effects on aquatic ecosystems washed into a stream? Many of these questions are asked about agricultural chemicals. Given the similarities between chemicals applied to forests, rangeland, and cropland, a comprehensive examination of nutrients and other chemicals and their effects on nonpoint-source pollution in various ecosystems should be performed.

Increasing complexity of problems such as acid deposition and chemical buildups in watersheds point to the value of long-term records. Thus, the value of research locations such as Hubbard Brook Experimental Forest, New Hampshire; Fraser Experimental Forest, Colorado; Coweeta Hydrologic Laboratory, North Carolina (50 years old); Crossett Experimental Forest, Arkansas (60 years old); and the Wind River Experimental Forest, Wyoming (70 years old) is better understood today. Today, the Forest Service maintains 84 experimental forests across the nation. However, the agency had a total of 113 experimental forests at one time or another this century; 16 were lost in the 1960s. If long-term records such as those available on the 84 experimental forests are allowed to lapse, the capability to answer difficult and complex forest related questions nay also be lost.

The final cumulative effect needing research is defining instream flows necessary to support various instream water uses in different situations. Each water withdrawal affects water volume in a stream and the suitability of that stream for fish and wildlife habitat and recreation. Considered alone, most proposed withdrawals or diversions are not large enough to cause significant impacts on suitability of instream flows. However, when all withdrawals and diversions are considered, the effects of one additional permit to withdraw or divert water may be substantial.

Land managers and owners are frequently asked to make judgments about levels of instream flows needed to avoid detrimental effects on instream water uses. Little information is available to guide these decisions. Research to develop procedures for quantifying and evaluating cumulative effects of withdrawals and diversions will be helpful in the long-term. Developing initial estimates of suitable flows needed under certain conditions could be most helpful in the short-term.

MAINTAINING LAND PRODUCTIVITY

Maintaining land productivity was mandated by the National Forest Management Act of 1976. The Forest Service's research mission could focus on soil productivity to help fulfill agency obligations under that act.

The objective of soil productivity research is to develop an ability to use site characteristics to predict the productivity of a site for a variety of resources. Work is underway to predict timber outputs from site characteristics. A major task is to define nutritional needs of major commercial timber species. For the most part, little is known about this subject. The most knowledge exists for loblolly pine, but many gaps still exist.

Relationships between soil productivity and agricultural crops are much better known than those between soil productivity and trees. Some results are available for forage from agricultural research. Interdisciplinary teams have been responsible for many advances in the agricultural field, particularly in plant breeding and seed development. A similar interdisciplinary approach may prove useful for soil productivity research in forested ecosystems. This team, having skills in genetics, silviculture, soil science, and ecological modeling could take advantage of the synergy among specialties. Not only must models be constructed, but validation methods also need to be developed.

NOTES

1. Providing technical and financial assistance to nonindustrial private forest landowners has been a Forest Service responsibility for many years. Providing assistance to rangeland owners is an SCS responsibility.

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Table A.3.—Freshwater withdrawals (million gallons per day) for municipal central supplies in the United States for 1960 to 1985, by water resource region, with projections of demand to 2040

Water resource region	1960	1965	1970	1975	1980	1985	2000	2010	2020	2030	2040
Groundwater											
New England	170	260	330	280	330	421	565	679	795	890	949
Mid-Atlantic	670	890	1100	1300	1100	1402	1885	2263	2650	2966	3163
South Atlantic-Gulf	810	990	1300	1500	1900	2422	3256	3910	4577	5124	5464
Great Lakes	363	400	700	460	440	561	754	905	1060	1187	1265
Ohio	400	510	620	700	730	930	1251	1502	1758	1969	2099
Tennessee	73	71	64	79	89	113	153	183	214	240	256
Upper Mississippi	410	570	870	1200	1100	1402	1885	2263	2650	2966	3163
Lower Mississippi	210	270	390	470	610	777	1045	1255	1469	1645	1754
Souris-Red-Rainy	15	15	20	22	27	34	46	56	65	73	78
Missouri Basin	316	340	430	490	530	675	908	1091	1277	1429	1524
Arkansas-White-Red	265	310	250	370	320	408	548	658	771	863	920
Texas-Gulf	449	510	590	670	800	1020	1371	1646	1927	2157	2301
Rio Grande	141	160	180	280	240	306	411	494	578	647	690
Upper Colorado	12	19	28	26	23	29	39	47	55	62	66
Lower Colorado	148	230	250	320	370	472	634	761	891	998	1064
Great Basin	130	110	160	190	400	510	685	823	964	1079	1150
Pacific Northwest	350	410	460	460	530	675	908	1091	1277	1429	1524
California	1300	1900	1600	1700	1900	2422	3256	3910	4577	5124	5464
Alaska	8	12	24	35	23	29	39	47	55	62	66
Hawaii	74	100	120	170	180	229	308	370	434	485	518
Caribbean	7	19	34	59	75	96	129	154	181	202	216
Total Groundwater	6321	8096	9520	10781	11717	14933	20077	24110	28225	31597	33697
Surface Water											
New England	870	950	1100	1100	1200	1170	1638	1858	2071	2239	2341
Mid-Atlantic	3160	3140	4100	4000	4300	4193	5870	6659	7423	8023	8387
South Atlantic-Gulf	970	990	1400	1700	1900	1853	2594	2942	3280	3545	3706
Great Lakes	3000	3400	3700	2700	3500	3413	4778	5420	6042	6530	6827
Ohio	1100	1300	1500	1500	1500	1463	2048	2323	2589	2799	2926
Tennessee	240	180	240	250	320	312	437	496	552	597	624
Upper Mississippi	600	580	690	1800	820	800	1119	1270	1415	1530	1599
Lower Mississippi	170	230	220	280	310	302	423	480	535	578	605
Souris-Red-Rainy	18	21	25	26	30	29	41	46	52	56	59
Missouri Basin	510	630	590	720	850	829	1160	1316	1467	1586	1658
Arkansas-White-Red	360	420	490	570	1200	1170	1638	1858	2071	2239	2341
Texas-Gulf	490	460	550	690	2200	2145	3003	3407	3798	4105	4291
Rio Grande	100	94	130	74	74	72	101	115	128	138	144
Upper Colorado	37	34	30	51	100	98	137	155	173	187	195
Lower Colorado	73	66	140	190	350	341	478	542	604	653	683
Great Basin	140	160	160	190	410	400	560	635	708	765	800
Pacific Northwest	840	840	830	710	730	712	996	1130	1260	1362	1424
California	1400	2100	1800	2000	2200	2145	3003	3407	3798	4105	4291
Alaska	15	20	35	46	30	29	41	46	52	56	59
Hawaii	11	8	12	11	15	15	20	23	26	28	29
Caribbean	62	120	170	230	280	273	382	434	483	522	546
Total Surface Water	14166	15743	17912	18838	22319	21765	30466	34562	38527	41643	43532
Total Withdrawals											
New England	1040	1210	1430	1380	1530	1650	2265	2621	2971	3251	3466
Mid-Atlantic	3830	4030	5200	5300	5400	5822	7995	9250	10487	11473	12232
South Atlantic-Gulf	1780	1980	2700	3200	3800	4097	5626	6509	7380	8074	8608
Great Lakes	3363	3800	4400	3160	3940	4248	5833	6749	7652	8371	8925
Ohio	1500	1810	2120	2200	2230	2404	3302	3820	4331	4738	5052
Tennessee	313	251	304	329	409	441	606	701	794	869	926
Upper Mississippi	1010	1150	1560	3000	1920	2070	2843	3289	3729	4079	4349
Lower Mississippi	380	500	610	750	920	992	1362	1576	1787	1955	2084
Souris-Red-Rainy	33	36	45	48	57	61	84	98	111	121	129
Missouri Basin	826	970	1020	1210	1380	1488	2043	2364	2680	2932	3126
Arkansas-White-Red	625	730	740	940	1520	1639	2250	2604	2952	3230	3443
Texas-Gulf	935	970	1140	1360	3000	3235	4442	5139	5826	6374	6796
Rio Grande	245	254	310	354	314	339	465	538	610	667	711
Upper Colorado	41	53	58	77	123	133	182	211	239	261	279
Lower Colorado	229	296	390	510	720	776	1066	1233	1398	1530	1631
Great Basin	270	270	320	380	810	873	1199	1387	1573	1721	1835
Pacific Northwest	1190	1250	1290	1170	1260	1359	1865	2158	2447	2677	2854
California	2700	4000	3400	3700	4100	4421	6070	7023	7962	8711	9288
Alaska	23	32	59	81	53	57	78	91	103	113	120
Hawaii	85	108	132	181	195	210	289	334	379	414	442
Caribbean	69	139	204	289	355	383	526	608	689	754	804
Total Withdrawals	20487	23839	27432	29619	34036	36699	50392	58301	66100	72316	77100

Source: Data for 1960 through 1985 from USGS Circulars. Data for 2000 through 2040 are Forest Service estimates based upon trends in the historical data.

Table A.4.—Freshwater withdrawals (million gallons per day) for industrial self-supplied use in the United States for 1960 to 1985, by water resource region, with projections of demand to 2040

Water resource region	1960	1965	1970	1975	1980	1985	2000	2010	2020	2030	2040
Groundwater											
New England	130	140	180	200	180	81	111	128	147	166	187
Mid-Atlantic	630	700	1000	630	580	261	438	505	579	656	737
South Atlantic-Gulf	1140	1300	1500	1900	1800	809	1031	1188	1362	1542	1734
Great Lakes	421	360	300	300	630	283	244	281	322	365	410
Ohio	600	890	750	740	1300	585	553	638	731	828	930
Tennessee	230	49	45	140	97	44	56	64	74	84	94
Upper Mississippi	480	620	630	690	650	292	390	450	516	584	657
Lower Mississippi	450	470	980	950	1000	450	581	670	767	869	977
Souris-Red-Rainy	5	7	5	2	4	2	2	3	3	3	4
Missouri Basin	183	270	360	400	380	171	226	261	299	338	380
Arkansas-White-Red	310	400	250	290	320	144	170	197	225	255	287
Texas-Gulf	352	340	390	340	240	108	192	222	254	288	323
Rio Grande	78	75	110	84	16	7	42	48	55	62	70
Upper Colorado	5	8	12	28	23	10	12	14	16	19	21
Lower Colorado	75	110	170	210	160	72	107	123	141	160	180
Great Basin	110	65	85	120	130	58	66	77	88	99	112
Pacific Northwest	400	400	620	2100	2300	1034	995	1147	1314	1489	1674
California	300	480	410	390	430	193	244	281	322	365	410
Alaska	12	7	8	0	6	3	3	3	4	4	5
Hawaii	110	65	160	97	9	4	53	61	70	79	89
Caribbean	29	38	40	72	85	38	39	45	52	58	66
Total Groundwater	6050	6794	8005	9683	10340	4650	5555	6405	7339	8314	9345
Surface Water											
New England	1100	1100	1100	1300	1300	898	907	987	1064	1139	1212
Mid-Atlantic	2830	3200	5600	3700	2900	2003	2990	3255	3508	3755	3995
South Atlantic-Gulf	1970	1600	2100	2600	4100	2832	2157	2348	2530	2709	2882
Great Lakes	7200	8700	8300	6900	5100	3523	4976	5416	5837	6249	6647
Ohio	6600	7700	5100	5200	3700	2556	3431	3735	4025	4309	4584
Tennessee	1200	1000	1300	1500	2000	1382	1176	1281	1380	1477	1572
Upper Mississippi	1200	1000	1100	1100	2600	1796	1176	1281	1380	1477	1572
Lower Mississippi	940	2100	3100	3300	3200	2211	2353	2561	2760	2955	3144
Souris-Red-Rainy	80	98	73	31	5	3	27	29	31	34	36
Missouri Basin	280	180	160	120	300	207	142	155	167	179	190
Arkansas-White-Red	681	440	370	630	530	366	375	408	440	471	501
Texas-Gulf	819	570	1000	330	280	193	395	430	463	496	527
Rio Grande	11	8	97	9	0	0	26	28	30	33	35
Upper Colorado	28	30	52	63	560	387	165	180	194	208	221
Lower Colorado	25	27	42	58	86	59	46	50	53	57	61
Great Basin	200	140	130	120	370	256	152	165	178	191	203
Pacific Northwest	1700	1400	1100	1300	1400	967	931	1014	1093	1170	1244
California	64	85	48	55	58	40	39	43	46	50	53
Alaska	70	95	100	90	120	83	76	83	89	95	102
Hawaii	33	51	100	94	36	25	56	61	66	71	75
Caribbean	130	140	180	98	30	21	75	82	89	95	101
Total Suface Water	27161	29664	31152	28598	28675	19810	21673	23591	25425	27218	28955
Wastewater											
New England	0	0	0	0	0	0	0	0	0	0	0
Mid-Atlantic	70	130	130	150	160	120	266	312	359	406	453
South Atlantic-Gulf	0	0	0	0	0	0	0	0	0	0	0
Great Lakes	0	0	0	0	0	0	0	0	0	0	0
Ohio	0	0	0	0	0	0	0	0	0	0	0
Tennessee	0	0	0	0	0	0	0	0	0	0	0
Upper Mississippi	0	0	0	0	0	0	0	0	0	0	0
Lower Mississippi	0	0	0	0	0	0	0	0	0	0	0
Souris-Red-Rainy	0	0	0	0	0	0	0	0	0	0	0
Missouri Basin	0	0	0	0	0	0	0	0	0	0	0
Arkansas-White-Red	0	2	5	4	0	0	5	6	7	8	9
Texas-Gulf	0	2	1	5	0	0	4	4	5	6	6
Rio Grande	0	4	0	0	0	0	0	0	0	0	0
Upper Colorado	0	0	0	0	0	0	0	0	0	0	0
Lower Colorado	0	1	0	7	12	9	11	13	15	18	20
Great Basin	0	0	0	1	1	1	1	1	2	2	2
Pacific Northwest	0	0	0	0	0	0	0	0	0	0	0
California	1	1	4	2	9	7	9	11	12	14	15
Alaska	0	0	0	0	0	0	0	0	0	0	0
Hawaii	0	0	9	0	10	8	11	13	15	18	20
Caribbean	0	0	0	0	0	0	0	0	0	0	0
Total Wastewater	71	140	149	169	192	144	308	362	416	471	525
Total Withdrawals											
New England	1230	1240	1280	1500	1480	928	996	1097	1199	1300	1401
Mid-Atlantic	3460	3900	6600	4330	3480	2182	3369	3712	4054	4397	4739
South Atlantic-Gulf	3110	2900	3600	4500	5900	3699	3273	3606	3939	4272	4604
Great Lakes	7621	9060	8600	7200	5730	3592	5034	5546	6057	6569	7081
Ohio	7200	8590	5850	5940	5000	3135	3926	4325	4724	5123	5522
Tennessee	1430	1049	1345	1640	2097	1315	1188	1309	1430	1551	1671
Upper Mississippi	1680	1620	1730	1790	3250	2038	1583	1744	1905	2066	2227
Lower Mississippi	1390	2570	4080	4250	4200	2633	2930	3227	3525	3823	4121
Souris-Red-Rainy	85	105	78	33	9	6	28	31	34	37	39
Missouri Basin	463	450	520	520	680	426	402	443	484	525	566
Arkansas-White-Red	991	840	620	920	850	533	559	616	672	729	786
Texas-Gulf	1168	910	1390	670	520	326	603	665	726	787	849
Rio Grande	106	83	207	93	16	10	74	81	89	96	104
Upper Colorado	29	38	64	91	583	365	173	190	208	225	243
Lower Colorado	104	137	212	268	246	154	170	187	204	222	239
Great Basin	310	205	215	240	500	313	223	246	269	291	314
Pacific Northwest	2100	1800	1720	3400	3700	2320	2062	2272	2482	2691	2901
California	364	565	458	445	488	306	325	358	391	424	457
Alaska	82	102	108	90	126	79	76	83	91	99	107
Hawaii	143	116	260	191	45	28	116	128	140	151	163
Caribbean	159	178	220	170	115	72	118	130	142	154	166
Total Withdrawals	33225	36458	39157	38281	39015	24460	27228	29996	32764	35532	38300

Source: Data for 1960 through 1985 from USGS Circulars. Data for 2000 through 2040 are Forest Service estimates based upon trends in the historical data.

Table A.5.—Freshwater withdrawals (million gallons per day) for domestic self-supplied use in the United States for 1960 to 1985, by water resource region, with projections of demand to 2040

Water resource region	1960	1965	1970	1975	1980	1985	2000	2010	2020	2030	2040
Groundwater											
New England	37	95	94	110	130	129	171	191	209	223	231
Mid-Atlantic	260	270	340	380	430	428	566	632	691	738	764
South Atlantic-Gulf	320	540	460	510	720	717	948	1058	1158	1235	1279
Great Lakes	290	260	270	280	270	269	356	397	434	463	480
Ohio	190	240	240	280	290	289	382	426	466	497	515
Tennessee	57	64	51	42	61	61	80	90	98	105	108
Upper Mississippi	160	190	200	190	290	289	382	426	466	497	515
Lower Mississippi	50	63	110	77	94	94	124	138	151	161	167
Souris-Red-Rainy	10	13	19	24	23	23	30	34	37	39	41
Missouri Basin	98	94	110	130	210	209	277	309	338	360	373
Arkansas-White-Red	69	98	88	100	130	129	171	191	209	223	231
Texas-Gulf	30	33	80	100	120	119	158	176	193	206	213
Rio Grande	9	10	20	25	33	33	43	49	53	57	59
Upper Colorado	1	4	6	6	15	15	20	22	24	26	27
Lower Colorado	1	10	24	36	37	37	49	54	59	63	66
Great Basin	14	26	37	28	32	32	42	47	51	55	57
Pacific Northwest	39	95	220	220	230	229	303	338	370	394	409
California	190	81	120	120	130	129	171	191	209	223	231
Alaska	5	6	4	6	11	11	14	16	18	19	20
Hawaii	6	0	0	0	4	4	5	6	6	7	7
Caribbean	2	1	0	2	5	5	7	7	8	9	9
Total Groundwater	1838	2193	2493	2666	3265	3251	4300	4800	5250	5600	5800
Surface Water											
New England	2	5	2	2	1	0	1	1	0	0	0
Mid-Atlantic	2	1	2	2	2	1	1	1	1	0	0
South Atlantic-Gulf	0	0	2	2	0	0	0	0	0	0	0
Great Lakes	10	10	7	4	3	1	2	1	1	1	1
Ohio	31	41	33	25	21	10	11	9	6	4	4
Tennessee	1	0	1	0	0	0	0	0	0	0	0
Upper Mississippi	17	16	6	8	10	5	5	3	2	2	2
Lower Mississippi	5	1	0	1	1	0	1	0	0	0	0
Souris-Red-Rainy	0	0	0	0	0	0	0	0	0	0	0
Missouri Basin	15	12	11	14	22	10	9	7	5	4	4
Arkansas-White-Red	5	6	6	7	25	12	9	7	4	3	3
Texas-Gulf	0	0	0	0	0	0	0	0	0	0	0
Rio Grande	0	0	1	1	1	0	1	0	0	0	0
Upper Colorado	14	2	1	1	43	20	13	10	7	5	5
Lower Colorado	0	0	0	0	0	0	0	0	0	0	0
Great Basin	2	1	1	1	4	2	1	1	1	1	1
Pacific Northwest	30	6	29	34	32	15	17	12	8	6	6
California	17	9	9	9	9	4	5	3	2	2	2
Alaska	1	2	2	3	0	0	1	0	0	0	0
Hawaii	2	0	0	0	0	0	0	0	0	0	0
Caribbean	9	4	3	18	3	1	5	3	2	2	2
Total Surface Water	163	116	116	132	177	83	80	60	40	30	30
Total Withdrawals											
New England	39	100	96	112	131	127	167	186	202	241	222
Mid-Atlantic	262	271	342	382	432	418	550	615	665	707	732
South Atlantic-Gulf	320	540	462	512	720	697	916	1025	1109	1178	1220
Great Lakes	300	270	277	284	273	264	347	389	420	447	462
Ohio	221	281	273	305	311	301	396	443	479	509	527
Tennessee	58	64	52	42	61	59	78	87	942	100	103
Upper Mississippi	177	206	206	198	300	291	382	427	462	491	508
Lower Mississippi	55	64	110	78	95	92	121	135	146	155	161
Souris-Red-Rainy	10	13	19	24	23	22	29	33	35	38	39
Missouri Basin	113	106	121	144	232	225	295	330	357	379	393
Arkansas-White-Red	74	104	94	107	155	150	197	221	239	254	263
Texas-Gulf	33	33	80	100	120	116	153	171	185	196	203
Rio Grande	10	10	21	26	34	33	43	48	52	56	58
Upper Colorado	6	6	7	7	58	56	74	83	89	95	98
Lower Colorado	10	10	24	36	37	36	47	53	57	61	63
Great Basin	16	27	38	29	36	35	46	51	55	59	61
Pacific Northwest	69	101	249	254	262	254	333	373	403	429	444
California	207	90	129	129	139	135	177	198	214	227	235
Alaska	6	8	6	9	11	11	14	16	17	18	19
Hawaii	8	0	0	0	4	4	5	6	6	7	7
Caribbean	11	5	3	20	8	8	10	11	12	13	14
Total Withdrawals	2005	2309	2609	2798	3442	3334	4380	4900	5300	5630	5830

Source: Data for 1960 through 1985 from USGS Circulars. Data for 2000 through 2040 are Forest Service estimates based upon trends in the historical data.

Table A.6.—Freshwater withdrawals (million gallons per day) for livestock watering use in the United States from 1960 to 1985, by water resource region, with projections of demand to 2040

Water resource region	1960	1965	1970	1975	1980	1985	2000	2010	2020	2030	2040
Groundwater											
New England	7	6	7	4	4	10	6	7	7	7	8
Mid-Atlantic	38	37	46	68	79	196	83	88	93	96	98
South Atlantic-Gulf	63	79	110	150	130	322	167	179	188	195	199
Great Lakes	64	57	62	60	64	159	80	85	90	93	95
Ohio	58	54	58	78	63	156	85	91	96	99	101
Tennessee	10	16	11	9	12	30	14	15	15	16	16
Upper Mississippi	200	260	200	200	220	546	266	284	299	310	316
Lower Mississippi	18	22	22	25	17	42	27	29	31	32	33
Souris-Red-Rainy	11	14	12	13	10	25	15	16	17	17	18
Missouri Basin	182	210	270	300	270	670	360	385	405	420	428
Arkansas-White-Red	56	60	66	86	85	211	102	109	114	118	121
Texas-Gulf	10	53	71	85	78	193	100	107	113	117	119
Rio Grande	8	38	17	18	26	64	26	28	29	30	31
Upper Colorado	1	2	6	6	2	5	6	6	7	7	7
Lower Colorado	9	16	18	32	12	30	27	28	30	31	32
Great Basin	10	23	35	38	34	84	46	49	52	53	54
Pacific Northwest	21	24	18	28	21	52	29	31	32	33	34
California	57	34	38	42	36	89	50	53	56	58	59
Alaska	0	0	0	0	0	0	0	0	0	0	0
Hawaii	1	1	1	6	5	12	5	5	6	6	6
Caribbean	1	1	1	1	15	37	7	8	8	8	9
Total Groundwater	825	1007	1069	1249	1183	2934	1501	1603	1688	1749	1783
Surface Water											
New England	6	6	5	5	5	11	7	7	8	8	8
Mid-Atlantic	26	23	33	27	32	69	41	44	46	48	49
South Atlantic-Gulf	67	68	51	96	110	239	114	122	129	134	136
Great Lakes	28	22	24	25	20	43	31	33	35	36	37
Ohio	69	80	84	110	90	195	126	135	142	148	151
Tennessee	28	21	20	28	29	63	34	36	39	40	41
Upper Mississippi	91	56	60	63	51	111	77	82	87	90	92
Lower Mississippi	23	23	33	23	25	54	36	38	41	42	43
Souris-Red-Rainy	10	6	2	3	4	9	4	4	5	5	5
Missouri Basin	137	160	170	180	120	261	208	223	235	244	249
Arkansas-White-Red	86	93	120	140	150	326	182	194	205	213	217
Texas-Gulf	8	37	42	51	120	261	94	101	107	111	113
Rio Grande	6	31	20	20	6	13	20	22	23	24	24
Upper Colorado	8	9	12	9	91	198	50	53	56	58	59
Lower Colorado	3	3	10	17	5	11	14	15	16	17	17
Great Basin	11	6	6	10	12	26	12	13	14	15	15
Pacific Northwest	38	35	34	25	34	74	41	44	47	48	49
California	25	50	54	58	50	109	72	77	81	84	86
Alaska	0	0	0	0	0	0	0	0	0	0	0
Hawaii	2	3	6	0	0	0	3	3	3	3	3
Caribbean	3	5	8	8	15	33	14	15	16	16	16
Total Surface Water	675	737	794	898	969	2104	1179	1261	1332	1383	1411
Total Withdrawals											
New England	13	12	12	9	9	21	13	14	15	15	16
Mid-Atlantic	64	60	79	95	111	260	124	132	140	145	148
South Atlantic-Gulf	130	147	161	246	240	562	282	301	317	329	335
Great Lakes	92	79	86	85	84	197	111	119	125	130	132
Ohio	127	134	142	188	153	358	210	224	237	245	250
Tennessee	38	37	31	37	41	96	47	51	53	55	57
Upper Mississippi	291	316	260	263	271	634	346	369	389	403	412
Lower Mississippi	41	45	55	48	42	98	63	67	71	74	75
Souris-Red-Rainy	21	20	14	16	14	33	19	20	22	22	23
Missouri Basin	319	370	440	480	390	913	570	609	642	666	679
Arkansas-White-Red	142	153	186	226	235	550	282	301	317	329	335
Texas-Gulf	18	90	113	136	198	463	195	208	219	227	232
Rio Grande	14	69	37	38	32	75	47	50	52	54	55
Upper Colorado	8	11	18	15	93	218	55	59	62	64	65
Lower Colorado	14	19	28	49	17	40	41	44	46	48	49
Great Basin	21	29	41	48	46	108	59	63	66	69	70
Pacific Northwest	59	59	52	53	55	129	70	74	78	81	83
California	82	84	92	100	86	201	121	129	136	141	144
Alaska	0	0	0	0	0	0	0	0	0	0	0
Hawaii	3	4	7	6	5	12	8	8	9	9	9
Caribbean	4	6	9	9	30	70	21	22	24	24	25
Total Withdrawals	1501	1744	1863	2147	2152	5038	2683	2864	3020	3131	3195

Source: Data for 1960 through 1985 from USGS Circulars. Data for 2000 through 2040 are Forest Service estimates based upon trends in the historical data.

Table A.7.—Freshwater withdrawals (million gallons per day) for thermoelectric steam cooling use in the United States for 1960 to 1985, by Forest Service Region, with projections of demand to 2040

Forest Service region	1960	1965	1970	1975	1980	1985	2000	2010	2020	2030	2040
Groundwater											
Northern	3	1	1	2	2	1	1	1	1	1	1
Rocky Mountain	26	79	341	347	89	65	72	71	71	70	69
Southwestern	23	23	49	52	51	43	48	47	47	46	46
Intermountain	0	1	7	14	12	17	19	19	19	19	18
Pacific Southwest	303	330	383	521	1020	95	106	104	103	102	102
Pacific Northwest	0	0	0	0	0	1	1	1	1	1	1
Southern	530	618	167	172	208	201	223	220	217	215	214
Eastern	36	62	486	300	208	206	229	226	223	221	220
Alaskan	0	1	1	2	8	4	5	5	5	5	5
Total Groundwater	920	1115	1435	1410	1598	633	703	694	686	679	676
Surface Water											
Northern	65	136	413	780	1101	958	1153	1284	1414	1544	1675
Rocky Mountain	1526	984	1095	1119	2842	2873	3457	3848	4239	4630	5020
Southwestern	51	16	22	132	103	69	83	92	102	111	121
Intermountain	128	198	175	136	192	74	89	99	109	119	129
Pacific Southwest	152	697	1254	1131	1110	416	500	557	614	670	727
Pacific Northwest	3698	5	26	29	23	439	528	588	648	707	767
Southern	22571	27311	39400	48258	58076	49796	59926	66700	73475	80249	87021
Eastern	44849	61154	75865	78019	83295	75592	90970	101254	111538	121821	132101
Alaskan	86	1	68	18	22	26	31	35	38	42	45
Total Surface Water	73125	90503	118319	129622	146764	130243	156738	174457	192176	209893	227606
Total Withdrawals											
Northern	68	137	414	781	1103	959	0	1284	1413	1543	1673
Rocky Mountain	1552	1063	1437	1465	2931	2938	3534	3932	4329	4727	5124
Southwestern	74	39	71	184	154	112	135	150	165	180	195
Intermountain	128	199	182	150	204	91	110	122	135	147	159
Pacific Southwest	455	1027	1639	1651	2131	511	614	684	753	822	891
Pacific Northwest	3698	5	26	29	23	440	529	588	648	707	767
Southern	23101	27929	39565	48432	58284	49996	60145	66910	73676	80441	87207
Eastern	44883	61217	76349	78321	83502	75798	91184	101441	111698	121955	132212
Alaskan	86	2	69	20	30	30	36	41	45	49	53
Total Withdrawals	74045	91618	119754	131032	148362	130876	157441	175151	192862	210572	228282

Source: Data for 1960 through 1985 from USGS Circulars. Data for 2000 through 2040 are Forest Service estimates based upon trends in the historical data.

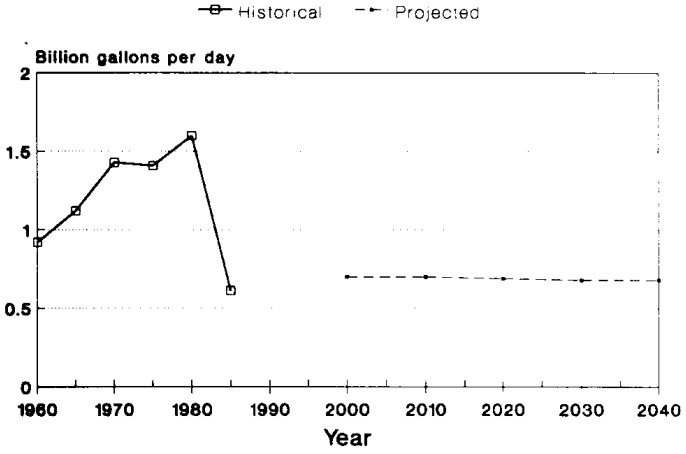


Figure A.3.—Thermoelectric steam cooling, fresh groundwater withdrawals.

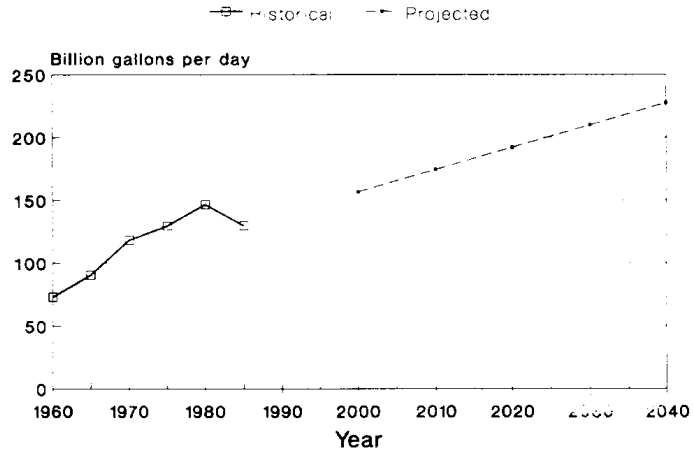


Figure A.4.—Thermoelectric steam cooling, fresh surface water withdrawals.

Table A.8.—Freshwater withdrawals (million gallons per day) for irrigation use in the United States for 1960 to 1985, by Forest Service Region, with projections of demand to 2040

Forest Service region	1960	1965	1970	1975	1980	1985	2000	2010	2020	2030	2040
Groundwater											
Northern	541	626	551	929	1085	878	867	910	950	977	1001
Rocky Mountain	4077	5170	7534	12564	15037	12127	11972	12569	13118	13496	13823
Southwestern	3910	5100	5100	5500	5300	3670	3623	3804	3970	4084	4183
Intermountain	2442	3058	2469	3802	4341	3783	3735	3921	4092	4210	4312
Pacific Southwest	8880	11590	16550	17430	18460	11436	11290	11853	12371	12727	13036
Pacific Northwest	660	740	980	1150	1110	1100	1086	1140	1190	1224	1254
Southern	9819	15429	12054	15300	14759	12645	12484	13107	13679	14073	14414
Eastern	127	280	296	429	862	857	846	888	927	953	977
Alaskan	0	0	0	0	0	0	0	0	0	0	0
Total Groundwater	30403	41572	45251	57074	61153	56292	55575	58347	60894	62649	64167
Surface Water											
Northern	6977	9314	10634	13771	12864	12128	12250	13143	14017	14736	15424
Rocky Mountain	11521	15999	17695	14652	17969	17310	17485	18759	20007	21033	22015
Southwestern	2620	3500	3900	4400	5400	4670	4717	5061	5398	5674	5939
Intermountain	11823	15653	16967	16231	15551	20364	20570	22069	23537	24745	25900
Pacific Southwest	9940	14580	17680	18520	19450	21070	21283	22834	24353	25602	26797
Pacific Northwest	7900	9300	9500	10400	11100	9550	9647	10349	11038	11604	12146
Southern	2706	5909	4956	5884	7034	6174	6236	6691	7136	7502	7852
Eastern	110	140	217	256	435	430	434	466	497	522	546
Alaskan	0	0	0	0	0	0	0	0	0	0	0
Total Surface Water	54069	74360	81686	85012	90456	85767	86635	92947	99129	104215	109080
Wastewater											
Northern	0	0	0	1	3	0	1	1	1	1	1
Rocky Mountain	39	0	86	80	2	5	23	20	18	16	14
Southwestern	0	78	22	54	3	29	23	20	18	16	14
Intermountain	48	52	59	9	13	17	10	9	8	7	6
Pacific Southwest	430	400	177	160	150	253	149	132	116	102	90
Pacific Northwest	0	3	3	4	4	5	3	3	3	2	2
Southern	34	0	15	53	70	119	64	57	50	44	39
Eastern	10	1	0	0	30	26	15	13	11	10	9
Alaskan	0	0	0	0	0	0	0	0	0	0	0
Total Wastewater	562	535	366	365	279	453	290	257	225	199	176
Total Withdrawals											
Northern	7518	9940	11186	14701	13952	13006	13005	13831	14624	15246	15827
Rocky Mountain	15637	21169	25316	27295	33008	29441	29439	31309	33105	34513	35827
Southwestern	6530	8678	9022	9954	10703	8369	8368	8900	9411	9811	10184
Intermountain	14313	18763	19495	20041	19905	24164	24162	25696	27171	28327	29405
Pacific Southwest	19250	26570	34407	36110	38060	32759	32757	34837	36836	38403	39865
Pacific Northwest	8560	10043	10483	11554	12214	10655	10654	11330	11981	12490	12966
Southern	12559	21338	17025	21237	21863	18938	18936	20139	21294	22200	23045
Eastern	247	421	513	685	1327	1312	1312	1395	1475	1538	1597
Alaskan	0	0	0	0	0	0	0	0	0	0	0
Total Withdrawals	84933	116467	127303	142451	151888	142512	142500	151551	160248	167063	173423

Source: Data for 1960 through 1980 from USGS Circulars. In addition to the irrigation of crops, this data also includes irrigation of recreational facilities (e.g. golf courses and ski slopes) and other uses (e.g. landscape plantings) if water source is self-supplied. Data for 1985 from the Soil Conservation Service, modified by additional nonagricultural irrigation use. Data for 2000 through 2040 are Forest Service estimates based upon trends in the historical data.

Table A.9.—Freshwater withdrawals (million gallons per day) for municipal central supplies in the United States for 1960 to 1985, by Forest Service Region, with projections of demand to 2040

Forest Service region	1960	1965	1970	1975	1980	1985	2000	2010	2020	2030	2040
Groundwater											
Northern	62	66	75	94	113	135	182	218	256	286	305
Rocky Mountain	350	353	419	471	466	550	740	889	1040	1165	1242
Southwestern	184	261	322	443	488	583	784	941	1102	1234	1316
Intermountain	221	256	313	345	593	538	723	868	1016	1137	1213
Pacific Southwest	1276	1995	1730	1884	2072	4202	5649	6784	7942	8891	9482
Pacific Northwest	371	311	359	337	365	422	567	681	798	893	952
Southern	1796	2185	2626	3182	3811	4471	6011	7219	8451	9460	10089
Eastern	2053	2657	3652	3989	3786	3991	5366	6443	7543	8444	9006
Alaskan	8	12	24	35	23	41	55	66	77	87	93
Total Ground Water	6321	8096	9520	10781	11717	14933	20077	24110	28225	31597	33697
Surface Water											
Northern	115	95	116	121	132	143	200	227	253	273	286
Rocky Mountain	418	532	500	637	813	911	1275	1447	1613	1743	1822
Southwestern	66	71	136	147	281	261	365	414	462	499	522
Intermountain	183	193	200	265	533	374	523	594	662	716	748
Pacific Southwest	1410	2068	1810	2018	2216	1461	2045	2320	2586	2795	2922
Pacific Northwest	789	775	769	662	670	948	1327	1505	1678	1814	1896
Southern	2531	2801	3630	4258	6986	6322	8850	10039	11191	12096	12645
Eastern	8640	9187	10716	10683	10658	11310	15831	17960	20020	21639	22621
Alaskan	15	20	35	46	30	35	49	56	62	67	70
Total Surface Water	14166	15743	17912	18838	22319	21765	30466	34562	38527	41643	43532
Total Withdrawals											
Northern	177	160	191	215	244	278	382	442	501	548	584
Rocky Mountain	768	885	919	1108	1279	1462	2007	2322	2633	2880	3071
Southwestern	250	330	457	590	770	844	1159	1341	1520	1663	1773
Intermountain	403	447	512	609	1127	912	1252	1448	1642	1796	1915
Pacific Southwest	2684	4054	3536	3900	4290	5663	7776	8996	10200	11159	11897
Pacific Northwest	1160	1087	1128	1000	1035	1370	1881	2176	2468	2700	2878
Southern	4326	4978	6253	7439	10798	10794	14821	17147	19441	21269	22676
Eastern	10696	11867	14378	14677	14439	15301	21010	24308	27559	30151	32146
Alaskan	23	32	59	81	53	76	104	121	137	150	160
Total Withdrawals	20487	23839	27432	29619	34036	36699	50392	58301	66100	72316	77100

Source: Data for 1960 through 1985 from USGS Circulars. Data for 2000 through 2040 are Forest Service estimates based upon trends in the historical data.

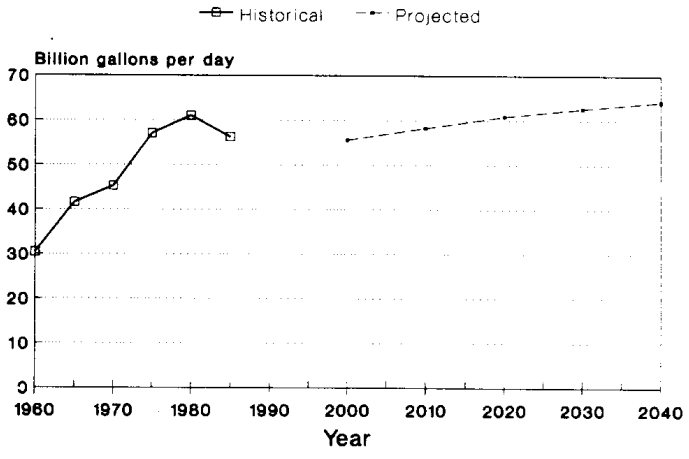


Figure A.5.—Irrigation, fresh groundwater withdrawals.

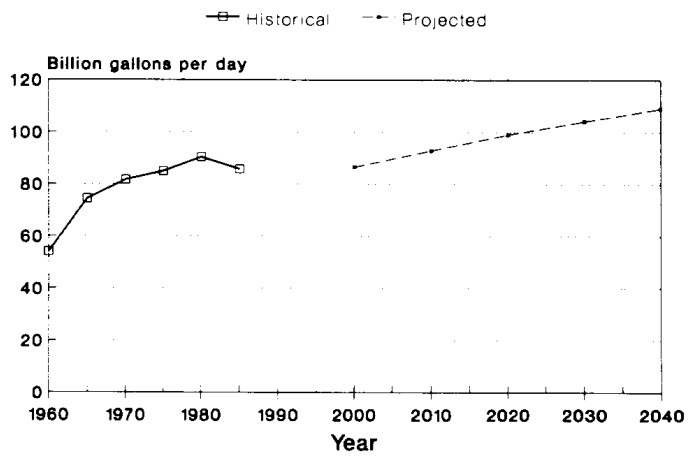


Figure A.6.—Irrigation, fresh surface water withdrawals.

Table A.10.—Freshwater withdrawals (million gallons per day) for industrial self-supplied use in the United States for 1960 to 1985, by Forest Service Region, with projections of demand to 2040

Forest Service region	1960	1965	1970	1975	1980	1985	2000	2010	2020	2030	2040
Groundwater											
Northern	57	48	114	446	497	76	91	104	120	136	152
Rocky Mountain	230	210	342	385	332	156	186	215	246	279	313
Southwestern	79	171	222	254	147	68	82	94	108	122	137
Intermountain	175	155	373	1625	1804	187	223	257	295	334	375
Pacific Southwest	415	542	569	485	430	420	502	579	663	751	844
Pacific Northwest	211	298	260	209	230	159	190	219	251	284	320
Southern	2747	2621	3268	3716	3646	1872	2236	2578	2954	3346	3761
Eastern	2124	2743	2849	2563	3248	1704	2036	2348	2690	3048	3425
Alaskan	12	7	8	0	6	8	10	11	13	14	16
Total Groundwater	6050	6794	8005	9683	10340	4650	5555	6405	7339	8314	9345
Surface Water											
Northern	193	112	149	120	108	40	44	48	51	55	58
Rocky Mountain	221	181	187	198	827	146	160	174	188	201	214
Southwestern	20	26	38	25	20	8	9	10	10	11	12
Intermountain	233	212	260	277	564	38	42	46	49	53	56
Pacific Southwest	76	102	128	136	81	121	132	144	155	166	177
Pacific Northwest	3234	1242	998	1130	1245	674	737	803	865	926	985
Southern	6473	6454	9089	9262	10524	7711	8437	9183	9897	10595	11271
Eastern	16641	21241	20202	17360	15187	10965	11996	13058	14073	15066	16027
Alaskan	71	94	100	90	120	106	116	126	136	146	155
Total Surface Water	27161	29664	31152	28598	28675	19810	21673	23591	25425	27218	28955
Wastewater											
Northern	0	0	0	0	0	0	0	0	0	0	0
Rocky Mountain	0	0	0	0	0	0	0	0	0	0	0
Southwestern	0	0	0	0	2	5	4	5	6	6	7
Intermountain	0	1	0	8	11	0	12	14	16	18	20
Pacific Southwest	1	1	13	2	19	3	15	17	20	22	25
Pacific Northwest	0	0	0	0	0	1	0	0	0	1	1
Southern	0	7	6	9	0	55	39	46	53	60	66
Eastern	70	131	130	150	160	81	238	280	322	364	406
Alaskan	0	0	0	0	0	0	0	0	0	0	0
Total Wastewater	71	140	149	169	192	144	308	362	416	471	525
Total Withdrawals											
Northern	250	160	264	567	605	116	129	142	155	168	181
Rocky Mountain	454	391	528	584	1161	302	336	370	405	439	473
Southwestern	101	197	260	280	167	76	85	94	102	111	120
Intermountain	411	366	634	1907	2366	225	251	276	302	327	353
Pacific Southwest	498	644	697	623	510	541	602	663	724	786	847
Pacific Northwest	3437	1540	1258	1339	1480	833	927	1022	1116	1210	1304
Southern	9247	9075	12358	12979	14203	9583	10667	11752	12836	13921	15005
Eastern	18745	23985	23052	19912	18488	12670	14103	15537	16971	18405	19838
Alaskan	83	101	108	90	126	114	127	140	153	166	179
Total Withdrawals	33225	36458	39157	38281	39105	24460	27228	29996	32764	35532	38300

Source: Data for 1960 through 1985 from USGS Circulars. Data for 2000 through 2040 are Forest Service estimates based upon trends in the historical data.

Table A.11.—Freshwater withdrawals (million gallons per day) for domestic self-supplied use in the United States for 1960 to 1985, by Forest Service Region, with projections of demand to 2040

Forest Service region	1960	1965	1970	1975	1980	1985	2000	2010	2020	2030	2040
Groundwater											
Northern	23	27	32	44	82	48	61	68	74	79	81
Rocky Mountain	71	80	97	110	168	105	134	148	162	172	178
Southwestern	37	10	38	56	64	64	81	90	98	104	108
Intermountain	24	46	47	54	73	80	101	112	122	130	134
Pacific Southwest	202	79	120	120	133	131	166	184	201	213	221
Pacific Northwest	18	74	203	189	169	168	213	236	258	274	283
Southern	542	888	869	928	1238	1115	1416	1568	1709	1815	1877
Eastern	915	984	1083	1160	1327	1531	1945	2153	2347	2492	2578
Alaskan	5	6	4	6	11	9	11	13	14	15	15
Total Groundwater	1838	2193	2493	2666	3265	3251	4131	4573	4985	5293	5475
Surface Water											
Northern	1	0	2	1	1	0	0	0	0	0	0
Rocky Mountain	4	9	7	7	68	3	5	5	5	5	5
Southwestern	3	2	1	1	1	1	2	2	2	2	2
Intermountain	3	2	2	4	6	2	3	3	3	3	3
Pacific Southwest	22	9	9	9	10	30	47	47	47	47	47
Pacific Northwest	30	5	26	30	30	10	15	15	15	15	15
Southern	22	25	17	29	14	16	25	25	25	25	25
Eastern	77	63	50	47	47	20	31	31	31	31	31
Alaskan	1	2	2	3	0	1	1	1	1	1	1
Total Surface Water	163	116	116	132	177	83	129	129	129	129	129
Total Withdrawals											
Northern	25	27	34	45	83	48	68	76	83	89	92
Rocky Mountain	76	89	104	117	235	109	152	170	187	200	207
Southwestern	41	12	39	57	65	65	91	102	113	120	125
Intermountain	27	48	49	58	79	82	115	128	141	150	156
Pacific Southwest	224	87	129	129	143	161	225	252	277	296	307
Pacific Northwest	46	78	229	219	199	178	248	278	306	326	338
Southern	567	912	887	958	1253	1131	1582	1772	1946	2077	2154
Eastern	994	1047	1133	1207	1374	1550	2169	2429	2668	2847	2953
Alaskan	6	8	6	9	11	10	14	15	17	18	18
Total Withdrawals	2005	2309	2609	2798	3442	3334	4664	5224	5737	6123	6351

Source: Data for 1960 through 1985 from USGS Circulars. Data for 2000 through 2040 are Forest Service estimates based upon trends in the historical data.

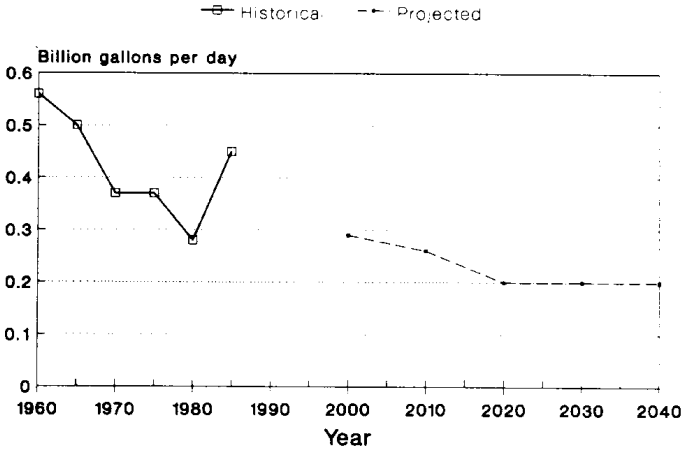


Figure A.7.—Irrigation, wastewater withdrawals.

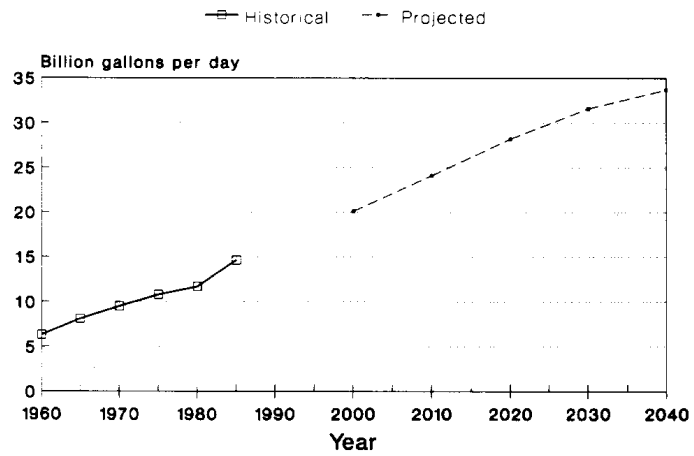


Figure A.8.—Municipal supplies, fresh groundwater withdrawals.

Table A.12.—Freshwater withdrawals (million gallons per day) for livestock watering use in the United States for 1960 to 1985, by Forest Service Region, with projections of demand to 2040

Forest Service region	1960	1965	1970	1975	1980	1985	2000	2010	2020	2030	2040
Groundwater											
Northern	17	35	36	42	36	258	132	141	149	154	157
Rocky Mountain	136	167	208	236	225	179	92	98	103	107	109
Southwestern	19	42	32	43	20	36	18	20	21	21	22
Intermountain	16	38	45	55	43	851	436	465	490	507	517
Pacific Southwest	58	35	39	48	42	42	21	23	24	25	25
Pacific Northwest	11	13	7	7	11	25	13	14	14	15	15
Southern	180	220	277	346	326	992	507	542	571	591	603
Eastern	388	456	426	472	479	541	277	296	311	322	329
Alaskan	0	0	0	0	0	10	5	5	6	6	6
Total Groundwater	825	1007	1069	1249	1183	2934	1501	1603	1688	1749	1783
Surface Water											
Northern	49	40	27	28	26	45	31	33	35	36	37
Rocky Mountain	72	91	119	99	173	126	211	225	238	247	252
Southwestern	9	37	40	44	12	75	14	15	16	17	17
Intermountain	21	17	18	16	29	30	36	38	40	42	43
Pacific Southwest	26	51	59	59	51	162	61	66	69	72	74
Pacific Northwest	26	24	21	21	21	813	25	27	29	30	30
Southern	243	263	281	359	475	542	577	618	652	677	691
Eastern	230	215	228	272	183	165	223	239	252	262	267
Alaskan	0	0	0	0	0	146	0	0	0	0	0
Total Surface Water	675	737	794	898	969	2104	1179	1261	1332	1383	1411
Total Withdrawals											
Northern	66	75	63	70	61	303	162	173	182	189	192
Rocky Mountain	209	258	328	335	399	305	162	173	183	190	194
Southwestern	27	79	72	87	32	111	59	63	67	69	70
Intermountain	37	56	63	70	72	881	469	501	528	548	559
Pacific Southwest	84	86	98	108	93	204	108	116	122	127	129
Pacific Northwest	37	37	28	28	32	838	446	476	502	521	531
Southern	421	485	558	705	803	1534	817	872	920	953	973
Eastern	620	670	654	744	660	706	376	401	423	439	448
Alaskan	0	0	0	0	0	156	83	89	93	97	99
Total Withdrawals	1501	1744	1863	2147	2152	5038	2683	2864	3020	3131	3195

Source: Data for 1960 through 1985 from USGS Circulars. Data for 2000 through 2040 are Forest Service estimates based upon trends in the historical data.

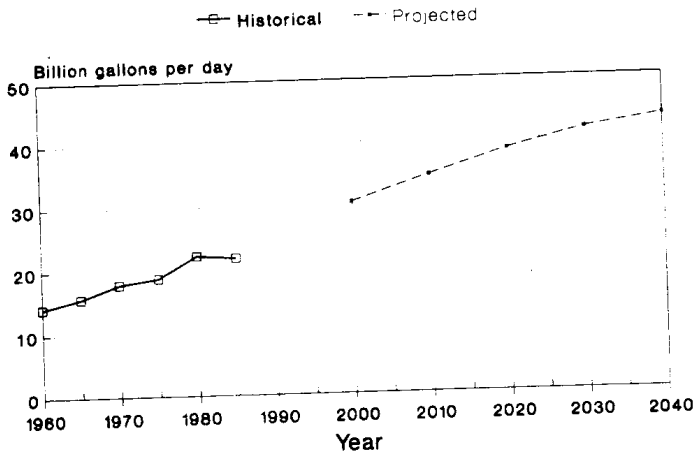


Figure A.9.—Municipal supplies, fresh surface water withdrawals.

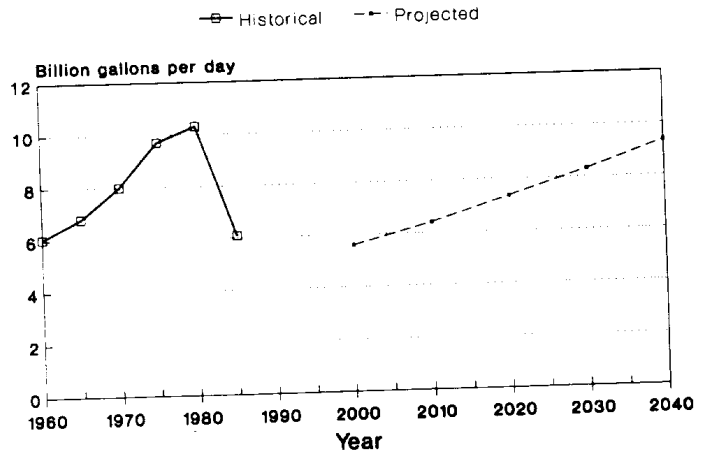


Figure A.10.—Industrial self-supplied water, fresh groundwater withdrawals.

Table A.13.—Freshwater consumption (million gallons per day) for thermoelectric steam cooling use in the United States for 1960 to 1985 by Water Resource region and Forest Service region, with projections of demand to 2040

Region	1960	1965	1970	1975	1980	1985	2000	2010	2020	2030	2040
Water resource region											
New England	1	3	3	96	21	31	50	60	68	78	91
Mid-Atlantic	15	27	35	140	260	389	623	747	843	969	1122
South Atlantic-Gulf	7	11	120	210	270	404	647	775	875	1006	1165
Great Lakes	12	11	14	52	93	139	223	267	301	346	401
Ohio	33	17	50	280	520	778	1246	1493	1685	1937	2245
Tennessee	0	8	64	59	20	30	48	57	65	75	86
Upper Mississippi	4	27	23	96	290	434	695	833	940	1080	1252
Lower Mississippi	19	20	190	290	400	598	959	1149	1296	1490	1727
Souris-Red-Rainy	2	1	1	1	1	1	2	3	3	4	4
Missouri Basin	12	31	34	68	350	523	839	1005	1134	1304	1511
Arkansas-White-Red	29	54	82	95	410	613	982	1177	1329	1527	1770
Texas-Gulf	52	140	100	380	360	538	863	1034	1167	1341	1554
Rio Grande	4	11	17	20	11	16	26	32	36	41	47
Upper Colorado	8	18	22	60	130	194	312	373	421	484	561
Lower Colorado	7	15	36	47	49	73	117	141	159	183	212
Great Basin	2	2	6	6	6	9	14	17	19	22	26
Pacific Northwest	0	0	0	9	2	3	5	6	6	7	9
California	17	18	24	32	41	61	98	118	133	153	177
Alaska	0	0	0	1	0	0	0	0	0	0	0
Hawaii	0	0	0	0	0	0	0	0	0	0	0
Caribbean	0	1	0	5	6	9	14	17	19	22	26
U.S. Total	224	415	821	1947	3240	4846	7764	9303	10499	12070	13985
Forest Service region											
Northern	2	2	1	20	26	41	66	79	89	102	118
Rocky Mountain	22	46	53	77	197	113	181	216	244	281	325
Southwestern	20	31	59	74	106	96	154	184	208	239	277
Intermountain	4	4	13	36	39	51	82	98	111	128	148
Pacific Southwest	17	18	24	32	41	26	41	50	56	65	75
Pacific Northwest	10	0	0	7	1	25	40	48	54	62	72
Southern	96	228	568	1061	1536	1085	1739	2083	2351	2703	3132
Eastern	53	87	106	630	1294	3406	5457	6539	7379	8483	9829
Alaskan	0	0	0	1	0	3	5	6	7	8	9
Total Consumption	224	415	821	1947	3240	4846	7764	9303	10499	12070	13985

Source: Data for 1960 through 1985 from USGS Circulars. Data for 2000 through 2040 are Forest Service estimates based upon trends in the historical data.

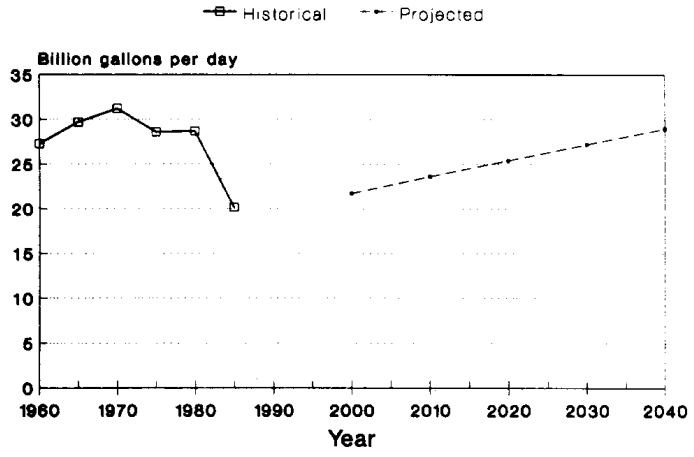


Figure A.11.—Industrial self-supplied water, fresh surface water withdrawals.

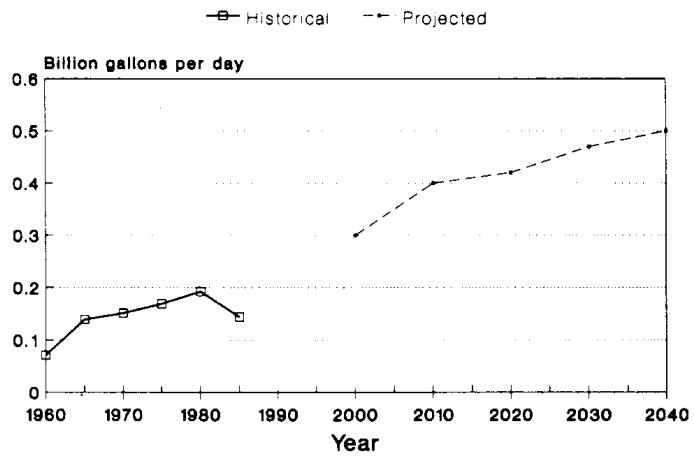


Figure A.12.—Industrial self-supplied water, wastewater withdrawals.

Table A.14.—Freshwater consumption (million gallons per day) for irrigation use in the United States for 1960 to 1985 by water resource region and Forest Service region, with projections of demand to 2040

Region	1960	1965	1970	1975	1980	1985	2000	2010	2020	2030	2040
Water resource region											
New England	7	26	64	57	52	46	55	57	60	61	63
Mid-Atlantic	82	122	120	200	240	212	253	264	275	284	292
South Atlantic-Gulf	797	1400	1500	1500	2300	2028	2421	2531	2637	2720	2797
Great Lakes	45	64	87	94	330	291	347	363	378	390	401
Ohio	12	24	35	32	150	132	158	165	172	177	182
Tennessee	14	8	7	7	7	6	7	8	8	8	9
Upper Mississippi	44	77	95	140	370	326	389	407	424	438	450
Lower Mississippi	660	1200	2200	4000	4800	4232	5053	5283	5504	5677	5838
Souris-Red-Rainy	9	17	12	41	60	53	63	66	69	71	73
Missouri Basin	6946	9800	12000	14000	15000	13225	15790	16509	17199	17740	18245
Arkansas-White-Red	3390	7700	6000	8000	8200	7229	8632	9025	9402	9698	9974
Texas-Gulf	4798	5500	4900	6500	4900	4320	5158	5393	5618	5795	5960
Rio Grande	3402	3900	3000	3200	2100	1851	2211	2311	2408	2484	2554
Upper Colorado	3505	3200	4000	1500	2000	1763	2105	2201	2293	2365	2433
Lower Colorado	3395	3100	4700	5700	4300	3791	4527	4732	4930	5085	5230
Great Basin	3300	3000	2900	3400	3500	3086	3684	3852	4013	4139	4257
Pacific Northwest	8000	10000	10000	9900	11000	9698	11580	12106	12612	13009	13379
California	13000	16000	21000	21000	23000	20278	24212	25313	26371	27201	27975
Alaska	0	0	1	0	0	0	0	0	0	0	0
Hawaii	370	530	750	500	610	538	642	671	699	721	742
Caribbean	250	230	98	150	200	176	211	220	229	237	243
U.S. Total	52026	65898	73469	79921	83119	73282	87498	91479	95303	98301	101098
Forest Service region											
Northern	3471	5750	6663	3901	4109	3041	3631	3796	3955	4079	4196
Rocky Mountain	9193	12029	14586	16513	17656	15997	19101	19970	20804	21459	22069
Southwestern	4224	4436	5882	6812	5706	4439	5301	5542	5773	5955	6124
Intermountain	7186	8276	7624	7773	8770	8211	9804	10250	10679	11015	11328
Pacific Southwest	14453	15659	21044	21537	23636	18818	22469	23491	24473	25243	25961
Pacific Northwest	4124	4436	4564	5209	5606	6889	8225	8600	8959	9241	9504
Southern	9143	14913	12646	17564	16356	14699	17550	18349	19116	19717	20278
Eastern	233	398	460	613	1278	1187	1417	1481	1543	1592	1637
Alaskan	0	0	1	0	0	0	0	0	0	0	0
Total Consumption	52026	65898	73469	79921	83119	73282	87498	91479	95303	98301	101098

Source: Data for 1960 through 1980 from USGS Circulars. In addition to the irrigation of crops this data also includes irrigation of recreational facilities (e.g. golf courses and ski slopes) and other uses (e.g. landscape plantings) if water source is self-supplied. Data for 1985 from the Soil Conservation Service, modified by additional nonagricultural irrigation use. Data for 2000 through 2040 are Forest Service estimates based upon trends in the historical data.

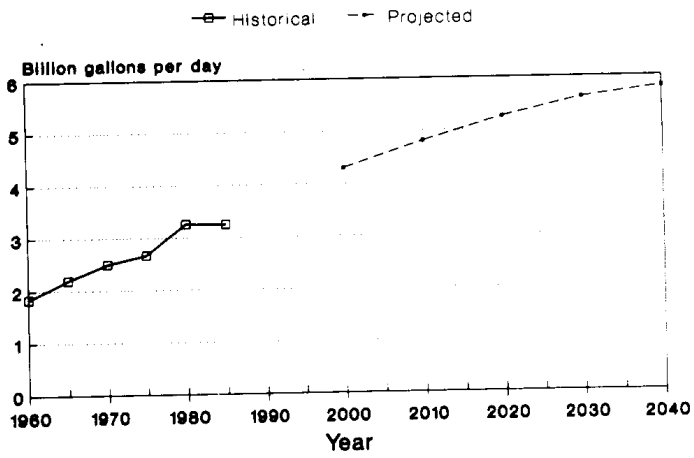


Figure A.13.—Domestic self-supplied water, fresh groundwater withdrawals.

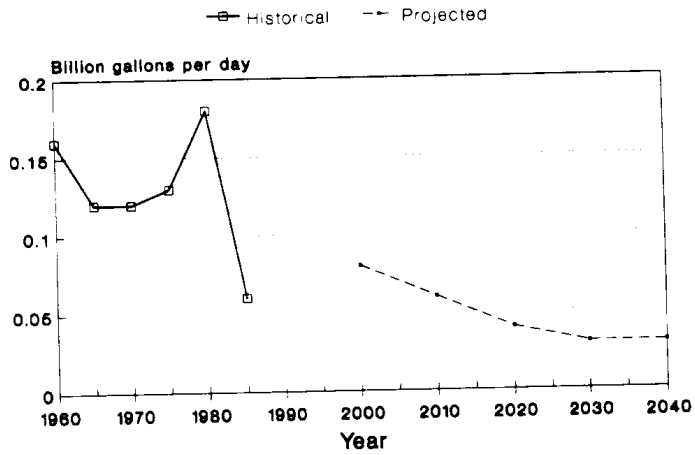


Figure A.14.—Domestic self-supplied water, fresh surface water withdrawals.

Table A.15.—Freshwater consumption (million gallons per day) for municipal central supplies in the United States for 1960 to 1985 by water resource region and Forest Service region, with projections of demand to 2040

Region	1960	1965	1970	1975	1980	1985	2000	2010	2020	2030	2040
Water resource region											
New England	150	160	190	180	150	130	217	239	258	272	280
Mid-Atlantic	452	681	750	760	710	615	1027	1132	1223	1289	1326
South Atlantic-Gulf	300	360	590	930	780	676	1128	1244	1344	1416	1457
Great Lakes	400	520	500	410	310	269	448	494	534	563	579
Ohio	190	230	270	240	240	208	347	383	414	436	448
Tennessee	60	46	36	40	44	38	64	70	76	80	82
Upper Mississippi	130	160	190	170	180	156	260	287	310	327	336
Lower Mississippi	110	200	240	310	400	347	578	638	689	726	747
Souris-Red-Rainy	9	11	19	20	22	19	32	35	38	40	41
Missouri Basin	212	240	250	290	360	312	521	574	620	653	672
Arkansas-White-Red	196	260	250	330	310	269	448	494	534	563	579
Texas-Gulf	396	350	380	560	550	477	795	877	948	998	1027
Rio Grande	124	110	150	190	140	121	202	223	241	254	261
Upper Colorado	10	14	19	26	41	36	59	65	71	74	77
Lower Colorado	110	150	190	240	390	338	564	622	672	708	728
Great Basin	67	69	140	140	310	269	448	494	534	563	579
Pacific Northwest	150	210	260	230	290	251	419	463	500	526	542
California	370	1300	1400	1500	1700	1473	2458	2711	2929	3086	3175
Alaska	0	7	11	4	33	29	48	53	57	60	62
Hawaii	25	38	46	55	60	52	87	96	103	109	112
Caribbean	11	21	43	42	75	65	108	120	129	136	140
U.S. Total	3472	5137	5924	6667	7095	6149	10259	11316	12226	12878	13250
Forest Service region											
Northern	74	61	91	87	99	86	143	158	171	180	185
Rocky Mountain	191	241	235	275	348	302	503	555	600	632	650
Southwestern	123	161	227	283	438	380	634	699	755	795	818
Intermountain	108	121	202	212	417	362	603	665	719	757	779
Pacific Southwest	395	1324	1455	1557	1757	1522	2540	2802	3027	3188	3280
Pacific Northwest	113	186	209	176	217	188	313	345	373	393	404
Southern	1139	1301	1612	2323	2172	1882	3140	3464	3742	3942	4056
Eastern	1329	1735	1881	1749	1615	1399	2335	2575	2783	2931	3016
Alaskan	0	7	11	4	33	29	48	53	57	60	62
Total Consumption	3472	5137	5924	6667	7095	6149	10259	11316	12226	12878	13250

Source: Data for 1960 through 1985 from USGS Circulars. Data for 2000 through 2040 are Forest Service estimates based upon trends in the historical data.

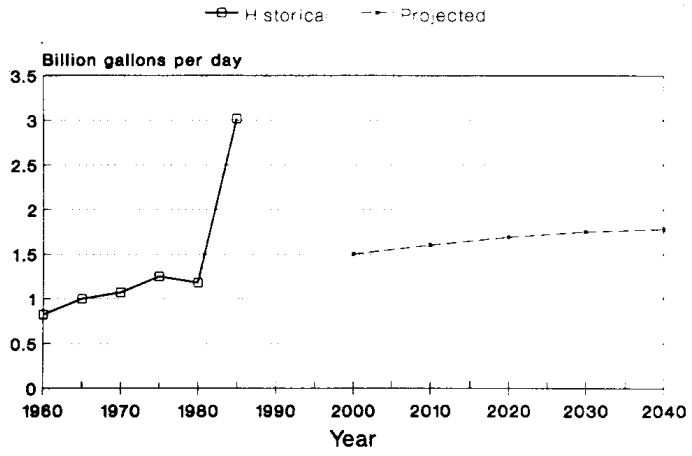


Figure A.15.—Livestock watering, fresh groundwater withdrawals.

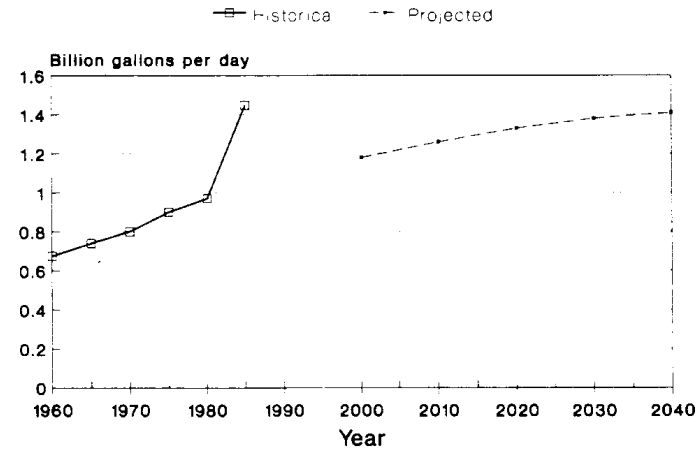


Figure A.16.—Livestock watering, fresh surface water withdrawals.

Table A.16.—Freshwater consumption (million gallons per day) for industrial self-supplied use in the United States for 1960 to 1985 by water resource region and Forest Service region, with projections of demand to 2040

Region	1960	1965	1970	1975	1980	1985	2000	2010	2020	2030	2040
Water resource region											
New England	84	79	96	64	66	72	88	100	112	123	135
Mid-Atlantic	460	470	330	340	280	307	375	424	473	523	573
South Atlantic-Gulf	430	260	540	540	1100	1204	1473	1665	1859	2054	2249
Great Lakes	280	360	450	370	370	405	495	560	625	691	757
Ohio	310	410	260	360	420	460	562	636	710	784	859
Tennessee	240	170	72	120	220	241	295	333	372	411	450
Upper Mississippi	36	58	75	98	170	186	228	257	287	317	348
Lower Mississippi	380	450	780	810	740	810	991	1120	1251	1382	1513
Souris-Red-Rainy	7	2	6	5	6	7	8	9	10	11	12
Missouri Basin	55	71	65	52	77	84	103	117	130	144	157
Arkansas-White-Red	185	330	210	270	330	361	442	500	558	616	675
Texas-Gulf	239	350	580	290	350	383	469	530	592	653	716
Rio Grande	31	46	97	55	13	14	17	20	22	24	27
Upper Colorado	5	8	21	27	63	69	84	95	106	118	129
Lower Colorado	32	51	100	190	150	164	201	227	254	280	307
Great Basin	9	36	62	63	100	109	134	151	169	187	204
Pacific Northwest	91	83	150	310	350	383	469	530	592	653	716
California	80	110	170	180	190	208	254	288	321	355	389
Alaska	0	4	4	0	1	1	1	2	2	2	2
Hawaii	13	4	4	4	0	0	0	0	0	0	0
Caribbean	7	10	18	37	20	22	27	30	34	37	41
U.S. Total	2974	3362	4090	4185	5016	5492	6715	7594	8478	9365	10257
Forest Service region											
Northern	32	24	28	50	57	33	41	46	51	57	62
Rocky Mountain	54	71	113	119	165	172	211	238	266	294	322
Southwestern	28	92	137	221	125	159	194	220	245	271	297
Intermountain	43	61	100	211	278	47	57	65	72	80	87
Pacific Southwest	95	114	175	183	191	679	830	939	1048	1158	1268
Pacific Northwest	154	64	126	149	171	159	194	220	245	271	297
Southern	1524	1581	2220	2075	2781	1945	2378	2690	3003	3317	3633
Eastern	1045	1351	1187	1177	1247	2282	2790	3155	3523	3891	4262
Alaskan	0	4	4	0	1	16	19	22	24	27	29
Total Consumption	2974	3362	4090	4185	5016	5492	6715	7594	8478	9365	10257

Source: Data for 1960 through 1985 from USGS Circulars. Data for 2000 through 2040 are Forest Service estimates based upon trends in the historical data.

Table A.17.—Freshwater consumption (million gallons per day) for domestic self-supplied use in the United States for 1960 to 1985 by water resource region and Forest Service region, with projections of demand to 2040

Region	1960	1965	1970	1975	1980	1985	2000	2010	2020	2030	2040
Water resource region											
New England	31	84	47	36	63	46	48	49	50	51	51
Mid-Atlantic	86	88	130	100	110	106	112	115	117	119	120
South Atlantic-Gulf	310	490	360	340	440	357	375	385	392	398	401
Great Lakes	96	100	78	61	74	67	70	72	73	74	75
Ohio	140	200	180	140	200	163	171	175	179	182	183
Tennessee	54	61	31	25	39	30	31	32	33	33	33
Upper Mississippi	73	100	130	48	190	115	121	124	127	128	130
Lower Mississippi	52	58	100	68	67	74	77	79	81	82	83
Souris-Red-Rainy	7	14	19	11	23	17	17	18	18	19	19
Missouri Basin	89	85	96	110	170	118	124	127	129	131	132
Arkansas-White-Red	70	96	84	97	120	94	99	102	104	105	106
Texas-Gulf	29	33	80	100	120	94	99	101	103	105	106
Rio Grande	6	7	13	17	18	15	16	16	17	17	17
Upper Colorado	2	2	3	3	17	7	8	8	8	8	8
Lower Colorado	6	5	17	27	27	22	23	24	24	25	25
Great Basin	8	15	13	6	14	10	11	11	11	12	12
Pacific Northwest	23	75	200	180	200	182	191	196	200	202	204
California	120	51	73	76	84	73	77	79	80	81	82
Alaska	0	0	0	0	0	0	0	0	0	0	0
Hawaii	6	0	0	0	3	1	1	1	1	1	1
Caribbean	9	4	3	4	2	3	3	3	3	3	3
U.S. Total	1217	1568	1657	1449	1981	1592	1675	1716	1751	1776	1791
Forest Service region											
Northern	12	24	29	40	75	45	47	49	50	50	51
Rocky Mountain	68	80	88	97	152	106	111	114	116	118	119
Southwestern	31	8	24	37	39	31	33	34	35	35	35
Intermountain	9	23	19	14	27	19	20	20	21	21	21
Pacific Southwest	133	50	71	74	85	72	76	78	79	81	81
Pacific Northwest	18	67	190	169	168	165	173	178	181	184	185
Southern	519	798	721	661	842	696	732	750	766	777	783
Eastern	427	517	513	356	594	458	482	494	504	511	515
Alaskan	0	0	0	0	0	0	0	0	0	0	0
Total Consumption	1217	1568	1657	1449	1981	1592	1675	1716	1751	1776	1791

Source: Data for 1960 through 1985 from USGS Circulars. Data for 2000 through 2040 are Forest Service estimates based upon trends in the historical data.

Table A.18.—Freshwater consumption (million gallons per day) for livestock watering use in the United States for 1960 to 1985 by water resource region and Forest Service region, with projections of demand to 2040

Region	1960	1965	1970	1975	1980	1985	2000	2010	2020	2030	2040
Water resource region											
New England	13	11	12	9	9	11	11	12	12	12	13
Mid-Atlantic	58	51	65	76	86	103	105	110	116	119	121
South Atlantic-Gulf	127	140	150	240	240	287	292	308	323	333	338
Great Lakes	85	72	82	78	77	92	94	99	103	107	109
Ohio	130	130	140	170	140	168	170	180	188	194	197
Tennessee	38	36	30	32	40	48	49	51	54	55	56
Upper Mississippi	290	300	250	250	270	323	328	347	363	374	381
Lower Mississippi	41	44	55	47	41	49	50	53	55	57	58
Souris-Red-Rainy	21	19	15	16	14	17	17	18	19	19	20
Missouri Basin	301	360	410	440	380	455	462	488	511	527	536
Arkansas-White-Red	139	150	180	220	230	275	280	295	309	319	324
Texas-Gulf	16	89	110	140	190	227	231	244	255	263	268
Rio Grande	13	68	36	37	26	31	32	33	35	36	37
Upper Colorado	7	10	17	14	22	26	27	28	30	30	31
Lower Colorado	12	16	28	47	11	13	13	14	15	15	16
Great Basin	19	16	21	20	17	20	21	22	23	24	24
Pacific Northwest	55	55	47	47	49	59	60	63	66	68	69
California	66	45	50	54	47	56	57	60	63	65	66
Alaska	0	0	0	0	0	0	0	0	0	0	0
Hawaii	2	3	7	5	5	6	6	6	7	7	7
Caribbean	4	6	8	9	7	8	8	9	9	9	9
U.S. Total	1437	1621	1713	1951	1901	2276	2311	2442	2555	2635	2681
Forest Service region											
Northern	65	74	61	67	60	98	100	105	110	114	116
Rocky Mountain	196	251	304	307	314	271	275	291	304	314	319
Southwestern	22	78	71	86	18	59	60	63	66	68	69
Intermountain	32	36	39	38	38	96	98	103	108	112	114
Pacific Southwest	68	47	56	59	51	157	160	169	176	182	185
Pacific Northwest	35	35	26	25	29	50	51	54	56	58	59
Southern	416	472	540	680	769	911	925	977	1022	1054	1073
Eastern	603	628	614	689	623	633	643	680	711	733	746
Alaskan	0	0	0	0	0	0	0	0	0	0	0
Total Consumption	1437	1621	1713	1951	1901	2276	2311	2442	2555	2635	2681

Source: Data for 1960 through 1985 from USGS Circulars. Data for 2000 through 2040 are Forest Service estimates based upon trends in the historical data.

APPENDIX B: DEMAND EQUATIONS

INTRODUCTION

Demand equations were estimated using the 1987 release of *BMDP for the Personal Computer*, which executes the same routines outlined by Dixon et al. (1985). The stepwise regression routine was used to explore possible independent variables (table 11) for each dependent variable and transformation. Further analyses were performed using multiple linear regression.

Several different curve forms were tested for fit against the data. The prior assumption was that a logarithmic curve form was the most appropriate, given the emphasis on recycling and conservation engendered by legislation of the early 1970s. Semilogarithmic (Y = ln a + b ln X) and double logarithmic (ln Y = ln a + b ln X; shown below as exp[c + b ln x] where c = ln a) curve forms were explored in preference to linear forms. The *BMDP Data Manager for the Personal Computer* (Engelman et al. 1986) was used to perform the natural logarithm transformations of dependent and independent variables.

Unless otherwise specified, F statistics listed are for equations with a single explanatory variable and a time series of six data points (1960 to 1985 inclusive). The critical values for F1,5 are 4.06, 6.61, and 16.3 for 10%, 5%, and 1%, respectively.

THERMOELECTRIC STEAM COOLING

EQUATIONS

Total freshwater withdrawals =
exp[7.6658 + 0.5656 ln kWh]
$R^2 = .93$ F = 51.6

Groundwater withdrawals = No significant equations

Fresh surface water withdrawals =
exp[7.6241 + 0.5701 ln kWh]
$R^2 = .94$ F = 60.0

Freshwater consumption =
−10642 − 3.2887 kWh + 182.446 civilian labor force
$R^2 = .98$ F = 91.2

DISCUSSION

Because no significant equations emerged for groundwater withdrawals, demand for fresh groundwater withdrawals was estimated as the difference between total freshwater withdrawals and fresh surface water withdrawals. Saline surface water (oceans and estuaries) is an alternative source of water for thermoelectric steam cooling. Because those utilities using groundwater are usually located in arid areas far removed from coastal sites where saline surface sources are available, saline surface sources were ignored for purposes of estimating groundwater withdrawals.

Billion kWh of power generated was selected as the best independent variable for projecting steam cooling withdrawals and consumption. The double exponential form suggests that conservation and recycling will continue to grow, but at a decreasing rate. Billion kWh were projected based upon the GNP relationships identified by the U.S. Department of Energy and the GNP projections from the basic assumptions for this Assessment.

IRRIGATION

EQUATIONS

Total freshwater withdrawals =
−227076 + 50465.68 ln kWh
$R^2 = .88$ F = 30.2

Groundwater withdrawals =
−94490 + 20168.35 ln kWh
$R^2 = .66$ F = 7.9

Fresh surface water withdrawals =
−133814 + 30414.04 ln kWh
$R^2 = .94$ F = 67.3

Wastewater withdrawals =
1736 −186.71 ln kWh
$R^2 = 57.8$ F = 5.5

Freshwater consumption =
−84411 + 22194.83 ln kWh
$R^2 = .79$ F = 14.8

DISCUSSION

The wastewater withdrawals equation has an F statistic that is significant at the 7% level. Because wastewater withdrawals represent only 0.2% of the total demand for irrigation water in 1985, this level of significance was judged acceptable for projecting irrigation withdrawals. No other form or independent variable gave better results.

Billion kWh was selected as the most relevant independent variable to explain irrigation withdrawals and consumption. Electricity is the primary energy source used to pump water from aquifers and surface sources and pressurize sprinkler water delivery systems.

MUNICIPAL SUPPLIES

EQUATIONS

Total freshwater withdrawals =
exp[−1.1803 + 2.138 ln population]
$R^2 = .987$ F = 235.4

Groundwater withdrawals =
exp[−5.1671 + 2.6840 ln population]
$R^2 = .976$ F = 120.9

Fresh surface water withdrawals =
exp[−0.0643 + 1.8497 ln population]
$R^2 = .971$ F = 98.9

Freshwater consumption =
−76821 + 15504.6 ln population
$R^2 = .95$ F = 72.8

DISCUSSION

Population is the most relevant independent variable for explaining changes in municipal withdrawals and consumption. Municipal supplies also serve some commercial and industrial facilities but usage by these firms is largely for people-related purposes so population growth remains relevant.

INDUSTRIAL SELF-SUPPLIED WATER USE

EQUATIONS

No demand equations were statistically significant.

Freshwater consumption =
−21953 + 3335.4 ln GNP
$R^2 = .989$ F = 374.7

DISCUSSION

GNP was expected to be the most relevant independent variable for projecting industrial self-supplied water use. But regression equations could not be developed with GNP or any other independent variable in the data set that explained a significant portion of the variation in industrial self-supplied water withdrawals. Although GNP continued to grow at nearly the same rate as during the 1960s and 1970s, water pollution legislation and policy changes forced changes in withdrawals independent of continued growth in GNP. The change in withdrawals was so abrupt and happened so recently that statistically defensible projections of industrial self-supplied use cannot yet be made. Consequently, projections were based on simple time trends.

Projections assume that a major adjustment in water use occurred in the 1980s. Further, that industrial self-supplied use will soon resume growing at about 95% of the annual rate of growth between 1960 and 1980—roughly 275 mgd per year. This total rate of increase was disaggregated into 130 mgd per year in fresh surface water withdrawals, 90 mgd per year in groundwater withdrawals, and 54 mgd per year in wastewater withdrawals.

The consumption equation, however, explains virtually all the variation in consumption and is highly significant.

DOMESTIC SELF-SUPPLIED WATER USE

EQUATIONS

Total freshwater withdrawals =
−2535 + 28.089 population
$R^2 = .94$ F = 58.8

Groundwater withdrawals =
−2838 + 25.916 population
$R^2 = .96$ F = 104.

Fresh surface water withdrawals = no significant independent variable

DISCUSSION

Population was selected as the most relevant independent variable for explaining variation in rural domestic water withdrawals. The statistical analysis of fresh surface water withdrawals produced no significant independent variables, merely a highly significant intercept term. Consequently, surface water withdrawal estimates were computed as the difference between the projected total and projected groundwater withdrawals.

Statistical analyses of freshwater consumption yielded no significant equations. R-squared for the equations tested varied between .03 and .35 and the best F-statistic had a probability value of about .08. Thus, a combination of time and population trends were used to project freshwater consumption (fig. 30).

LIVESTOCK WATERING USE

EQUATIONS

Total freshwater withdrawals =
−12200 + 2650 ln population
$R^2 = .96$ F = 72.8

Groundwater withdrawals =
−6619 + 1446.32 ln population
$R^2 = .87$ F = 19.53

Fresh surface water withdrawals =
−5581 + 1203.68 ln population
$R^2 = .95$ F = 53.6

Freshwater consumption =
−8467 + 1919.02 ln population
$R^2 = .90$ F = 26.5

DISCUSSION

The 1985 livestock water withdrawal and consumption estimates are significantly different from previous estimates because aquaculture water use (fish farming) is included for the first time (fig. 33). Defining aquaculture as part of livestock water use is a major structural change in the data series. To eliminate effects of the structural change when estimating regression equations, 1985 estimates were not used. Consequently, the equations are

based only on the data from 1960 to 1980 and projections ignore future aquaculture water withdrawals and consumption.

Population was selected as the most relevant independent variable because it stands as a surrogate for red meat consumption. The basic assumption for red meat consumption for this Assessment was to hold per capita red meat consumption constant over the projection period. A similar case could be made for assuming per capita consumption of dairy products is constant over the projection period. Because per capita consumptions are constant, growth in the demand for animal products becomes a function of population.

Aquaculture water usage was relatively low from 1960 to 1980. Some states included aquaculture in the industrial self-supplied category; others in the livestock category. Between 1980 and 1985, the volume of water used in aquaculture grew rapidly as consumers ate more fish and poultry instead of beef and pork. Thus, USGS decided to standardize how states reported aquaculture water use declaring it an element of livestock use. This change in definition probably also contributed to difficulties in estimating industrial self-supplied water use equations. Sufficient data may be available by 1998 so the next RPA analysis of the water situation can include aquaculture in its livestock water projections.

APPENDIX C: SUMMARY OF STATE WATER QUALITY LAWS AFFECTING FORESTRY OPERATIONS

Significant features of water quality legislation are given, by region, in the tables that follow: South—Table C.1; North—table C.2; Rocky Mountain region—table C.3; and Pacific Coast region—table C.4 (source: Haines and Siegel (1988)).

Table C.1—Significant features of water quality legislation in the South

State	Statute and reference	Administering agency	Basic provisions	Penalties for violations	Significance for forest management	Related statutes
Alabama	Water Pollution Control Act. Ala. Code, Sec. 22-22-1 to 14. Enacted 1971; amended 1973, 1979, 1982.	Alabama Water Improvement Commission.	Pollutants harmful to fish or wildlife, or constituting a public hazard are subject to regulation. Commission granted permit issuing authority for control of discharges of such pollutants into waterways. Commission may issue cease-and-desist orders and commence civil actions to enjoin actual or threatened violations.	Civil: $100 to $10,000 fine per day of violation of a Commission rule or order. Criminal: $2,500 to $25,000 per day of violation and/or imprisonment for up to one year. Penalty may be doubled on second conviction. Payment of costs of damage, and restocking of fish and wildlife.	No reference to silvicultural discharges or wastes from timber transport or harvesting. Law probably applicable to nonpoint pollution if damage to fish or wildlife clearly attributable.	Coastal Preservation Act (Ala. Code, Sec. 9-7-14 to 9-7-22) Activities permitted include planting and harvesting of trees including normal road construction.
Arkansas	Water and Air Pollution Control Act. Ark. Stat. Ann. Sec. 82-1901 to 1991. Enacted 1949; amended 15 times, 1953 to 1985.	Department of Pollution Control and Ecology (under authority of Arkansas Pollution Control Commission).	Department given broad authority to issue permits and orders, and to promulgate rules and standards, with respect to prohibited pollutants. Department can initiate civil action to force compliance with orders and standards.	Civil: up to $5,000 fine per day of violation plus payment of administrative expenses and damages. Criminal: violation considered misdemeanor. Up to $10,000 and/or one year in prison per day of violation.	Definition of pollution and Department's vested powers sufficiently broad to apply to nonpoint sources. Prohibited pollutants include decayed wood, sawdust, shavings, bark and sand. One member of the State Pollution Control Commission must be from the State Forestry Commission.	Stream Obstruction Statutes (Ark. Stat. Ann. Sec. 41-4052 and Sec. 41-4066 to 41-4067) prohibit obstructing any improved drainage project or any natural drain with trees, tree tops or limbs. Tree Removal in Riparian Areas (Sec. 41-4068 to 41-4069) prohibits removal of trees growing below normal high water mark of any navigable river or stream.
Florida	Air and Water Pollution Control Act. Fla. Stat. Ann. Sec. 403.011 to 403.291. Enacted 1971; amended 1972, 1974,1977, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1985.	Department of Environmental Regulation.	Department given broad powers to develop water pollution abatement programs. Department must issue permits for all pollutant discharges pursuant to federal administrative requirements. Department may issue orders and seek injunctive relief against violations. Exception: Water owned entirely by one person excluded from Department control unless affecting other properties or water.	Civil: up to $10,000 fine per day of violation. Criminal: Violation considered first degree misdemeanor. Fine of $2,500 to $25,000 and/or one year in prison per day of violation. False statement or misrepresentation: up to $10,000 and/or six months in prison. Department can initiate civil action to establish liability and recover damages, including those for fish mortality.	Powers granted to Department are sufficiently broad to include regulatory authority over nonpoint pollution from land management activities.	Warren Henderson Wetlands Protection Act of 1984 (Fla. Stat. Ann. T.29 Sec. 403.91 to 403.929) empowers Florida's five water management districts to regulate silvicultural activities which divert or impede normal water flow. Some districts require permits, others notification and/or merely compliance with standards.
Georgia	Water Quality Control Act. Ga. Code Ann. Chap. 12-5-20 to 12-5-53. Enacted 1971; amended 1972, 1974, 1977, 1978, 1982, 1983, 1986.	Division of Environmental Protection, within Department of Natural Resources (under authority of Georgia Water Quality Control Board).	Water Quality Control Board has broad authority to promulgate rules and regulations to control water pollution. Division of Environmental Protection can issue permits for both point and nonpoint discharges; can also issue stop orders. Statute applies to all waters except those entirely confined and retained on the property of a single ownership. All aspects of the program are to be consistent with the Federal Water Pollution Control Act.	Civil: up to $25,000 fine per day of violation. Criminal: violation considered misdemeanor. Fine of $2,500 to $25,000 per day of violation and/or one year in prison. Penalty doubled for repeated offense. False misrepresentation: felony; up to $10,000 and/or two years in prison. Assessment of civil liability for damages.	Division of Environmental Protection has explicit authority to issue permits for discharge of nonpoint pollutants. 1978 amendment to Water Quality Control Act provides for state administration of Federal Water Pollution Control Act Section 404 permit program.	
Kentucky	Environmental Protection Law. Ky., Rev. Stat., Sec. 224.005 to 224.997. Enacted 1972; amended 1974, 1978, 1980, 1982, 1984.	Bureau of Environmental Protection within the Department of Natural Resources and Environmental Protection.	Department has broad authority to issue water quality rules and regulations; and to issue discharge permits in accordance with Federal Water Pollution Control Act guidelines. Department may initiate court action against violations. Exceptions: exemptions may be granted for up to one year if discharge is not likely to have a measurable impact on water quality and/or compliance would produce undue hardship without equal or greater benefit to the public.	Civil: up to $10,000 fine per day of violation. Criminal: violation considered misdemeanor; fine of $1,000 to $15,000 and/or imprisonment for up to one year per day of violation. Payment of costs of damage, and restocking of fish and wildlife.	Legislative authority broad enough to cover nonpoint pollution at discretion of Department. Department required to monitor environment for more effective and efficient control practices.	Kentucky Wild Rivers Act (Ky. Rev. Stat., Sec. 146.200 to 146.350) permits only selective cutting of timber within boundaries of designated wild river areas. Stream Obstruction Statute (151.310 to 151.320) prohibits the deposit of any matter which disturbs the flow of water in streams without a permit.

Louisiana	Water Control Law. La. Rev. Stat. 30:1073 and 30:1091–1097. Enacted 1979; amended 1980, 1983, 1984 1987.	Department of Environmental Quality and the Office of Water Resources (OWR)	The OWR is empowered to develop a general water protection plan and to regulate and restrain the discharge of pollution into waters. The Department establishes standards and guidelines; promulgates rules and regulations; and issues permits for the control of water pollution. Commission may initiate civil liability action.	No penalties may be imposed for unintentional pollution in connection with production of agricultural products. Commission may recover civil damages. Violations: polluting waters with substance which is not likely to endanger human life or health is a misdemeanor; punishable by a fine of up to $25,000/ day of violation and/or up to one year imprisonment. Polluting with a substance which could endanger human life or health is a felony punishable by a fine of up to $100,000/day and/or 10 years imprisonment. Civil penalties are up to $25,000/day of violation. Up to $50,000/day for failure to take corrective action after compliance order is issued.	Legislative authority broad enough to cover nonpoint pollution at discretion of Department. Specifically empowers the Department to develop a nonpoint source management program. Law includes a provision prohibiting persons engaged in logging operations from leaving trees or treetops in navigable waters. Administrative regulations exempt silvicultural operations from permit requirements.	State and Local Coastal Resources Management Act of 1978 (La. Rev. Stat., Sec. 49:213.1 to 49:13.22). Permits are not required for silvicultural activities when forest practices used consistently in the past are employed. An experimental or unconventional practice might require a permit. Natural and Scenic River System Act (Sec. 56:1841–1849.2) permits only selective cutting within 100 feet of scenic rivers. Requires removal of tree tops from rivers.
Mississippi	Air and Water Pollution Control Act. Miss. Code, Sec. 49–17–1 to 49–17–53. Enacted 1966; amended 1968, 1971, 1972, 1973, 1977, 1978, 1980, 1981, 1985.	Commission of Natural Resources under authority of Bureau of Pollution Control of Department of Natural Resources.	Commission empowered to develop standards and programs for prevention, abatement and control of water pollution. A separate permit board issues permits for the discharge of contaminants. Commission can issue cease-and-desist orders during an emergency.	Civil: up to $25,000 fine per day of violation. Criminal: $2,500 to $25,000 per day of violation. Commission can initiate civil action to recover actual damages.	Commission's powers are broad enough to be applied to nonpoint sources of pollution.	Stream Obstruction Law (Miss. Code Sec. 97–15–41) prohibits the felling of trees or leaving logs in excess of six inches in diameter or tree tops in a running stream.
North Carolina	Water and Air Resources Acts. N.C. Gen. Stat. Sec. 143–214. Enacted 1951; amended 1957, 1959, 1967, 1969, 1973, 1975, 1977, 1979, 1983, 1985.	Department of Natural Resources and Community Development under authority of Environmental Management Commission.	Commission has broad powers over water pollution, is authorized to issue permits for discharge of pollutants, and can issue orders directed at a violator after a hearing is held	Civil: up to $10,000 fine per day of violation. Criminal: violation considered misdemeanor; fine of up to $15,000 per day of violation, not to exceed a total of $200,000 for each 30- day period, and/or imprisonment for up to six months. Commission can initiate civil action to recover actual damages.	Sawdust and wood shavings are listed as potential pollutants in the law. Nonpoint pollutants are covered under the statute's definition of water pollution which includes "alterations resulting from the concentration or increase of natural pollutants caused by man-related activities".	Stream Obstruction statutes (N.C. Gen. Stat., Sec. 77–13 and 77–14) prohibit the felling of any tree, or the leaving of slash, stumpage, sawdust, shavings, etc. in any stream so as to obstruct drainage.
Oklahoma	Pollution Control Coordinating Act. Okla. Stat. Title 82, Sec. 931 to 942. Enacted 1968; amended 1971, 1974, 1976, 1981, 1983. Pollution Remedies Law, Okla. Stat. Title 82, Sec. 926.1 to 926.13. Enacted 1972, amended 1981.	Water Resources Board under authority of Pollution Control Coordinating Board.	Department has executive authority over all state agencies administering pollution programs. Definition of pollution is broad and includes those substances potentially injurious to aesthetic sensibilities. Exception: law does not apply to waters entirely in one ownership unless affecting another's property or water.	Criminal: willful violation of any promulgated order is considered misdemeanor, punishable by maximum fine of $200 to $10,000 per day of violation and/or up to six months imprisonment. Civil penalty: up to $10,000. Civil liability for damages lies with those responsible for violation.	Broad authority granted to Department of Pollution Control and Water Resources Board covers nonpoint source pollution.	
South Carolina	Pollution Control Act. Code Laws S.C. Title 48, Sec. 48–1–10 to 48–1–350. Enacted 1971; amended 1973, 1974, 1975, 1978, 1980.	Department of Health and Environmental Control.	Department charged with responsibility of administering all state programs under Federal Water Pollution Control Act. Department has permit issuing authority, and can promulgate rules and regulations. Can issue orders and initiate legal proceedings to force compliance. Exception: no civil or criminal liabilities to be imposed for violations caused by acts of God, war, strike, riot, or catastrophe.	Civil: fine not to exceed $10,000 per day of violation. Criminal: Violation considered misdemeanor; punishable by fine of from $500 to $25,000 per day of violation and/or imprisonment for up to two years. Department can initiate civil liability proceedings to recover costs of damage.	The statute addresses the term "pollutant" in its broadest sense, thereby presumably covering all nonpoint sources. Statute specifically lists decayed wood, sawdust, shavings, bark and sand as potential pollutants.	Stream Obstruction statute (Code Laws S.C. Title 49, Sec. 1–20) prohibits streambank damage or obstructing waterways with felled timber. Scenic Rivers Act (Title 51, Sec. 5–120) prohibits timber harvesting within designated distances of Class 1 streams on state controlled lands. Stream Cleaning Act (Title 49, Sec. 1–30) requires landowners to clean out the streams adjacent to their properties twice a year and to keep them free of obstructions which would interrupt the flow of sand and water.

Table C.1—Significant features of water quality legislation in the South—Continued

State	Statute and reference	Administering agency	Basic provisions	Penalties for violations	Significance for forest management	Related statutes
Tennessee	Water Quality Control Act. Tenn. Code Ann. Sec. 69-3-101 to 69-3-121. Enacted 1971; amended 1972, 1973, 1977, 1979, 1981, 1982, 1984, 1985.	Division of Water Quality Control (within Department of Public Health) under authority of Water Quality Control Board.	Department of Public Health has broad authority to control water pollution, through regulations issued by Division of Water Quality Control. Nonpoint pollution caused by agricultural and forestry activities are exempt from regulation. Department of Public Health may issue cease-and-desist orders, and order corrective action.	Civil: up to $10,000 fine per day of violation. Criminal: violation is considered misdemeanor; punishable by fine of $50 to $25,000 per day of violation. Willful noncompliance, falsification of records, or misrepresentation considered felony and punishable by fine up to $25,000 and/or two years imprisonment. Department of Public Health can assess civil damages.	Pollution caused by agricultural or forestry activities subject to regulation only if point source involved. Statute specifically lists decayed wood, sawdust, silt, shavings, bark and rock as potential pollutants (subject to regulation if point source).	Scenic Rivers Act of 1968 (Tenn. Code Ann. Sec. 11-13-102 to 11-13-117). Commercial timber harvest is prohibited in protected river areas within conservation or public use easement.
Texas	Water Quality Act. Texas Code Ann., Water Code, Title 2, Sec. 5.001 to 5.357 and 26.001 to 26.225. Enacted in 1977; amended 1981, 1985.	State Water Commission and State Water Development Board under the Department of Water Resources.	Water Commission may grant authority to local governments to issue permits for discharge of waste into water. Commission itself can also issue rules, regulations and orders to control water quality.	Civil: $50 to $10,000 fine per day of violation. Criminal: $10 to $10,000 per day for violation of a rule or regulation.	The statute specifically covers agricultural waste, presumably including residues from forestry activities. Statute specifically lists decayed wood; sawdust; shavings; bark; runoff from irrigation; and rainfall runoff from cultivated or uncultivated rangeland, pastureland and farmland that may impair water quality.	Stream Obstruction Act (Texas Code Ann. Sec. 5.096) prohibits obstruction of navigable streams by cutting and felling of trees.
Virginia	Water Control Law. Code Va., Sec. 62.1-44.2 to 62.1-44.42. Enacted 1973; amended 1974, 1976, 1977, 1978, 1980, 1981, 1984, 1985, 1986.	Water Control Board.	After conducting a hearing, Board can issue special order to prohibit pollution, and also seek injunctive relief against violations.	Civil: not to exceed fine of $10,000 per day of violation. Criminal: $100 to $25,000 per day of violation. Civil action for damages may be initiated by Board if fish are killed as result of pollutant discharge.	Legislation is broad enough to cover nonpoint pollution. Statute specifically lists decayed wood, sawdust, shavings and bark as potential pollutants.	Sec. 62.1-194 of the Virginia Code prohibits depositing timber or like material into any waters of the state. Sec. 62.1-194.2 of the Code prohibits placing treetops or logs which obstruct the movement of fish or boats for more than one week in rivers or streams. Scenic Rivers Act (Sec. 10-167 to 10-175). Permitted activities on rivers or river segments are designated on an individual basis. Forestry uses have not been restricted to date. Act specifies that the continuance of forestry activities on designated rivers is encouraged. Wetlands Act (Sec. 62.1-13.1 to 62.1-13.20) specifically permits the harvesting of forest products in wetlands.

Table C.2—Significant features of water quality legislation in the North

State	Statute and reference	Administering agency	Basic provisions	Penalties for violations	Significance for forest management	Related statutes
Connecticut	Water Pollution Control Act. Conn. Gen. Stat. Ann. Title 22a Sec. 416 to 471. Enacted 1958; amended 17 times, 1967 to 1987.	Department of Environmental Protection	Department granted authority to develop plans for the prevention and control of water pollution. Department adopts water quality standards and regulations in compliance with the Federal Water Pollution Control Act, and issues discharge permits. Department empowered to issue corrective orders.	Civil: up to $10,000 fine per day of violation. Criminal: up to $25,000 fine and/or one year in prison per day of violation. False statement or misrepresentation: up to $10,000 fine and/or six months in prison.	The statute's definition of water pollution includes alterations of water resulting in changes in turbidity or temperature which may be harmful to fish or other aquatic life. Statute requires a permit for any discharge; regardless of whether or not the discharge may cause pollution.	River Protection Statute (Conn. Gen. Stat. Ann. T.25 Sec. 102pp to 102vv). Municipalities granted authority to establish river protection corridors and may restrict land use. Some towns along Connecticut River require forest management and sediment control plans for forest operations. Inland Wetlands Statute (T.22a Sec. 361 to 363). Permit required for filling or reclamation of wetlands, road construction and clear-cutting of timber. Stream Obstruction Statute (T.22a Sec. 361 to 363). Permit required for placement of fill or obstruction in coastal, tidal or navigable waters. Soil Erosion and Sedimentation Control Act (T.22a Sec. 326 to 329). Municipalities may adopt regulations to control erosion and sedimentation. Coastal Management Act (T.22a Sec. 90 to 112). Municipalities may issue zoning regulations for land use in coastal areas.
Delaware	Environmental Protection Act. Del. Code Ann. T.7 Sec. 6001 to 6060. Enacted 1953, amended 1982, 1983, 1984, 1985, 1986.	Department of Natural Resources and Environmental Control.	Department empowered to develop, administer and enforce pollution control programs. Department adopts rules and regulations and develops statewide water pollution management plan. Department issues permits for discharges and may grant variances to rules and regulations. Department also granted authority to publish a list of activities exempt from permitting procedure. Prior to issuance of permits, proposed activities must be approved by the county or municipality of jurisdiction through zoning procedures. Department may issue cease-and-desist orders for violations.	Civil: from $1,000 to $10,000 fine per day of violation. Criminal: from $50 to $500 fine per day for general violation of rule or regulation or permit condition. From $2,500 to $25,000 fine per day for willful or negligent violation. From $500 to $5,000 fine and/or six months imprisonment for false statement or misrepresentation. Department may initiate civil action to recoup cost of damages.	Authority granted Department is sufficiently broad to apply to non-point sources. Department list of activities exempt from regulation has not been published, to date. Rock, sand, decayed wood, sawdust, shavings, bark and agricultural wastes are listed as potential pollutants.	Sedimentation and Erosion Control Act (Del. Code Ann. T.7 Sec. 4001 to 4017) requires submission of sedimentation and erosion control plans for land disturbing activities. Most forestry operations are exempt from regulation. Pollution of Streams (T.7 Sec. 1112) prohibits the discharge of any wastes or deleterious substance in sufficient quantities to injure or destroy fish.
Illinois	Ill. Rev. Stat. Ch. 111 1/2 Sec. 1001 to 1052. Enacted 1970; amended 1972 to 1986, 14 times.	Environmental Protection Agency and Pollution Control Board.	Board adopts rules and regulations and establishes water quality standards. Agency recommends regulations for adoption by Board and administers certification and permit systems. Agency responsible for administering National Pollutant Discharge Elimination System program. Agency may take summary enforcement action and issue stop orders for violations.	Civil: up to $10,000 fine per violation and $1,000 per day of violation. Criminal: violations other than hazardous waste disposal: up to $25,000 fine per day of violation, in addition to any other penalties prescribed.	Prohibits placing of any contaminants on land so as to create a water pollution hazard. Potential pollutants include wood residues, sand, silt, rock and agricultural wastes. Water quality standards developed to insure waters are free of floating debris and unnatural turbidity with potential to harm aquatic life.	Fish Protective Regulations (Ill. Rev. Stat. Ch. 111 1/2 Sec. 1001 to 1052) prohibit deposit of wastes in waters or placing of wastes where they may wash into waters, which are harmful to aquatic life. Specifically prohibits deposit of trash, trees, or parts of trees in or along banks of water. Pollution of Streams (Ch. 34 Sec. 3116) grants authority to counties to prevent pollution and issue stop orders for the discharge of pollutants. Local Land Resource Management Planning Act (Ch. 85 Sec. 5803 to 5809) authorizes local government to adopt ordinances to control land use. Purpose of act includes forest land and natural resource conservation. Forest Preserves (Ch. 96 1/2 Sec 6308). Silvicultural activities are permitted in preserves. Prohibits deposit of debris, trees or tree limbs or shrubbery in or along banks of waters within preserves (state or county owned lands). River Conservancy Districts (Ch. 42 Sec. 383 to 410.1) requires the Board of Trustees of river conservancy districts to control pollution through their police powers. Soil and Water Conservation District Law (T. 5 Sec. 106 to 138.2). Directors of districts may adopt land use ordinances for the control of erosion and sedimentation and prevention of water pollution with the approval of three-quarters of district landowners in a referendum. Flood Water Control (Ch. 19 Sec. 65 and 70) requires a permit for placement of woody plant material in or along banks of streams or for construction of stream crossings. Flood plains (Ch. 19 Sec. 65F). Requires a permit for any type of construction in designated floodplains.

Table C.2—Significant features of water quality legislation in the North —Continued

State	Statute and reference	Administering agency	Basic provisions	Penalties for violations	Significance for forest management	Related statutes
Indiana	Stream Pollution Control Act. Ind. Stat. Ann. T.13 Sec. 1-3-1 to 1-3-18. Enacted 1943; amended 1945, 1949, 1957, 1978, 1985, 1987.	Stream Pollution Control Board and Department of Environmental Management.	Board adopts rules and regulations and establishes standards for the discharge of pollutants. Department issues permits for discharges. Board may issue cease-and-desist orders and bring enforcement actions for violations.	Civil action may be initiated for failure to comply with orders to cease polluting activities within 60 days of issuance. Additional civil penalty of $100 per day of violation past date specified in order or for additional days granted. Criminal: violations are Class B misdemeanor and subject to fine of up to $1,000 and/or 180 days imprisonment.	Act prohibits any discharges which may impair fish life. Broad definition of pollutant includes both organic and inorganic matter which is disposed of in any way into waters, including runoff and seepage.	Stream Obstruction Statutes (Ind. Stat. Ann. T.14 Sec. 2-5-9 and T.13 Sec. 2-4-4) prohibit the obstruction of any navigable waters or other waterway which prohibits the free passage of fish. Scenic and Recreational Rivers Preservation Act (T.13 Sec. 2-26-1 to 2-26-11) requires approval of the Department of Natural Resources Commission prior to harvesting below the high flood mark of designated rivers, which may be up to 200 feet. River Commission Act (T.13 Sec. 2-27-1 to 2-27-27). Activities which significantly alter the natural and scenic qualities of designated rivers are generally prohibited. Individual river commissions have authority to issue permits for activities otherwise prohibited. Exception to permitting authority: activities visible from five feet above water surface. Flood Control Act (T. 13 Sec. 2-22-1 to 2-22-20) prohibits obstruction of any floodway which could adversely affect fish, wildlife or botanical resources.
Iowa	Water Quality Act. Iowa Code Ann. Sec. 455B. 171 to 455B. 210. Enacted 1965; amended 13 times, 1969 to 1986.	Department of Natural Resources and the Water Pollution Control Commission.	Commissioner establishes water quality standards and rules for discharges in accordance with the Federal Water Pollution Control Act. Department enforces rules and standards and issues permits. Department authorized to issue cease-and-desist orders.	Civil: up to $5,000 per day of violation. Civil penalty provided in Act as alternative to criminal. Criminal: up to $10,000 per day of violation. Repeated offense: up to $20,000 per day of violation. False statement or misrepresentation: up to $10,000 and/or six months in prison.	Definition of water pollution includes any alteration or contamination which is injurious to fish or other aquatic life. Act authorizes local governments to adopt ordinances and regulations for land use in flood plain areas.	Erosion Control Law (Iowa Code Ann. Sec. 467A.2 to 467A.75). Erosion control plan not required for timber harvest. However, operations must not exceed soil loss limits established for each district. Logging road construction may require erosion control plan if more than 25,000 square feet of soil are disturbed. Sec. 109.14 prohibits the obstruction of waters which impede the free passage of fish. Scenic Rivers System Act (Sec. 108A.1 to 108A.7) authorizes political subdivisions to zone or otherwise establish land use controls along designated rivers.
Maine	Protection and Improvement of Waters Act. Maine Rev. Stat. Ann. T.38 Sec. 361 to 489. Enacted 1954; amended 12 times, 1957 to 1985.	Board of Environmental Protection and municipalities under authority of the Board.	Board charged with the control and prevention of water pollution. Board issues permits and licenses, establishes water quality standards and parameters for the classification of waters. Board also establishes criteria for mixing zones required for the dilution of pollutants.	Civil: from $100 to $10,000 fine per day of violation. Criminal: up to $25,000 per day of violation. False statement or misrepresentation: up to $10,000 and/or six months in prison. Court may order restoration of site.	Statute includes sand, dirt, rock and agricultural wastes of any kind as potential pollutants. Prohibited deposits include sawdust, chips, bark and other forest products refuse. Permit may be required for operations conducted below high water mark of ponds over ten acres and in protected river corridors. In wetlands, "normal and customary" forest practices are exempt from permit requirement. Log driving is prohibited and the storage of logs in waters requires a permit. Permit required for dredge and fill operations and for construction of permanent structures within or adjacent to streams or rivers when spoil, fill or structure may wash into waters. Under Shoreline Zoning, (Sec. 435 to 447) timber harvesting within 250 feet of normal high water mark of waters, but not associated road construction, is exempt from permit requirements. Timber harvesting is prohibited within shorelands of ponds larger than ten acres in resource protection districts. Creation of clearings within 50 feet of the high water mark of a shoreline is also restricted.	Coastal Management Policies (Maine Rev. Stat. Ann. T.38 Sec. 1801 to 1803) establishes general policies for the protection of coastal resources, with potential application to forestry. Maine Land Use Regulation Law (T.12 Sec. 681 to 689) authorizes Land Use Regulation Commission to issue rules, regulations and standards for land use in unorganized townships. Harvesting and road construction may require permit and/or compliance with standards. Standards limit clearcut size and restrict slash disposal. Regulations require control measures be used to minimize sedimentation and erosion during road and stream crossing construction.

Maryland	Water Pollution Control and Abatement. Ann. Code of Md. T.8 Sec. 1401 to 1502. Enacted 1957; amended 13 times, 1973 to 1987.	Department of the Environment.	Department is responsible for development and implementation of pollution control programs. Department adopts rules and regulations, establishes water quality standards, and issues permits. Department may order corrective actions for violations.	Civil: up to $10,000 fine per day. Criminal: violation considered misdemeanor. Fine of up to $25,000 per day and/or imprisonment for up to one year. Penalty doubled for repeated offenses. Falsification or misrepresentation: fine of up to $10,000 and/or six months in prison.	Statute prohibits the emission of soil or sediment into waters or placement of soil or sediment where it is likely to be washed into waters by runoff of precipitation or by any other flowing waters.	Scenic and Wild Rivers Act (Ann. Code of Md. T.8 Sec. 401 to 411). Harvesting in some river corridors is regulated by local ordinances. Sediment Control Act (T.8 Sec. 1101 to 1104). Sediment control plan for harvests disturbing 5,000 square feet or more of soil, or which cross watercourses with drainage area in excess of 400 acres (100 acres for trout streams). Watershed Sediment and Waste Control (T.8 Sec. 1201 to 1210). Permits required for excavating, grading or filling operations in Severn or Patuxent watersheds. Chesapeake Bay Critical Area (T.8 Sec. 1801 to 1816) applies to all land within 1,000 feet of mean high tide. Commercial harvests require approval of forest mgmt. & sediment control plans by district forestry board. Harvesting prohibited within 50 feet of tidal waters and perennial streams. Clearcutting other than loblolly pine or tulip poplar prohibited within 100 feet of these waters; road construction regulated too.
Massachusetts	Clean Waters Act. Mass. Gen. Laws Ann. Chap. 21, Sec. 26 to 53. Enacted 1966, amended 14 times, 1967 to 1985.	Division of Water Pollution Control within the Department Environmental Quality Engineering.	Division has broad authority to promulgate rules and regulations, establish minimum water quality standards, and issue permits. Division may also issue cease-and-desist orders against violators.	Civil: up to $10,000 fine per day of violation. Criminal: fine of $2,500 to $25,000 and/or one year in jail. Department may order corrective action for violations.	Statute's definition of "pollutant" includes any element of agricultural, industrial or commercial waste, including runoff, whether originating at a point or major non-point source. Regulations exempt silvicultural operations including road construction from which there is natural runoff. Act specifies, however, that some silvicultural operations, such as stream crossings for roads, may require a Section 404 permit.	Scenic and Recreational Rivers and Streams (Mass. Gen. Laws Ann. Chap. 21 Sec. 17B). Counties may regulate, restrict or prohibit activities which could alter or pollute protected rivers and streams. Ordinances could be adopted to restrict silvicultural activities. Protection of Coastal Wetlands (Chap. 130 Sec. 105). Activities which involve dredge or fill or otherwise alter, or pollute lands subject to tidal action may be regulated, restricted or prohibited. Alteration of Lands Bordering Waters (Chap. 131 Sec. 40) requires written notice of intent to fill, dredge, or alter freshwater or coastal wetlands or any land subject to tidal action and a plan describing activities and their effect on the environment. Pollution of Coastal Waters (Chap. 130 Sec. 23 to 27) prohibits discharge of injurious substances, including sawdust and shavings, which directly or indirectly injure fish in coastal waters. Forest Cutting Practices Act (Chap. 132 Sec. 40–46) requires Intent to Cut/Cutting Plan for harvesting. Also requires additional wetlands or steep slopes plan, if applicable. Wetlands plan exempts operations from state Wetlands Law (Chap. 131 Sec. 40). Regulations address harvesting systems, skid trail location, stream crossing and road construction. Also limit clearcut size and require buffer and filter strips along streams. Additional rules for wetlands and steep slopes.
Michigan	Act establishing Michigan Water Resource Commission. Michigan Compiled Laws, Title 3, Sec. 520 to 532. Enacted 1929, amended 1941, 1947, 1949, 1963, 1965, 1968, 1972, 1977.	Michigan Water Resources Commission.	Commission authorized to regulate the storage or discharge of any substance which may affect water quality. Commission establishes water quality standards and issues permits for discharges. Commission has control over alterations of watercourses, floodplains, rivers and streams and may prohibit their obstruction. Act prohibits filling or grading lands located in flood plains or streambeds, except for agricultural purposes, without a permit. Copper or iron mining operations may be exempted from this provision.	Civil: up to $10,000 fine per day of violation. Criminal: from $2,500 to $25,000 fine per day of violation. Penalty doubled for repeated offense. Violator liable for restitution of damages to natural resources. Courts may impose probation in addition to fines.	Act prohibits discharge of any substance which is injurious to the value or utility of riparian lands or to fish, aquatic life or plants.	Stream Obstruction Statutes (Mich. Compiled Laws T.9 Sec. 334, T.13 Sec. 1657, T.9 Sec. 1175, T.18 Sec. 231) prohibit obstruction of streams or navigable waters with logs, lumber, apparatus or waste materials which prevent the free passage of fish or obstruct navigation. Soil Erosion and Sedimentation Control Act of 1972 (T.13 Sec. 1820(1) to 1820(17)). Counties delegated authority to enforce rules and regulations issued by the Commission and issue or deny permits for activities which may result in erosion or sedimentation. Empowers local governments to adopt more stringent requirements than issued by Commission. Act exempts logging from regulation. However, stream crossings constructed to conduct operations may require a permit. Shorelands Protection and Management Act (T.13 Sec 1831 to 1845) empowers Commission and local governments to adopt rules for land use along Great Lakes shorelands. Commission rules may restrict cutting or vegetation, requires buffer

Table C.2—Significant features of water quality legislation in the North—Continued

State	Statute and reference	Administering agency	Basic provisions	Penalties for violations	Significance for forest management	Related statutes
						strips be retained and/or management plans in designated areas. Inland Lakes and Streams Act (T.11 Sec. 475 (1) to 475 (15) requires a permit for activities which: (1) dredge or fill bottomland; (2) place a structure in bottomland; or (3) structurally interfere with natural flow of inland lake or stream. Permit required for both temporary and permanent stream crossing. Natural Rivers Act of 1970 (T. 11 Sec. 501 to 516). Counties and townships may require a permit or restrict or prohibit cutting timber along some rivers. Act limits restricted corridor to 100 feet. Gaemaere-Anderson Wetlands Protection Act (T.18 Sec. 595 (51) to 595 (72)) exempts silviculture, lumbering, and harvesting of forest products from permit requirements. Act also exempts minor drainage to improve site for silviculture or lumbering.
Minnesota	Water Pollution Control Act. Minn. Stat. Ann. Sec. 115.01 to 115.83. Enacted 1961; amended 15 times, 1963 to 1987.	Minnesota Pollution Control Agency.	Agency granted broad powers to establish rules and standards and issue permits and orders for pollution control. Enforcement powers include actions to recover civil penalties, injunctions and actions to compel performance.	Criminal: violations considered misdemeanor. Fine from $300 to $40,000 per day and/or one year imprisonment. Second conviction: up to $50,000 per day and/or two years imprisonment. Civil: up to $10,000 fine per day of violation. Exempted from civil liability are acts of God, war, negligence of the state, or sabotage or vandalism.	Definition of "other wastes" includes sawdust, shavings, bark, sand and agricultural wastes. Pollutants include any discharges which are harmful to fish or other aquatic life.	Pollution of Waters Act (Minn. Stat. Ann. Sec. 144.35) and Work in Public Waters Act (Sec. 105.42) prohibit the deposit of any sewage or other material which will impair the health of water or placing materials where they may fall or drain into a pond or stream. Sec. 105.42 includes excavation or filling activities. Public Waters and Wetlands Act (Sec. 105.37 to 105.391) empowers state to regulate activities which will change the course, current or cross-section of wetlands or public waters. Prohibits draining wetlands unless replaced with wetlands of equal or greater value. Silviculture not exempted. Any physical change below high water mark would require a permit, including logging road and skid trail construction and associated bridges and culverts. Shoreland Development Act (Sec. 105.485) requires counties and municipalities to adopt an ordinance for use and development of shorelands consistent with state model ordinance and rules. Current rules emphasize destruction of view. Proposed rules for silviculture include (1) maintaining buffer strips adjacent to waters; (2) restrictions for landing and yarding areas and skid and haul roads; (3) prohibition of clearing of vegetation on slopes 30 percent or greater; (4) requiring prompt reforestation; and (5) requiring permit and erosion control plan for forest conversions. Excessive Soil Loss Act (Sec. 40.19 to 40.27) encourages local governments to adopt soil loss ordinances consistent with state model and minimum standards. Forestry included as an "agricultural activity" in rules. A plan may be required for restoring erosion damage after harvest if soil loss is excessive. County Planning and Zoning Act (Sec. 394.21 to 394.26) grants authority to Board of County Commissioners to establish zoning districts for land use, including forestry. Floodplain Management (Sec. 104.01 to 104.07) encourages local governments to adopt ordinances for land use in flood-plains. Ordinances restrict fill, deposit or other use which unduly restrict the capacity of floodplains. Some counties require permit for logging road construction in floodplains. Wild and Scenic Rivers Act (Sec. 104.31 to 104.40). State rules prohibit clearcutting within designated distances of rivers depending on river classification. Trees greater than four inches in diameter may be removed provided continuous tree cover is maintained. County regulations may be adopted which are more restrictive than state.

Missouri	Clean Water Act. Ann. Missouri Stat. T.12 Sec. 644.006 to 644.141. Enacted 1972; amended 1973, 1982, 1983, 1987.	Missouri Clean Water Commission and Department of Natural Resources.	Commission granted broad powers to issue orders and permits. Commission adopt and enforce rules and regulations, and prescribes water quality standards. Department may initiate civil action to force compliance with standards and rules.	Criminal: $2,500 to $25,000 fine and/or one year imprisonment per day of violation. Subsequent convictions: up to $50,000 fine and/or two years imprisonment. False statement or misrepresentation: up to $10,000 fine and/ or six months imprisonment. Civil: up to $10,000 fine per day of violation. Action may be brought to restore damages.	Definition of pollution includes alterations of water turbidity and contamination which is harmful to fish and other aquatic life. Act states that contamination includes both direct and indirect sources including surface runoff. Commission authorized to conduct a planning process to identify silvicultural nonpoint sources of pollution and to develop procedures and methods, including land use requirements, to control sources.	Steam Obstruction Statute (Ann. Missouri Stat., T.16 Sec. 252.200) prohibits obstructing the free passage of fish through any waters of the state. Water Conservancy District Act (T.16, Sec. 257.010 to 257.490) empowers citizens to form river basin conservancy districts through which land use may be regulated.
New Hampshire	Water Pollution and Disposal of Wastes Act. N.H.R.S. Ann. Sec. 149:1 to 149:26. Enacted 1947; amended 11 times, 1955 to 1986.	New Hampshire Water Supply and Pollution Control Commission.	Commission has broad authority for the discharge of pollutants in waters and alterations near waters. Commission issues permits, promulgates rules and regulations, and classifies waters into one of four quality types. Commission may issue cease-and-desist orders.	Civil: up to $10,000 fine per day of violation. Criminal: up to $25,000 fine per day and/or six months in prison.	Act includes decayed wood, sawdust, bark, shavings and other substances harmful to human, animal, fish or aquatic life as potential pollutants. Prohibits placing trees or parts thereof in waters. Detailed plans must be submitted for forest operations in lands bordering water. Upon approval of the Commission, a permit will be issued. Requirement can be circumvented by signing of an agreement to implement appropriate BMP's to protect water quality. If operator fails to comply with BMP's, he is subject to penalties under the law and will be required to submit detailed plans for future operations.	Fill and Dredge in Wetlands (N.H.R.S. Ann. Sec. 483-A:1 to 483-A:7) requires permit for some activities in wetlands such as construction of stream crossings. Slash and Mill Waste (Sec. 224:44-b) prohibits disposal of slash in waters or within 25 feet of streams or rivers capable of float-ing a canoe or within 50 feet of navigable rivers or ponds greater than 10 acres. Limits slash dispos-al to 4 feet above ground between 50 and 150 feet of ponds greater than 10 acres or navigable streams or rivers. Cutting of Timber near Public Waters and Highways (Sec. 224: 44-a) limits cutting of trees to 50 percent of basal area within 150 feet of ponds greater than ten acres and navigable streams and rivers or within 50 feet of any other continuously flowing stream or river.
New Jersey	Water Pollution Control Act. N.J. Stat. Ann. T.58 Sec. 10A-1 to 10A-37. Enacted 1977; amended 1981, 1984, 1986.	Department of Environmental Protection.	Commissioner of Department of Environmental Protection empowered to adopt rules and regulations, classify bodies of water and establish water quality standards for each class, and issue permits. Commissioner may, by regulation, exempt certain discharges from permit requirements. Possible exemptions include: (1) Uncontrolled nonpoint source discharges composed entirely of stormwater runoff; (2) nonpoint discharges in general; and (3) discharges of dredge and fill material.	Civil: up to $50,000 fine per day of violation. Criminal: fine of $5,000 to $50,000 and/or six months imprisonment per day of violation. Penalty doubled for repeated offense. False statement or misrepresentation: up to $20,000 fine and/or up to six months imprisonment. Assessment of civil liability for damages.	Act defines pollutants to include dredged spoil, rock, sand, agricultural waste or other residue. Silvicultural nonpoint source pollution could be exempted at the discretion of the Commissioner through regulations.	Flood Hazard Area Control Act (N.J. Stat. Ann. T.58 Sec. 16A-50 to 16A-66) requires permits for land disturbing activities affecting more than 5,000 square feet in flood hazard areas. Logging road construction may require a permit for extensive operations. Stormwater Management Plan (T.40 Sec. 55D-93 to 99). Municipalities required to adopt ordinances to minimize stormwater runoff and control nonpoint source pollution. "Nonpoint pollutants" include silvicultural sources. To date, ordinances have not been adopted. Soil Erosion and Sediment Control Act (T.4 Sec. 24-39 to 24-55). Soil Conservation Committee establishes standards and may require plans for the control of sedimentation and erosion from land disturbing activities involving 5,000 square feet or more of soil. To date, plans have not been required for silvicultural operations. Could be applied when large areas are disturbed during logging road construction. Wild and Scenic Rivers Act (T.13 Sec. 8-45 to 8-54). Department of Environmental Protection establishes minimum standards for land use in river corridors. Municipalities may adopt rules and regulations more stringent than Department. To date, no regulations or standards have been adopted. Pinelands Protection Act (T.13 Sec. 18A-1 to 18A-49) applies to approximately one million acres. Pinelands Commission requires harvesting plan be approved by the Bureau of Forestry prior to issuance of a permit by the Commission. Act prohibiting the draining of deleterious substances into waters (T.23 Sec. 5-28 to 5-29.1) exempts application of chemicals on forest crops. Freshwater Wetlands Act(T.13 Sec. 9B-1 to 30) regulates dredging, draining, filling, and other alterations of freshwater wetlands, including cutting of trees. Exempt from permitting process are "normal" silvicultural operations; includes harvesting and road construction in compliance with BMP's and a management plan approved by State Forester. Conversion of wetlands to manipulate tree species composition not exempt.

Table C.2—Significant features of water quality legislation in the North—Continued

State	Statute and reference	Administering agency	Basic provisions	Penalties for violations	Significance for forest management	Related statutes
New York	Water Pollution Control Act. Cons. Laws of N.Y. Art. 17 Sec. 0101 to 1907. Enacted 1972; amended 12 times, 1973 to 1987.	Department of Environmental Conservation	Department determines classifications of waters and adopts standards of quality and purity for each class. Department adopts rules and regulations to prevent pollution and issues permits. Department authorized to issue cease-and-desist orders for violations.	Civil: up to $1,000 fine per violation Criminal: fine from $2,500 to $25,000 per day of violation and/or one year imprisonment. Penalty double for repeated offenses.	Potential pollutants include substances which may be harmful to aquatic life. Prohibited "industrial wastes" include substances resulting from the development or recovery of any natural resource, which may be a potential pollutant. Prohibited "other wastes" include sawdust, decayed wood, shavings and bark. Act prohibits the discharge of both organic and inorganic matter which is not in compliance with Department standards.	Wild, Scenic and Recreational Rivers (Cons. Laws of N.Y. Art. 15 Sec. 2701 to 2723). Regulations require a permit for clearcuts in excess of 25 acres and include numerous rules for road and stream crossing construction, felling and skidding trees, debris removal, and buffer strips in river corridors. Fish and Wildlife Law (Art. 11 Sec. 0501 to 0536) Act prohibits the deposit of sawdust, shavings, or bark in waters in amounts which would harm fish or wildlife. Prohibits obstruction of waters which hinder the passage of fish. Prohibits the deposit of soil in streams or on banks of streams inhabited by trout. Freshwater Wetlands Regulations (Art. 24 Sec. 0701 to 0705). Act regulates draining, dredging or filling of freshwater wetlands. Permits required for clearcuts within wetlands, but are usually not granted. Selective cutting is exempt from regulation. Clearcuts in areas adjacent to wetlands require permit, and are usually granted. Stream Protection Law (Art. 15 Sec. 0501 to 0503). Act requires a permit for changing, modifying, or disturbing streams or banks of streams within designated water classifications. Excavation or fill in navigable waters (Art. 15 Sec. 0505) requires permit for excavation or fill below the high water mark of navigable waters and in adjacent wetlands or marshes.
Ohio	Water Pollution Control Act. Ohio Rev. Code Ann. Sec. 6111.01 to 6111.99) Enacted 1953, amended 14 times, 1955 to 1984.	Department of Environmental Management	Department promulgates rules and regulations and establishes water quality standards. Department issues permits and orders for pollution control. Act prohibits placing any waste in a location where water pollution could result without a permit. Exception: application or runoff of materials used for agricultural purposes. Department may seek injunction against violators.	Criminal: up to $25,000 fine and/or one year imprisonment.	Definition of pollutant includes decayed wood, sawdust, bark shavings, other wood debris and silt.	Pollution Control Program (Ohio Rev. Code Ann. Sec. 1501.20) requires Soil and Water Conservation Commission to develop program for agricultural pollution abatement to meet state water quality standards. Commission currently has no enforcement power. Department of Natural Resources is seeking amendment for $100 fine per day for pollution resulting from agricultural (including silvicultural) sedimentation. Watershed District Law (Sec. 6105.01 to 6105.99) prohibits obstruction of restricted floodway without consent of Board of Directors of watershed districts.
Pennsylvania	Clean Streams Act. Penna. Stat. Ann. T.35 Sec. 691.1 to 691.1001. Enacted 1937; amended 1945, 1956, 1965, 1970, 1976, 1978, 1980.	Department of Environmental Resources and Environmental Quality Board	Department has broad authority to adopt rules and regulations and establish standards to control pollution. Department issues permits for discharges and may seek injunctions and issue orders for abatement of polluting activities.	Civil: up to $10,000 fine per day of violation. Criminal: from $100 to $10,000 fine for violation. Default of payment: 90 days imprisonment. Willful or negligent violations: from $2,500 to $25,000 fine and/or one year imprisonment. Additional offense within two years of first offense: from $2,500 to $50,000 fine and/or two year imprisonment.	Act defines pollution to include contamination which is injurious to fish or other aquatic life and alterations resulting in changes in water temperature. Exempt from penalties is pollution in the form of sediment resulting from an act of God on land for which an approved conservation plan has been implemented. By inference, other causes of sedimentation, including that resulting from forest operations, would be subject to regulation. Under regulations issued under the Act, detailed, site specific plans are required for erosion and sedimentation control for silvicultural operations where earth disturbing activities exceed 25 acres.	Flood Plain Management Act (Penna. Stat. Ann. T.32 Sec. 679.101 to 679.601). Plans to control obstruction of flood waters implemented by local governments. Some may regulate forest operations. Storm Water Management Act (T.32 Sec. 680.1 to 680.17). Local governments may enact ordinances for the control of runoff and sedimentation and erosion. Some may regulate forest operations. Dam Safety and Encroachment Act (T.32 Sec. 693.1 to 693.27). Permit required for both permanent and temporary water crossings constructed during harvesting operations. Scenic Rivers Act (T.32 Sec. 820.21 to 820.29). Recommended guidelines for silvicultural operations have been issued. Protection of Property and Water Act (T.30 Sec. 2501 to 2506). Permits required for activities which alter streams, water or watersheds in any way which may damage fish.

Rhode Island	Water Pollution Control Act. Gen. Laws of R.I. T.46 Sec. 12-1 to 12-37. Enacted 1920; amended 24 times, 1921 to 1986.	Department of Environmental Management	Department empowered to adopt standards and issue rules and regulations for the control of water pollution. Department classifies waters and issues permits for the discharge of pollutants. Department has authority to issue stop orders for violations.	Civil: up to $5,000 fine per day of violation. Criminal: up to $10,000 fine and/or 30 days imprisonment per day of violation. False statement or misrepresentation: up to $5,000 and/or 30 days imprisonment.	Act defines pollutant to include agricultural wastes. Legislation is sufficiently broad to cover nonpoint sources of pollution. Act prohibits placing any pollutant where it is likely to enter waters or to place any solid waste materials, junk or debris whether organic or inorganic in waters.	Soil Erosion and Sediment Control Act (Gen. Laws of R.I. T.45 Sec. 46-1 to Sec. 46-6). Cities and towns may require permits for earth disturbing activities. Act exempts harvest activities on property utilized for silvicultural purposes. Road construction may require a permit and erosion control plan if extensive or if involving slopes greater than ten percent. Freshwater Wetland Act (T.2 Sec. 1-18 to 1-27) prohibits excavation, draining or filling of wetlands. Also prohibits placing garbage, earth, rock, sand or other materials in waters. Harvesting operations may require a management plan, depending on extent of operations.
Vermont	Water Pollution Control Act. V.S.A. T.10 Sec. 1250 to 1384. Enacted 1947; amended 15 times, 1949 to 1987.	Vermont Resources Board and Department of Water Resources and Environmental Engineering within the Agency of Environmental Conservation.	Act establishes classification parameters for waters. Board adopts standards of water quality for various classes. Agency establishes rules and regulations for pollution control and has authority to issue permits. Act addresses stormwater runoff and alteration of wetlands. Agency authorized to bring suit to force compliance with Act and may order corrective action for violations.	Civil: up to $10,000 fine per day of violation. Criminal: up to $25,000 fine and/or six months imprisonment per day of violation. Falsification or misrepresentation: up to $10,000 fine and/or six months imprisonment. Sawmill Waste: $100.00 fine per offense.	Act prohibits deposit of sawdust, shavings, edgings, slabs or other sawmill refuse into waters or placing wastes in such a manner as to wash into waters. Forest operations must comply with acceptable management practices (AMP's) to be exempt from permitting requirements under Act. Department of Forests, Parks and Recreation issues AMP's.	Protection of Navigable Waters and Shorelands Act (V.S.A. Sec. 1421 to 1426). Municipalities authorized to adopt shoreland zoning bylaws to control pollution and protect fish and aquatic life. Some forest operations may be restricted. Water Resources Management Act (Sec. 901 to 923) grants broad authority to Water Resources Board for protection of wetlands. Board may not adopt rules which restrain silvicultural activities without consent of the Department of Forests, Parks and Recreation. An Act Relating to Regulation of Wetlands (Senate Bill 95 No. 188). Sections related to forestry duplicate Water Resource Management Act. Rules and regulations currently being developed will restrict some forest operations such as draining wetlands to harvest and road and stream crossing construction in wetlands.
West Virginia	Water Pollution Control Act. W. Va. Code, Chap. 20, Art. 5A-1 to 5A-21. Enacted 1969; amended 1976, 1978, 1983.	Division of Water Resources (within Department of Natural Resources) under authority of Water Resources Board.	Division of Water Resources is authorized to carry out requirements of Federal Water Pollution Control Act; has permit issuing authority and may issue stop orders. Exception: law does not apply to farm ponds, industrial settling ponds and water treatment facilities.	Civil: fine not to exceed $10,000 per day of violation. Fine can be imposed only by civil action initiated in circuit court of county where violation occurs. Criminal: violation considered misdemeanor; punishable by fine of $100 to $25,000 per day of violation and/or up to one year in jail. Department of Natural Resources can initiate court action to recover costs of damage.	Law is sufficiently broad to include nonpoint pollutants under its provisions. Decayed wood, sawdust, shavings, and other wood residues are specifically listed as potential pollutants. Stringent water turbidity standards have been established. Exceptions for logging have been made where a site specific BMP plan is in effect.	Stream Obstruction Law (W. Va. Code, Chap. 61, Art. 3-47) prohibits any felling of timber that would obstruct a navigable or floatable stream. Natural Stream Preservation Act (Chap. 20, Art. 5B-1 to 17) prohibits activities which obstruct the free-flowing characteristics of designated streams without a permit. Act has not been applied to forest operations to date.

Table C.2—Significant features of water quality legislation in the North—Continued

State	Statute and reference	Administering agency	Basic provisions	Penalties for violations	Significance for forest management	Related statutes
Wisconsin	Water and Sewage Act. Wis. Stat. Ann. Sec. 144.01 to 144.27. Enacted 1913; amended 15 times, 1919 to 1986.	Department of Natural Resources.	Department has broad authority for supervision and control over state waters. Department develops regional plans, establishes water quality standards, adopts rules and regulations, and issues permits for discharges. Department may issue temporary emergency orders to protect public health and stop orders for abatement of pollution. Department required to prepare comprehensive plan for application of municipal ordinances regulating navigable waters and shorelands. Act authorizes municipal construction site erosion control and storm water management zoning ordinances. Department required to develop standards for ordinances.	$200 to $5,000 fine per day of violation.	Prohibits the disposal of garbage or refuse where it is likely to be washed into water. Prohibited are discharges which are deleterious to fish and unnecessary siltation resulting from gross neglect of land erosion. Act establishes a nonpoint source pollution program providing technical and financial assistance. Department promulgates rules and standards concerning BMP's which must be met for cost sharing grants.	Wetlands Zoning Act (Wis. Stat. Ann. Sec. 61.351) requires villages to enact ordinances consistent with Department of Natural resources (DNR) minimum standards to protect shorelands. Access roads and stream crossings for logging operations may require permit and/or be subject to DNR standards. Shoreland Zoning on Navigable Waters Act (Sec. 59.971) requires counties to enact zoning ordinances to protect shorelands within 1,000 feet of lakes and ponds and 300 feet from rivers and streams. Clearcuts are limited to 30 feet for each 100 feet along shorelands within a 35 foot corridor. Slash Disposal Act (Sec. 26.12) requires timber owners or operators to remove logging slash from lakes and streams. Environmental Impact Statement (EIS) Act (Sec. 23.40). DNR determines whether EIS required based on information submitted when applying for permit. Permit required for stream crossing, therefore would be subject to review. Soil and Water Conservation Law (Sec. 92.02 to 92.16) requires Department of Agriculture to develop model ordinances for land use for adoption by counties and municipalities. Local ordinances may restrict land management practices which cause excessive erosion, sedimentation, nonpoint source pollution, or stormwater runoff. Ordinances must be approved in referendum. Wild Rivers Act (Sec. 30.26) designates Pike, Pine and Popple rivers for preservation. Requires DNR to work with counties and towns to establish program for river protection. Requires DNR to cooperate with USFS, timber companies, and private landowners in implementing land use practices. Some ordinances restrictive to forest practices have been adopted. Lower St. Croix River Preservation Act (Sec. 30.27) requires local governments within designated protected areas to enact zoning ordinances in compliance with DNR guidelines and standards. Some ordinances have been restrictive to forest operations. Obstruction of Navigable Waters (Sec. 30.15) prohibits placing any obstruction in navigable water or tributaries which impedes navigation. Enlargement and Protection of Waterways Act (Sec. 30.19). Prohibits grading or otherwise removing top soil from banks of navigable waters which expose more than 10,000 square feet. Exempts agricultural land use. Changing of Streamcourse Act (Sec. 30.195) prohibits changing of course or straightening of navigable streams without permit. Under authority of Sec. 30.15, 30.19, and 30.195, both temporary and permanent stream crossings associated with logging require a permit.

Table C.3—Significant features of water quality legislation in the Rocky Mountain Region

State	Statute and reference	Administering agency	Basic provisions	Penalties for violations	Significance for forest management	Related statutes
Arizona	Ariz. Rev. Stat. Ann. Sec. 49-201 to 321 resulting from additions, transfers and renumbering from Title 36 (enacted in 1956 with subsequent amendments). Enacted in 1986, effective 1987.	Department of Environmental Quality.	Department to promulgate water quality standards for all navigable waters, and develop a program for control of nonpoint source pollution into such waters. As part of this program, Department may establish BMP's for silvicultural activities. Forestry operations may require either individual or general permit at Department's option. Department may issue order requiring initiate compliance with statutory provisions; order will become final and enforceable within 30 days unless administrative hearing is requested. Department may request a temporary restraining order, preliminary or permanent injunction, or any other relief necessary to protect public health.	Civil penalties up to $25,000 per day per violation plus costs of litigation. Monetary damages to be paid to water quality assurance revolving fund. Criminal penalties range from felony to misdemeanor depending upon whether the violator was fully knowledgeable, negligent, or reckless. Violators may also be responsible for remedial action costs.	Sections R9-21-202 to 205 of Administrative Rules and Regulations of Arizona 1986 prohibit water quality degradation. Otherwise, Department has no non-point source program beyond water quality standards. No forestry BMP's have been developed and none are expected. Only standards likely to affect forestry practices are turbidity and temperature. Regulations governing use of agricultural pesticides currently under development for protection of groundwater.	Ariz. Rev. Stat. Ann. Sec. 17-231, 237; requires cooperation between Department of Environmental Quality and Game and Fish Commission in abatement of water pollution injurious to wildlife. Commission may also bring suit in such matters. Ariz. Rev. Stat. Ann. Sec. 45-573 requires cooperation between Department of Environmental Quality and Department of Health Services on development of water quality management plans.
Colorado	Colorado Water Quality Control Act. Colo. Rev. Stat. Sec. 25-8-101 to 703. Enacted 1973, supplemented 1986.	Department of Health through Water Quality Control Commission.	Policy objectives of legislation are two-fold: (1) protect quality of water resources, and (2) maximize the beneficial use of water resources consistent with the welfare of the state. Act does not supersede or materially diminish prior established water rights. Water Quality Commission within Department has authority to classify waters and promulgate water quality standards to control pollution. In developing standards, Commission is directed to consider whether pollution is from a natural source. Commission may promulgate regulations for the keeping of logs in water. Commission may not adopt standards for agricultural nonpoint sources of discharge which materially injure existing water rights. Department is to administer standards and programs developed by Commission. Department required to establish permit system for regulation of point sources of pollution; there are no particular provisions governing nonpoint sources. Department may issue "cease and desist" and "clean-up" orders. Failure to comply with such orders may result in temporary restraining order or injunction.	Civil: up to $10,000 per day of violation. Civil penalty credited to water quality control fund. Criminal: up to $12,500 if violator is negligent or reckless; up to $25,000 if violator is fully knowledgeable of the offense.	Standards that may be promulgated under the Act's authority which could impact forest management include those for turbidity, temperature, and suspended solids. At present, however, there are no standards for turbidity and suspended solids, and there is no program for regulation of nonpoint pollution sources. No forestry BMP's have been developed. An assessment and management plan for nonpoint sources of pollution is currently under development. No reference exists for excluding forest management operations from the point source pollution permit requirement as there is for irrigation return flow.	Colorado Soil Conservation Act (35-70-101 to 121) established State Soil Conservation Board to conserve and protect water resources, including: (1) the initiation of watershed planning to prevent flooding, and (2) the construction of structures to maintain soil stability and control erosion. Colo. Rev. Stat. 33-5-101 to 106 provides that no state agency may modify a watercourse without notification and a permit to insure protection of fishing streams. Law does not operate to diminish existing water rights and does not apply to irrigation projects. State Board of Agriculture has authority under Colo. Rev. Stat. 23-30-202 to "foster and promote" control of soil erosion on forest lands. Pesticide Applicators' Act (Colo. Rev. Stat. 35-10-101 to 125) provides that regulation of distribution, use, and application of pesticides is to involve balance of social utility and cost. Colo. Rev. Stat. 36-8-101 to 110. Regulates use of streams for floating logs to be used for any purpose; such use requires a permit from state engineer. Colo. Rev. Stat. 20-30-202 authorizes State Board of Forestry to "foster and promote" the control of soil erosion on forest lands. Colo. Rev. Stat. 23-30-301 states that policy objective of Colorado State Forest Service is to: "conserve forest cover on watersheds".

Table C.3—Significant features of water quality legislation in the Rocky Mountain Region—Continued

State	Statute and reference	Administering agency	Basic provisions	Penalties for violations	Significance for forest management	Related statutes
Idaho	Environmental Protection and Health Act of 1972. Idaho Code, Sec. 39-101 to 118. Enacted 1947; amended 1973, 1979, 1980, supplemented 1987.	Department of Health and Welfare, Environmental Protection Division.	Department to promulgate and enforce regulations to enhance and preserve water quality. Department authorized to recommend rules to Board of Health and Welfare regarding water pollution, and issue permits as prescribed by law. Department also authorized to conduct investigations of violations of water quality standards. Department may use compliance schedule to assure timely compliance with regulations. Department authorized to implement water quality standards adopted by legislature.	Civil penalty of $1,000 per day of violation or $10,000, whichever is greater, plus reimbursement of remedial costs incurred by the state. Criminal: willful or negligent violation is misdemeanor offense punishable by fine of up to $300 for each violation. Each day a violation occurs is separate offense.	Water quality standards acknowledge economic necessity of nonpoint pollution activities. Management of nonpoint pollution designed to only reduce such pollution; state's position is that it cannot be eliminated without severe economic impact. Generally, standards prohibit sediment in quantities which impair beneficial use of water. Nonpoint sources of pollution specifically include silt, sand and rock resulting from silvicultural activities, or from log storage in water. Silvicultural BMP's designed to protect water quality established in rules promulgated under Forest Practices Act (Idaho Code Sec. 38-1301 to 1312) These rules certified as approved water quality BMP's by Section 16.01.2300.05 of water quality standards issued by Department. BMP's are mandatory for all forestry operations. Department responsible for evaluation and modification of BMP's to insure protection of beneficial use of water. Failure to meet water quality standards is *not* violation of law, but rather occasion for evaluating effectiveness of BMP's in protecting water quality. Operators failing to follow BMP's are subject to compliance schedule and fine. Injunctive and judicial relief are also available. Where BMP's have not been developed, activity must be conducted to minimize detrimental impact to water.	The Idaho Forest Practices Act (Idaho Code Sec. 38-1301 to 1312) authorizes promulgation of rules to establish BMP's to protect water quality during all phases of forest management. Drainage systems must control runoff waters from exposed surfaces. Slash and waste materials must not enter streams. Streams to be protected by avoiding skidding and cable yarding in or through them, and by retaining vegetation to shade water and stabilize soil. Chemical, road construction, and reforestation BMP's are also designed to protect water quality. BMP's last evaluated for effectiveness in protecting water quality in 1985. Results indicated that revision of Forest Practices Act rules was necessary. Rules revised in 1986 and incorporated into 1987 draft of Forest Practices Water Quality Plan. Feedback cycle for continuous proposal, implementation, and evaluation of BMPs also included. Violation of BMPs is misdemeanor. Stream Channel Protection Act (Idaho Code 42-3801 to 3812) protects against deleterious alteration of stream channels. Alterations impacting wildlife, aquatic life, recreation, or other facets of water quality require a permit from Department of Water Resources. Act does not diminish existing water rights. Failure to obtain permit (misdemeanor) may result in fine of $150 to $500, plus additional fine of up to $150 per day that violation continues. Department has issued regulations governing stream channel alterations; these are certified as approved BMP's which are mandatory for forestry operations. Idaho Code Section 52-101 provides that unlawful obstruction of free passage or use, in customary manner, of any navigable lake, or river, stream, canal or basin is considered public nuisance. Idaho Code Sections 42-3601 to 3604 provide that Department of Lands is to cooperate with federal agencies in planning "works of improvement" (as per Watershed Protection and Flood Prevention Act of 1954, 16 USC Sec. 1001-1009) to prevent erosion, floodwater, and sediment damage. Idaho Code Sections 58-101, 140 to 147 provides that encroachments into lakes regulated by Board of Land Commissioners. Violators subject to fine ranging from $150 to $2500. Idaho Code Sections 58-401-405 provide that trees on state lands needed for conservation of irrigation water cannot be felled. Nonmerchantable dead and down timber on state land not required for water conservation (soil stabilization) may be informally sold by Department of Lands as firewood. Department of Water Resources must be given notice and opportunity to interpose objections prior to any timber sale.
Kansas	Water Supply and Sewage Act. Kansas Stat. Ann. Ch. 65 Art. 16 Sec. 1 to 71W. Enacted 1897; amended 1909, 1923, 1927, 1967, 1974, 1977.	Department of Health and Environment.	Department establishes water quality standards and issues permits for the discharge of sewage. Department adopts rules and regulations for petroleum products storage, salt solution mining and laboratory certification where water sample analysis conducted. Department may issue stop orders for violations.	Criminal: $2,500 to $25,000 fine per day of violation. False statement: up to $10,000 fine per day. Civil: up to $10,000 per day of violation. Violators also liable for costs of restoration of damages.	Definition of pollutant includes alterations which are harmful to plant, animal or aquatic life.	Stream Obstruction Statutes (Kansas Stat. Ann. Ch. 32 Art. 1 Sec. 2, Ch. 82A Art. 3 Sec. 01 and Ch. 24 Art. 2 Sec. 06) prohibit: (1) obstructing the free passage of fish. (2) willful obstruction or filling of any drain, ditch or watercourse, and (3) obstructions which change or diminish the course, current or cross-section of waters. Floodplain Regulation Act (Ch. 12 Art. 2 Sec. 06) grants local governments the authority to establish floodplain zones and restrict land use through ordinances and regulations. Must be approved by Chief Engineer of Water Resources.

Montana	Montana Water Quality Act. Mont. Code Ann. Sec. 75-5-101 to 75-5-641. Enacted 1967; amended 1971, 1973, 1974, 1975, 1977; supplemented 1985.	Department of Health and Environmental Sciences.	Purpose of Act is to protect both quality and quantity of water. Board of Health and Environmental Sciences authorized to adopt rules to achieve this objective, including classification of all waters and development of water quality standards. Standards and classes not to allow water to be degraded below its existing state, unless justified by economic or social development. Water quality standards need not exceed "natural" level of quality, where "natural" is defined as conditions or material present from water runoff over which man has no control or from developed land where all reasonable land, soil, and water conservation practices (BMP's) have been applied. New sources of pollution require permit; existing quality level must be maintained.	Civil: violators subject to fine of up to $10,000. Each day of violation constitutes separate offense. Criminal; willful or negligent violators subject to fine of up to $25,000 per day of violation and up to one year in prison. Subsequent convictions subject violators to $25,000 (maximum) fine and two years imprisonment.	Water quality standards focus on "natural" quality of water. Standards classify water by beneficial use; e.g. with respect to water classified for lower beneficial uses, greater deviation is allowed from level of pollutants naturally occurring in the stream. However, land management activities must not generate pollutants in excess of natural levels, regardless of stream class. Forestry BMP's developed by Department of State Lands include guidelines on road construction, harvesting, reforestation, and fire suppression. Under Memorandum of Understanding, both private and public forest managers have agreed to abide by established BMP's. Runoff and sedimentation acceptable if reasonable conservation practices (BMP's) are applied and beneficial uses of water are maintained. Exceptions to nondegradation rules allowed based on need for social and economic development.	Mont. Code. Sec. 76-13-101 to 601 provide for protection and conservation of forest, water, and range resources including regulation of streamflow and prevention of soil erosion. Mont. Code Sec. 75-6-101 to 13 provide for the protection of public water supplies. Prohibit building logging camps or roads near public water supplies, and industrial waste discharge from development of natural resources into such waters. The Natural Streambed and Land Preservation Act of 1975 (Mont. Code Sec. 75-7-101 to 124) prohibits unauthorized alteration of streambeds. Board of Natural Resources and Conservation authorized to issue regulations governing streambed alterations. Existing water rights are preserved. Failure to obtain permit may subject violator to fine of $25 to $500 per day plus remedial costs. Mont. Code Section 27-30-101 declares any obstruction or injury of navigable lake, river, bay, stream, or canal to be a nuisance. Mont. Code Sec. 75-7-201 to 217. Permit required for alteration of lakeshores.
Nebraska	Environmental Protection Act. Rev. Stat. Neb. T.81 Sec. 1501 to 15,127. Enacted 1971; amended 12 times, 1972 to 1987.	Department of Environmental Control and Environmental Control Council.	Council adopts rules and regulations and sets standards for land, air and water quality. Department enforces provisions of the Act and Council rules and regulations. Department issues permits and may order violator to take corrective action. Department may grant variances. Act addresses litter control and disposal.	Criminal: up to $5,000 fine per day of violation and/or six months imprisonment. Civil: up to $5,000 per day of violation. Violators responsible for pollution resulting in the death of fish or wildlife are liable for compensation to state for restocking fish or replenishing wildlife. Prosecutions civil in nature except where clear criminal intent or knowing violation takes place	Legislative authority sufficiently broad to include nonpoint sources of pollution. Purpose of Act includes the protection of fish and other aquatic life.	Floodplain Management Act (Rev. Stat. Neb. Sec. 31-1001 to 31-1031) requires a permit prior to obstruction of any watercourse or floodplain. Nebraska Natural Resource Commission develops and adopts minimum standards for incorporation into local governmental regulations. If not adopted by local governments, state regulations are automatically effective. Littering of Waters Act (Sec. 37-516) prohibits placing litter, trash, lumber or any material injurious to aquatic life in or near waters. Fishway Through Dams Act (Sec. 37-406) requires owner of dam or other obstructions across watercourse to insure flow of water sufficient for support of aquatic life. Stream Obstruction Statute (Sec. 455.160) prohibits and deems a nuisance any obstruction, diversion, filling up, ditching or draining any watercourse which has been prohibited by a resolution of the drainage district. Erosion and Sediment Control Law (Sec. 2-4601 to 2-4613) requires natural resource districts to adopt a program for implementation of state's erosion and sediment control plan, including soil loss limits. Regulations must be at least as stringent as state's. Silvicultural activities are regulated under the law.
Nevada	Nevada Water Pollution Control Law. Nev. Rev. Stat. Sec. 445.131 to 445.354. Enacted 1973; amended 1977, 1979, 1981, 1985.	Division of Environmental Protection within Department of Conservation and Natural Resources.	Purpose of Act is to maintain quality of water consistent with beneficial uses and encourage use of pollution control methods. State Environmental Commission authorized to adopt water quality standards and regulations to control nonpoint source pollution. Standards must protect designated beneficial use of each stream segment. Standards proposed may vary from those based on recognized criteria if circumstances justify. If existing water quality exceeds applicable standard, water quality must be maintained at the higher existing level.	Director may issue corrective order to remedy diffuse source of pollution, but no civil or criminal penalty other than injunctive relief or temporary restraining order may be imposed. Diffuse source violators are excepted from monetary penalties.	Commission authorized to regulate diffuse (non-point) sources of pollution, including those emanating from silvicultural operations, in order to enforce non-degradation policy of water quality standards. Diffuse source discharges must be controlled by reasonable methods, based on particular location and economic capability of project or development. Silvicultural activities exempt from discharge permits unless certified as significant contributor to pollution. Municipalities charged with administering pollution control regulations promulgated by Commission.	Nev. Rev. Stat. Sec. 472.043 provides for the maintenance of vegetative cover on forest and watershed land in order to conserve water and soil. State Forester Firewarden is authorized to enter into contracts and take other measures designed to meet this objective. Nevada Forest Practices Act of 1955 (Nev. Rev. Stat. Sec. 528.010 to 528.120) requires issuance of a permit prior to any logging or cutting operation. Permit mandates submission of a logging plan, including proposed road construction specifications and erosion control measures. Tractor logging on slopes in excess of 30 percent gradient requires a variance from State Forester Firewarden. Erodibility of soil must be considered in variance application. Variance is also required to harvest trees.

Table C.3—Significant features of water quality legislation in the Rocky Mountain Region—Continued

State	Statute and reference	Administering agency	Basic provisions	Penalties for violations	Significance for forest management	Related statutes
					Forestry operations must utilize BMP's developed by State Board of Forestry under state Forest Practice Act, for non-point pollution control. Accepted forestry BMP's focus on five planning criteria for control of runoff and sedimentation resulting from forest management activities: silvicultural treatments, logging methods, erosion control and road-building, hazard reduction, and forest protection.	operate equipment or construct logging roads within 200 feet of a body of water. Erosion control is primary objective. Nevada Forest Practices Act of 1955 is also reflected in numerous management specifications to prevent runoff and sedimentation. State Forester Firewarden authorized to adopt BMP's under the Act. As discussed above, regulations under Water Pollution Control Law require that selected BMP's, depending on particular situation, be utilized in conjunction with forestry operations in order to control non-point water pollution. Nev. Rev. Stat. Sec. 503.430. Forest products processing waste such as sawdust, shavings, etc. introduced into water at any time in a manner deleterious to fish is a misdemeanor offense. Nev. Rev. Stat. Sec. 445.080 to 120 concern the protection of Lake Tahoe. Permit required for alteration of shoreline. Nev. Rev. Stat. Sec. 445.100 authorizes State Environmental Commission to adopt regulations concerning Lake Tahoe watershed. Any timber operations within Tahoe Basin must have approval of Tahoe Regional Planning Commission. Nev. Rev. Stat. Sec. 244.365. Boards of County Commissioners authorized to bring suit against any violator who deposits sawdust in any river or stream. Nev. Rev. Stat. Sec. 535.100. Lumber mills prohibited from obstructing natural stream flow.
New Mexico	Water Quality Act. N.M. Stat. Ann. Sec. 74-6-1 to 13. Enacted 1978. amended 1985, supplemented 1986.	Water Quality Control Commission (composed of officials from relevant state resource management agencies). Lead agency is Department of Health and Environment.	Commission authorized to adopt comprehensive water quality standards, regulations, and classifications. Fixed-term, individual variances can be granted if compliance with regulations is unduly burdensome. Commission may require permit, issued by constituent agencies charged with administration of standards and regulations. No regulation or water quality standard is adopted until after public hearing. Persons affected by regulations may petition court for relief. Court may strike regulations which are illegal, arbitrary, or not supported by evidence as to their purpose. Commission may seek injunctive relief. Commission *not* authorized to regulate pollution confined entirely within property on which it occurs.	Civil: penalties not to exceed $1,000 for each violation. Each day violation occurs is separate offense. Violators also liable for reasonable remedial costs. Violation of permit regulations is misdemeanor punishable by fine of $300 to $10,000 per day and one year imprisonment. Civil penalty for permit violation may not exceed $5,000 per day.	Water quality standards as such are unenforceable, but are primarily used as guidelines in evaluating discharge permits. The standards primarily affecting forest management activities are those protecting high quality cold water fisheries and domestic water supplies. These standards are very stringent. Water quality regulations prohibit disposal of refuse in a natural watercourse. Voluntary guidelines (BMP's) concerning most aspects of forest management have been certified by Water Quality Control Commission. State water quality management plan requires evaluation of effectiveness of voluntary BMP's in protecting water quality. Evaluation was due at end of 1987, after three year trial period.	Forest Conservation Act (N.M. Stat. Ann. Sec. 68-2-1 to 25) authorizes Forestry Division of Natural Resources Department to enforce all laws and regulations concerning logging and forest land conservation in order to maintain water quality. N.M. Stat. Ann. Sec. 30-8-2. Water pollution defined and declared a public nuisance, punishable as a misdemeanor. N.M. Stat. Ann. Sec. 17-4-29 requires persons floating logs, timber, or other forest products to deposit 1000 trout fingerlings annually into fisheries specified by Department of Game and Fish. Violation of statute is a misdemeanor, but statute is rarely if ever enforced. N.M. Stat. Ann. Sec. 72-10-2 authorizes commissioners elected from community to bring suit against any person who obstructs community spring, dam, or breakwater.

North Dakota	Water Pollution Control Law. N. Dak. Century Code, Sec. 61-28-01 to 61-28-06. Enacted 1967; amended 1969, 1971, 1973, 1975, 1983.	Department of Health and Water Pollution Control Board.	Department authorized to adopt rules and regulations for pollution control and establish water quality standards. Department issues permits and orders. Department may seek injunction to stop violations.	Criminal: up to $25,000 fine per day of violation and/or one year imprisonment. Penalty is doubled for second offense. Civil: up to $10,000 fine per day of violation.	Definition of pollution sufficiently broad to include nonpoint sources. Rock, sand and agricultural wastes are potential pollutants.	Soil Conservation District Law (N. Dak. Century Code, Sec 4-22-01 to 4-22-51). Land use regulations, including those for forestation and reforestation, may be adopted upon approval of two-thirds of the voters in the district through referendum. Obstruction of Watercourse Statute (Sec. 61-01-07) prohibits obstruction of or diversion of water from any ditch, drain or watercourse. Water Resource District Law (Sec. 61-16.1-09 to 61-16.1-52). District boards are authorized to adopt rules and regulations to prevent pollution or other misuse of water resources, streams or bodies of water. Permit required for draining ponds, sloughs, or lakes over 80 acres in size. State engineer empowered to take action to rehabilitate damages. Floodplain Management Act (Sec. 61-16.2-01 to 61-16.2-13) requires communities to adopt ordinances in compliance with national flood insurance program. Encourages communities to adopt and enforce floodplain management ordinances. Activities which increase base flood level prohibited. Little Missouri Scenic River Act (Sec. 61-29-01 to 61-29-06). Little Missouri River Commission empowered to promulgate management policies. Prohibits diversion of water for purposes other than agriculture, recreation, or dredging on Missouri River or tributaries of river.
South Dakota	Water Pollution Control Act. S. Dak. Code Laws Ch. 34A-2 Sec. 1 to 99. Enacted 1935; amended 15 times, 1939 to 1987.	Department of Water and Natural Resources under authority of Water Management Board.	Water Management Board authorized to issue water quality and effluent standards, classify waters as to beneficial uses, and establish rules for issuance of permits. Department issues permits and enforces permit conditions, and may issue orders for prevention, abatement, or control of pollution. Board may initiate court action against continuation of a violation or failure to comply with an emergency order.	Violations Class 1 misdemeanor. Criminal: up to $10,000 fine per day of violation and up to one years imprisonment. Civil: up to $10,000 per day of violation.	Definition of pollution includes alterations which exceed water quality standards for temperature or turbidity or which are likely to be harmful to birds, fish or other aquatic life. Potential pollutants include agricultural wastes, rock, sand and dredged spoil. Act infers it is applicable to non-point source discharges (Sec. 34A-2-39.1).	Restriction on Riparian Use Act (S. Dak. Code Laws Ch. 46 Sec. 5-1) prohibits polluting of natural springs or streams and activities which will alter their natural flow. Ch.46 Sec. 5-1.1 prohibits obstruction of navigable waters. Scenic Rivers Act (Ch. 46A-1-15 to 16) authorizes the Board of Water and Natural Resources to designate certain rivers or sections of rivers as wild, scenic, or recreational. After designation, no development shall occur which alters natural and scenic beauty. Act establishing Watershed Districts (Ch. 46A-14 Sec. 1 to 92). Watershed districts may be established to regulate the flow of streams, diversion of watercourses, and for imposition of preventative or remedial measures for control of soil erosion and siltation of watercourses. Soil Erosion and Sediment Damage Law (Ch.38-8A Sec. 1 to 28). Conservation district supervisors required to develop standards for control of erosion and sediment resulting from land disturbing activities. Political subdivisions responsible for granting permits. Process must insure activities are in compliance with standards. Some activities require submission of a plan. Agricultural activities, including forestry, are exempt provided standards are met. Protection of Fishing Waters Act (Sec. 41-13-1 to 41-13-11) prohibits the placement of sawdust, refuse or sedimentary materials into waters supporting game fish or to deposit it in such a way as to be carried into waters by natural causes.

Table C.3—Significant features of water quality legislation in the Rocky Mountain Region—Continued

State	Statute and reference	Administering agency	Basic provisions	Penalties for violations	Significance for forest management	Related statutes
Utah	Utah Water Pollution Control Act. Utah Code Ann. Sec. 26-11-1 to 20. Enacted 1953; amended 1981, 1982, 1987; supplemented 1987.	Water Pollution Control Committee (composed of Director of Department of Health and eight members appointed by governor), under Department of Health.	Committee to develop programs to prevent, control, and abate new and existing water pollution. Committee may promulgate water quality and effluent standards, and classifications based on "reasonable uses". Discharge of any pollutant into water which menaces public health or impairs beneficial uses of waters is public nuisance. Governor may identify areas with water quality problems. Committee authorized to classify waters according to reasonable present and future use, and to issue water quality standards for each classification. Public hearing required prior to promulgation of water quality standards or classes. Committee may seek injunctive relief, or compliance order.	Civil: up to $10,000 per day, or up to $25,000 per day for willful or grossly negligent violation of Secs. 26-11-6(2) and 26-11-14. Subsequent violations: maximum penalty of $50,000 per day.	Forest lands generally full into "Class 1 and 2" lands for the protection of domestic, recreational and other beneficial water uses. Turbidity and temperature standards are the ones most relevant to forest management. Discharges which do not meet use classification standards are prohibited. Water quality standards require existing quality not be degraded, unless reduction justified by economic or social development. Water for human consumption protected by higher standards. Diffuse sources of pollution (non-point) into such waters must be controlled by either BMP's or regulatory programs. No statewide system of forestry BMP's exists, but certain local BMP's are certified under state 208 water quality plan. Voluntary inclusion of BMP's in timber sale contracts has been effective in meeting water quality standards. State-wide certification of forestry BMP's is underway.	Utah Code Ann. Sec. 23-15-6 prohibits pollution of water crucial to wildlife, including aquatic life. Utah Code Ann. Sec. 76-10-203 prohibits obstruction of irrigation watergates by floating logs or timber (antiquated). Utah Code Ann. Sec. 17-8-5.5 Counties may issue ordinances for protection of flood plains and channels. Utah Code Ann. Sec. 65-1-75 authorizes State Land Board to take necessary measures to prevent damaging floods and conserve state's natural resources. Statute recognizes role of improper timber management in flooding and authorizes Board to take steps to prevent flooding resulting from poor timber management. Utah Code Ann. Sec. 63-11-17.5 authorizes Division of Parks and Recreation to regulate development on lands within their jurisdiction. Division may impose regulations which are stricter than municipal ordinances.
Wyoming	Wyoming Environmental Quality Act (Wyo. Stat. Sec. 35-11-101 to 1104. Enacted 1973; amended 1977, supplemented 1987.	Environmental Quality Department.	Discharge of any pollutant into water or alteration of physical, chemical, or biological properties of water is prohibited, except by permit. Division of Water Quality may develop regulations and water quality standards, including effluent limitations, and classify surface waters.	None specified.	Water quality standards serve as indicator as to whether BMP's should be developed. Violation of water quality standards by a nonpoint source is sufficient justification for development of BMP's. Water quality indicators relevant to forestry include water temperature and turbidity. To date, only turbidity has been used to limit forestry activities. Currently, no BMP's established for harvesting activities. Forest Management activities considered to have only minor impact on water quality in state. However, voluntary silvicultural BMP's are currently under development.	Wyo. Stat. Sec. 11-16-101 to 132 establish soil conservation districts to promote soil conserving practices. Wyo. Stat. Sec. 35-4-202. Sawmill owners who dump sawdust or chemical wastes into *natural* stream or lake thereby killing fish or rendering water impure are guilty of misdemeanor. Violation punishable by fine of $50 to $100 or imprisonment from one to six months. Each day of violation is separate offense. Wyo. Stat. Sec. 41-5-108 requires permit for floating logs in streams or rivers (antiquated). Wyo Stat. Sec. 41-8-101 to 126 create watershed improvement districts as subdistricts of soil conservation districts. Each improvement district must lie within a watershed. Improvement districts authorized to develop local watershed protection programs and ordinances, which could impact silvicultural activities.

Table C.4—Significant features of water quality legislation in the Pacific Coast Region

State	Statute and reference	Administering agency	Basic provisions	Penalties for violations	Significance for forest management	Related statutes
Alaska	Alaska Stat. Sec. 46.03.050 to 130, 320 to 800, 850. Enacted 1969, amended 1977, 1978, 1980, 1981, 1982, supplemented 1986.	Department of Environmental Conservation.	Law provides general prohibition of water, land and air pollution which has withstood constitutional challenge. Department may propose water quality standards and determine qualities and properties of water which indicate a polluted condition. After public hearings, Department authorized to develop water quality standards, classify waters as to minimum quality, or both. A short term variance from standards is available if economic or social development justify water quality reduction. Department also authorized to regulate use of pesticides. Activities impairing domestic water quality are prohibited as a nuisance. Department may issue compliance order for violation of water quality standards.	Civil penalty for initial violation ranges from $500 to $100,000 and up to $5,000 for each day violation continues. Penalty determined by degree of environmental damage, investigation and litigation costs, and economic savings realized by the violator. Violator is also liable for cost of restoring environment to original condition. Court may grant temporary or preliminary equitable relief. Violations punishable as misdemeanors. Each day a violation occurs is a separate offense.	Department has created water quality "use classes" which specify the degree of degradation not to be exceeded by human activity. Forest management is impacted by turbidity and sedimentation water quality parameters and pesticide regulation. Water quality standards consider social and economic factors as well as scientific criteria for protection of environment. Voluntary BMP's (in conjunction with Alaska Stat. 41.17.010) regulate forest management activities to meet requirements of water quality "use classes". Since BMP's are voluntary, standards may be enforced whether or not BMP's are being used.	Alaska Stat. Sec. 41.17.010 to 950 established Division of Forestry within Department of Natural Resources to execute forest management standards, policies, and guidelines. Department of Natural Resources may develop regulations for control of nonpoint sources of pollution, in cooperation with Department of Environmental Conservation. Scope of regulations includes all aspects of forest management with recognition of environmentally sensitive areas (e.g. stream buffer zone for eagle habitat) and BMP's. As voluntary guidelines, BMP's are not site-specific, but must be adapted to protect the water resources of the area. Department of Natural Resources is charged with review of proposed forest management plans and subsequent inspections to ensure compliance with water pollution regulations. Departments cooperate to evaluate plans to use broadcast chemicals. Violators are liable for civil fine up to $10,000, depending upon the amount of environmental damage, economic savings reaped by the violator, degree of intent or negligence, and past violations. Department of Natural Resources may issue a temporary stop order if violation is likely to result in irreversible harm. Department of Natural Resources may not usurp the statutory authority of other state agencies, unless authorized by Alaska Coastal Management Act or by the Department of Environmental Conservation. Alaska Stat. Sec. 16.05.870 to 900 provides that Department of Fish and Game shall identify specific water bodies important to spawning, rearing and migration of anadromous fish and review plans to use such waters (e.g. log dragging). Use of these waters without Departmental review and approval is a misdemeanor punishable by a $1,000 (maximum) fine. Violator is liable for restoration costs and other penalties imposed by the court. Alaska Stat. Sec. 16.10.010 prohibits the dumping of waste such as tree limbs or foliage, stumps, sawdust, planar shavings, earth or other debris into salmon spawning streams in support of the policies underlying Sec. 16.05.870. Permit for obstruction of such waters required by Department of Environmental Conservation. Violation of Sec. 16.10.010 is a misdemeanor punishable by a fine of $100 to $500. Alaska Stat. Sec. 16.20.185, 16.20.240 to 260 requires Department of Fish and Game to protect habitat of endangered species. Board of Fisheries and the Board of Game authorized to adopt regulations governing the taking of fish and game from critical habitat areas. Before land in these areas may be developed, leased or otherwise disposed" of, the Department of Fish and Game must be notified. Written approval of the plans for disposal of the land from the Department may be required. 5 AAC 95.010 to 990, regulations for management activities on game refuges and critical habitat areas, require a permit for such activities and mitigation of adverse environmental impacts. 6 AAC 80.100 incorporates Alaska Stat. 41.17 into Alaska Coastal Management Program. Attorney General's opinion (J-66-224-79) indicates that the Department of Natural Resources's regulation of forest management practices preempts only the forest management standards of Alaska Stat. 46.40 (Coastal Zone Management Act), and not the entire act

Table C.4—Significant features of water quality legislation in the Pacific Coast Region—Continued

State	Statute and reference	Administering agency	Basic provisions	Penalties for violations	Significance for forest management	Related statutes
California	Porter-Cologne Water Quality Control Act, California Water Code. California Stat. Sec. 13000 to 13361. Enacted 1969; effective 1970. Amended 1970, 1971, 1972, 1973, 1974, 1975, 1976, 1977, 1978, 1979, 1980, 1982, 1984, 1985, 1986.	Water Resources Control Board.	Authorizes Board to formulate water quality policy and to promulgate regulations for protecting water quality. Cities and counties may also adopt regulations, which must be consistent with those issued by Board. Identifies nine water quality regions and authorizes regional board for each. Provides for State Water Quality Control Plan, which is to include "basin" plans formulated by each regional board. Requires regional boards to establish water quality standards to protect beneficial uses. Authorizes regional boards to prescribe requirements for any discharge (essentially a permit program). If requirements have been prescribed, a waste discharge report must be filed with the Board.	Civil penalty for failure to file waste discharge reports and/or for deviations from discharge requirements ranges from $1,000 to $5,000 fine per day of violation, depending upon whether imposed administratively or judicially. Regional boards may issue cease and desist, and clean-up and abatement orders. Civil penalty for failure to adhere to cease and desist orders up to $6,000 per day of violation. If clean-up and abatement orders are ignored, state may take remedial action and the cost is imposed upon the violator.	Implications for forestry begin at the state level with the Water Resources Control Board. The Board has adopted a nondegradation policy which states that whenever existing water quality is better than that established by policy, such existing high quality will be maintained unless it can be demonstrated that any change will be consistent with maximum benefit to the people of the state, will not unreasonably affect present and anticipated beneficial use of such water, and will not result in water quality less than that prescribed by policy. Board has also required that each regional plan contain prohibitions against discharge of soil, silt, bark, slash, sawdust, or other organic or earthen material from logging operations into any stream or watercourse in quantities deleterious to fish, wildlife, or other beneficial uses, or against the placing of such materials at locations where they could pass into any stream or watercourse. The nondegradation policy and these two non-point pollution prohibitions summarize the Board's general position regarding protection of beneficial water uses from the adverse effects of timber harvesting and associated activities. Within this general framework, the nine regional boards carry the primary responsibility for on-the-ground regulation of water quality in accordance with their individual "basin" plans. With respect to forestry operations, these plans address the sources of pollution in each basin from timber operations, the types of impacts that such pollution may have on beneficial uses, and the water quality standards and objectives needed to protect water quality and beneficial uses. Regulation is effected through the water quality related rules promulgated under the state's forest practice act (Z'berg-Nejedly Forest Practice Act of 1973, Calif.Stat. Sec. 4511–4621). These rules are minimum protection standards applicable to all commercial timber operations on non-federal timberlands. The current rules interact with the State Water Code by defining the beneficial uses of water to include those uses listed in the Water Code. With respect to non-point pollution, the rules cover silvicultural methods, harvesting practices and erosion control, water-	Section 30417 of the 1976 California Coastal Act authorizes the Coastal Commission to identify special treatment areas within the coastal zone and to recommend forestry operation rules to the Board of Forestry which are adequate to protect the natural and scenic qualities of these areas. These rules impose higher than average standards for forestry activities within these areas. California Fish and Game Code (California Stat. Sec. 1603, 1606) provides that any person who obstructs or diverts any water body of those designated by the Department of Fish and Game must first notify the Department and follow procedures recommended by it; submitting a timber harvesting plan as required by the Forest Practice Act will constitute sufficient notice. California Statutes Section 5650 prohibits deposit of any slabs, sawdust, shaving, etc. into any waters of the state, with violation constituting a misdemeanor. California Statutes Section 5093.68 essentially imposes the same requirements as do the forest practice rules on "special treatment areas" designated under the state Wild and Scenic River Act.

				course and lake protection, and construction of logging roads and landings. The Forest Practice Act provides that timber operations will be exempt from the Water Code's waste discharge requirements if the forest practice rules promulgated under the Act are certified by the federal Environmental Protection Agency (EPA) as constituting best management practices (BMP's) for silviculture pursuant to Section 208 of the Federal Water Pollution Control Act. Such certification is presently pending. Until it is effective, the regional boards can impose specific waste discharge requirements on timber operations. As a practical matter, however, they seldom do.	
Hawaii	Basic Water Pollution Statute. Hawaii Rev. Stat. Ch. 342-1 to 20, 31-35. Enacted 1972; amended 1973, 1980, 1982, 1984, 1985. State Water Code. Hawaii Rev. Stat. Ch. 175C-1 to 101. Enacted 1987.	Department of Health.	*Water Pollution Statute*: Department charged with prevention, control and abatement of water pollution. Department may establish water quality and effluent standards, and promulgate regulations to control pollution according to local conditions. Pollution discharge into state waters controlled by permit. Department may also approve variances, issue "cease and desist" orders, and initiate court action for injunctive relief. *State Water Code*: authorizes Commission on Water Resource Management to develop statewide water management areas and instream waterflow standards. Commission authorized to promulgate instream flow standards on stream-by-stream basis. Water management areas control water use in areas where resource is threatened. Instream flow standards describe waterflow necessary to protect variable interests in streams, including recreational, wildlife, and fishery interests. Commission must hold public hearing for discussion of proposed standards. Permit required to alter stream channels. Administrative rules implementing State Water Code currently under development.	Civil: Department may initiate civil action to recover penalty. Criminal: for willful violation of any rule or regulation violator may be fined from $2,500 to $25,000 per day and may be imprisoned for up to one year.	Specifically designated pollutants include sediment, soil, and sand. Agricultural wastes also designated as potential pollutants. Established Water quality criteria relevant to forest management include those related to detrimental alteration of water turbidity or temperature.	Hawaii Pesticides Law (Hawaii Rev. Stat. Ch. 149A-31 to 33) regulates the application of pesticides and provides for the suspension or cancellation of pesticide use if chemical residues are detected in drinking water, or under other conditions of "unreasonable adverse [environmental] effects". Hawaii Rev. Stat. Ch. 180C-2. County governments may enact ordinances for erosion and sediment control, primarily from urban sources. Hawaii Rev. Stat. Ch. 183-1 to 45. Department of Natural Resources responsible for protecting, extending, and increasing forest reserves for watershed management. Forest and water zones established in each county. Zones encourage highest economic use of resource consonant with water conservation. In subzones within reserve zones, Department may specify land use—including commercial timber growing. Regulations may prohibit unlimited cutting of forest growth or forestry practices detrimental to water conservation. Hawaii Rev. Stat. Ch. 205A. Controls on development of coastal areas do not restrict planting, cultivation, and harvesting of trees or other forest products, unless such activities have a cumulative negative impact on water resources. Under such conditions forest management is "development" and subject to permit requirement. In issuing permits, County Planning Commission must seek to minimize impact on water quality. Hawaii Rev. Stat. Ch. 181 prohibits discharge of poisonous or noxious effluent into streams or shorewaters. Specifies guidelines for reclamation. Hawaii Rev. Stat. Ch. 339 prohibits dumping of litter into water. Definition of "litter" does not include nonpoint pollutants.

Table C.4—Significant features of water quality legislation in the Pacific Coast Region—Continued

State	Statute and reference	Administering agency	Basic provisions	Penalties for violations	Significance for forest management	Related statutes
Oregon	Ore. Rev. Stat. Sec. 468.700 to 468.778. Enacted 1953; amended numerous times.	Department of Environmental Quality	It is public policy to protect and improve water quality, and to prevent or abate pollution. Polluting water is not a reasonable or natural use of such waters and is prohibited, as is discharge of wastes which reduces quality. Environmental Quality Commission authorized to develop water quality standards based upon specifically enumerated quality criteria which are specified in statute. Persons who injure or destroy fish and wildlife or habitat are strictly liable for restoration costs.	Civil penalty of up to $500 per day of violation. Penalties for specified violations such as discharge permit violation up to $10,000 per day of violation.	Department of Environmental Quality has issued comprehensive water quality regulations. These include general guidelines and specific standards which apply to each individual drainage basin. Guidelines applicable to forestry address antidegradation, restrictions on log handling in public waters, and forest management activities. The latter are directed to be conducted in accordance with the Oregon Forest Practices Act (OFPA). Specific standards include water quality characteristics such as turbidity and temperature. Primary protection of water quality relative to forest management is thus derived from rules (BMP's) promulgated under the Forest Practices Act. These control impact of forest practices on water quality for three regions within state. Rules establish minimum standards for chemical use, slash disposal, reforestation, road construction, and harvesting. The rules have been certified by the federal Environmental Protection Agency (EPA) as acceptable BMP's for purposes of the Federal Water Pollution Control Act.	Oregon Forest Practices Act (Ore. Rev. Stat. Sec. 527.610 to 527.730) authorizes promulgation of rules (BMP's) regarding forest management activities and protection of water quality. Rules are designed to assure sustained yields of timber while protecting water, air, and soil quality. State Board of Forestry authorized to adopt rules as minimum standards for forestry practices. Rules must maintain water, air and soil quality, and provide for protection of fisheries, wildlife habitat and sensitive ecological sites. Board must resolve any conflicts between rules and special management requirements of sensitive areas. Forest practice activities must conform to water quality standards. Rules recently changed to require a written management plan if harvesting is to occur within 100 feet of a Class I stream or within 300 feet of a site inventoried for threatened and endangered species. Evaluation of OFPA indicates that forestry rules have been "moderately effective mechanism for improving water quality in forest streams". Violation of OFPA is a misdemeanor. Each day of violation is a separate offense. Forest Practice Rules (Ore. Admin. Rules 629-24-101 to 646) include general rules and specific standards for each of 3 regions. General rules require notification of the State Forestry Division prior to conducting forest management activities and prior approval of stream channel alterations. General rules also provide for stream classification system, criteria for riparian area boundaries, limits on use of chemicals, and slash disposal guidelines. Regional rules cover all aspects of forest management. A provision for the protection of waters requires landowners to maintain riparian areas along the boundaries of Class I water. Ore. Rev. Stat. Sec. 390.805 to 390.925 establish Oregon Scenic Waterways System in which recreation, fish, and wildlife interests are of paramount importance. Department of Transportation authorized to adopt rules regarding management of lands adjacent to scenic waterways. Rules restrict road construction and require timber harvests be conducted to maintain aesthetic value of water. Department must be given notice prior to timber harvest for evaluation of impact on scenic water. Department may attempt to alter timber harvest plan or acquire land by purchase, gift, or scenic easement. Ore. Admin. Rules 736-40-005 to 095 require timber harvests to conform to preservation of scenic beauty of waterway. Department of Transportation management of "adjacent lands" includes all land within 1/4 mile of streambank, excluding lands which do not affect the view from scenic waterway. Management prescribed by Department is determined by subjective evaluation. Ore. Rev. Stat. Sec. 541.605 to 695 require permit for removal of any material from streambank, with exceptions for forestry activities in compliance with Forest Practice Rules. Ore. Rev. Stat. Sec. 549.400 prohibits obstruction or pollution of any waterway or drainage improvement.

Washington	Washington Water Pollution Control Act. Wash. Rev. Code Ann. Sec. 90.48.010 to 90.48.910. Enacted 1971; amended 1973, 1975, 1983, 1985.	Department of Ecology.	It is state policy to insure water purity for all beneficial uses. Act creates Water Pollution Control Commission which is authorized to develop regulations and water quality standards. Any discharge which pollutes waters is prohibited. State may bring action against violators for costs of restoring environment. Department has sole responsibility for and authority over water quality standards and regulation of nonpoint sources of pollution in state. Regulations promulgated under state's Forest Practices Law must meet water quality standards and satisfy water pollution control laws. Department required to monitor water quality and has final authority to modify forest practice regulations as they pertain to water quality. Permit requirements and penalties imposed by Act do *not* apply to forestry activities that are in compliance with Forest Practices Act. Forest Practices Act and corresponding regulations must also satisfy requirements of Federal Water Pollution Control Act (33 USCA Sec. 1288, 1289, 1315).	Criminal: violations punishable by fine of up to $10,000 plus litigation costs. Violator may be imprisoned for up to a year. Each day of violation is separate offense. Civil: penalty of up to $10,000 per day of violation.	Department of Ecology has developed separate set of standards pertaining specifically to forestry operations. However, there is no criminal or civil penalty for degradation of water quality by practices which are in compliance with regulations issued under Forest Practices Act. Department of Ecology has not developed a forestry non-point pollution control program of its own. However, BMP's and regulations issued under Forest Practices Act are subject to modification by Department if they fail to meet water quality standards. Water quality characteristics relevant to forestry include those for temperature and turbidity. Forest Practices Act regulations have been certified as meeting requirements of Section 208 of Federal Water Pollution Control Act.	Forest Practices Act (Wash. Rev. Code Ann. Sec. 76.09.010 to 76.09.950) authorizes forest practices regulations which comply with Section 208 of Federal Clean Water Act concerning nonpoint pollution control. Department of Ecology may propose forest practices regulation relating to water quality in cooperation with Forest Practices Board; Department has final authority. Recent legislative changes authorize Department of Natural Resources to prepare hazard reduction plan for sites where soil erosion poses significant danger to public resources. Riparian zones protected by requiring some trees be left standing. Department of Natural Resources may issue "stop work" order, or a "notice to comply" to violators. Department of Ecology may enforce compliance with Act 6 if Department of Natural Resources fails to do so. Violators may be subject to a fine of $500 per day of violation plus an additional penalty of $100 to $1,000 and up to one year imprisonment. Statutory restrictions on authority of local governments to promulgate their own forest practice rules (Sec. 76.09.240(4)) held invalid in *Weyerhauser v. King County (91 Wash 2d. 721, 1979)*. Forest Practices Rules and Regulations (Wash. Admin. Code Ch. 173-202-010 to 020). Regulations pertaining to water quality protection are individually adopted by Forest Practices Board and Department of Ecology after the agencies have reached agreement. Water quality provisions are found in forest practices regulations concerning timber harvesting, reforestation, road construction and chemical application. Evaluation of regulations in 1980 indicated that impact of forestry on water quality is relatively low overall, but impact from individual operations was severe in some cases. Recently proposed amendments are the product of broad consensus among government agencies, public interest groups, and forest products industry. Primary goal is to maintain viable forest industry and protect quality of natural resources. Amendments accepted "in concept" by Forest Practices Board include (1) creation of riparian management zones, (2) limitations on road construction and timber harvests in riparian zones, and (3) further restrictions on application of silvicultural chemicals to protect water quality Wash. Rev. Code Ann. Sec. 7.48.010. Obstruction of stream channels used for rafting logs, timber, or lumber is a nuisance. Wash. Rev. Code Ann. Sec. 9.66.010. Unlawfully befouling, obstructing or interfering with a lake, navigable river, bay, stream, canal or basin is a public nuisance. Wash. Rev.

Table C.4—Significant features of water quality legislation in the Pacific Coast Region—Continued

State	Statute and reference	Administering agency	Basic provisions	Penalties for violations	Significance for forest management	Related statutes
						Code Ann. Sec. 75.20.050 to 140 concern protection of streambeds from impacts by hydraulic projects. Department of Fisheries authorized to evaluate projects and deny approval or require modification to protect fisheries. Violation of Act is a gross misdemeanor and a public nuisance. Civil penalty of up to $100 per day of violation may be imposed. Recently proposed amendments suggest giving Department of Fisheries or Department of Game discretion on penalty imposed: either fine, or gross misdemeanor charge punishable by fine and imprisonment. Wash. Rev. Code Ann. Sec. 76.32.040. This 19th century statute authorizes timber companies to channelize streams, remove obstacles, etc. Such improvement projects may not impede or obstruct stream outlets or interfere with use of such streams. Wash. Rev. Code Ann. Sec. 76.42.030 to 070 authorize Department of Natural Resources to remove wood debris from navigable waters. Disposal of wood debris into such waters is prohibited Wash. Rev. Code Ann. Sec. 79.01.128. Department of Natural Resources may modify management practices on public lands within municipal watersheds so that water quality exceeds state standards. Municipality must reimburse Department for additional management costs incurred. *Fransen v. State Board of Natural Resources* (66 Wash. 2d 672, 1965) held that state may not *sell* its forest lands to achieve statutory objective. Wash. Rev. Code Ann. Sec. 79.72.010 to 900 authorize Department of Parks and Recreation to take measures to protect scenic rivers. To date Department has relied upon existing regulations to protect scenic rivers' water quality. However, conservation plan with possible regulatory standards is under development. Wash. Rev. Code Ann. 88.28.050 imposes a fine of up to $200 per day upon persons who obstruct navigable streams, channels, or rivers, excluding booms to secure floating logs. Wash. Rev. Code Ann. Sec. 90.28.150 provides for stream improvements (clearing debris or straightening of channel) when necessary for logging. "Shoreline Management Act of 1971 (Wash. Rev. Code Ann. Sec. 90.58.010 to 930) is designed to protect natural character, ecology, and public access to shorelines, including banks of streams and lakes Act requires permit for development along shorelines, including logging road construction. Harvesting within 200 feet of identified shorelines is limited to selective cuts of no more than 30 percent of merchantable volume. Other" harvesting methods may be used if selective cut is ecologically detrimental, or for approved land development. Challenge to statutory limitation on road construction defeated (*Weyerhauser Co. v. King* 91 Wash. 2d 721, 1979).

ed strand board and waferboard consumption, which is projected to reach 16.0 billion square feet by 2040, more than 3.6 times its use in 1986. After slowly declining through 2010, softwood plywood consumption increases to 23.2 billion square feet in 2040. As a result of these trends, oriented strand board and waferboard panels comprise over 40% of total structural panel consumption in 2040, up sharply from about 16.6% in 1986. Consumption of panels is expected to increase across all end uses except for new housing and the all other category (table 98).

Imports of oriented strand board and waferboard from Canada increased rapidly in the late 1970s as demands outstripped the small, but growing, domestic industry's ability to manufacture these products (table 99). Continued increases in imports are expected through 2010, but fall afterwards as the domestic industry expands. Softwood plywood imports are small and are not expected to rise over the projection period.

Exports of softwood plywood, though showing some fluctuation, have trended upward since the early 1970s and are expected to continue to rise further as European markets grow and other markets open up. Exports of oriented strand board and waferboard have been small, and are expected to remain so in the projection period.

Domestic production of structural panel products is expected to grow in line with increases in U.S. consumption (table 99). Regional production of structural panel products has been undergoing wide-scale changes since the start of Southern pine plywood production in 1964. During the last decade, the expansion of oriented strand board and waferboard production has lead to the North becoming a major producer of structural panel products (table 100). There are other substantial regional shifts projected for structural panel production. By 2000, softwood plywood production declines both in the south-central and Douglas-fir regions. Oriented strand board and waferboard production nearly doubles in the North during the same period. Between 2000 and 2040, panel production for both softwood plywood and oriented strand board and waferboard expands in the North, South, and Pacific Coast sections. By 2040, production shares are 19%, 50%, and 26% for these three sections.

Nonstructural Panel Products

Nonstructural panels consumption, including hardwood plywood, insulating board, hardboard, and particleboard, rose to 18.2 billion square feet (3/8-inch basis) in 1986, nearly 3 times total use in 1960 (table 101).

Projected total demand for nonstructural panels increases to 23.2 billion square feet in 2000 and 26.6 billion square feet by 2040. Because of trends in major markets, as well as the assumptions about market penetration and product substitution, somewhat different trends in demand are projected for the various products. Little growth in insulating board, whose major market is residential construction, is expected. Hardwood plywood, used in manufacturing as well as construction, increases slowly through 2040, while particleboard rises until 2010, but shows little growth afterwards. Hardboard is the only nonstructural panel product to show a steady increase throughout the projection period.

Imports of hardwood plywood are the most important trade flow for the nonstructural panel products. Currently, about two-thirds of all the hardwood plywood consumed in the United States is imported, chiefly from Taiwan and Indonesia. Imports from such sources have risen rapidly over the past three decades, but are expected to stabilize in the future. Imports of the other nonstructural panel products—insulating board, hardboard, and particleboard—have also increased since the early 1980s but (with the exception of particleboard) are expected to continue at about current levels through 2040. Hardwood plywood exports, which have generally been less than 50 million square feet over the past 35 years, are expected to remain small through 2040. Insulating board exports have been relatively constant since the

Table 99.—Structural panel consumption, imports, exports, and production in the United States, specified years 1950–1986, with projections to 2040.

Year	Consumption			Imports			Exports			Production		
	Total	Softwood plywood	OSB/ waferboard	Total	Softwood plywood	OSB/ waferboard	Total	Softwood plywood	OSB/ waferboard	Total	Softwood plywood[1]	OSB/ waferboard
	Billion square feet (3/8-inch basis)											
1960	7.8	7.8	[2]	[2]	[2]	[2]	[2]	[2]	[2]	7.8	7.8	[2]
1970	14.2	14.2	[2]	[2]	[2]	[2]	0.1	0.1	[2]	14.3	14.3	[2]
1976	18.0	17.7	.2	.2	[2]	.1	.7	.7	[2]	18.5	18.4	.1
1986	25.3	20.8	4.5	.9	.1	.8	.6	.6	[2]	24.8	21.2	3.6
2000	25.4	17.1	8.3	1.3	.1	1.2	.7	.7	[2]	24.8	17.7	7.1
2010	28.6	17.9	10.7	1.4	.1	1.3	.7	.7	[2]	28.0	18.6	9.4
2020	32.7	19.7	13.0	1.1	.1	1.0	.9	.9	[2]	32.5	20.5	12.0
2030	35.3	20.9	14.4	.5	.1	.4	1.1	1.1	[2]	35.8	21.8	14.0
2040	38.8	22.8	16.0	.1	.1	[2]	1.1	1.1	[2]	39.8	23.8	16.0

[1] *Includes production from both domestic and imported species.*
[2] *Less than 50 million square feet.*
Note: Data may not add to totals because of rounding.

Table 100.—Structural panel production in the contiguous states by region, specific years 1952–1986, with projections to 2040.

Species group & region	1952	1962	1970	1976	1986	Projections 2000	2010	2020	2030	2040
					Billion square feet, 3/8-inch basis					
Softwoods										
Northeast	0	0.0	0.1	0.1	0.6	1.2	1.7	2.0	2.6	3.1
North Central[1]	0	0.0	0	0.1	1.5	2.5	3.0	3.4	3.9	4.3
Southeast	0	0.0	0.9	1.7	3.8	4.4	5.9	6.2	6.0	5.8
South Central	0	0.0	2.4	5.1	8.2	7.8	7.3	10.3	12.1	14.2
Rocky Mtn.	0	0.2	0.9	1.2	1.5	1.5	1.7	1.9	1.8	2.0
Pacific NW[2]										
Douglas-fir subregion (Western Oregon & Western Washington)	2.7	7.9	8.5	8.9	8.2	6.3	6.9	6.8	7.0	7.9
Ponderosa pine subregion (Eastern Oregon & Eastern Washington)	0	0.2	0.8	0.9	0.8	0.8	1.0	1.3	1.4	1.5
Pacific SW[3]	0.3	1.2	0.8	0.6	0.3	0.3	0.5	0.5	0.8	1.0
Total United States	3	9.5	14.4	18.6	24.9	24.8	28.0	32.6	35.6	39.8

[1]*The Great Plains are included in the North Central region.*
[2]*Excludes Alaska.*
[3]*Excludes Hawaii.*
Note: Data may not add to totals because of rounding.

Table 101.—Nonstructural panel consumption, imports, exports, and production in the United States, specified years 1960–1986, with projections to 2040.

Year	Consumption Total	Hardwood plywood	Insulating board	Hard-board	Particle-board[1]	Imports Total	Hardwood plywood	Insulating board	Hard-board	Particle-board[1]
					Billion square feet (3/8-inch basis)					
1960	6.5	1.8	3.8	.7	.5	.9	.7	.1	0.1	([2])
1970	13.2	3.8	4.3	1.6	3.5	2.3	2.0	.1	.2	([2])
1976	16.9	3.4	4.5	2.1	6.9	2.7	2.4	.1	.2	.1
1986	18.2	2.7	3.8	2.0	9.8	3.8	1.9	.5	.3	1.1
2000	23.2	3.6	4.0	3.7	11.9	2.6	1.7	.3	.3	.3
2010	24.7	4.0	4.2	4.3	12.1	2.8	1.7	.3	.4	.4
2020	25.9	4.6	4.3	5.0	12.1	2.8	1.7	.3	.4	.4
2030	25.5	4.4	4.1	5.3	11.8	2.8	1.7	.3	.4	.4
2040	26.6	4.5	4.1	5.5	12.5	2.8	1.7	.3	.4	.4
	Exports					**Production**				
1960	.1	([2])	([2])	([2])	([2])	6.1	1.1	3.8	.6	.5
1970	.2	0.1	.1	([2])	([2])	11.0	1.8	4.3	1.4	3.5
1976	.4	.1	.1	.1	.2	14.6	1.1	4.5	2.0	7.0
1986	.6	.1	.2	.1	.3	15.0	.8	3.5	1.7	9.0
2000	.4	([2])	.1	.1	.2	21.0	1.9	3.8	3.5	11.8
2010	.6	([2])	.1	.2	.3	22.5	2.3	4.0	4.1	12.0
2020	.6	([2])	.1	.2	.3	23.7	2.9	4.1	4.8	12.0
2030	.6	([2])	.1	.2	.3	23.3	2.6	3.9	5.1	11.7
2040	.6	([2])	.1	.2	.3	24.4	2.8	3.9	5.3	12.4

[1]*Includes medium density fiberboard.*
[2]*Less than 50 million square feet.*
Note: Data may not add to total because of rounding.

early 1950s and are expected to remain at about 0.1 billion square feet over the projection period. Exports of both hardboard and particleboard are expected to increase slowly in response to growth in the major offshore markets.

Paper and Board

Consumption and production of paper and board is projected to increase although not as strongly as in the past (table 102). Total consumption is projected to exceed 100 million tons in 2000. By 2040, consumption reaches 173 million tons—more than double the 1986 level. Imports exceed exports over the projection period, with production approaching 166 million tons by 2040.[27]

Per capita consumption of paper and board rose 83% between 1952 and 1986. From 1986 to 2040, per capita consumption is projected to increase by 54%. This reflects continued substitution of plastics and other materials in packaging and construction products, as well as slower growth in consumption of paper products in the communication industry, and in computer and copier applications.

Projected Fiber Consumption

By the year 2040, total fiber consumption in U.S. paper and board production is projected to increase to 162 million tons, more than double the 76 million tons consumed in 1986 (table 103). Projections show consumption of woodpulp increasing 93% from 1986 to 2040, to 116 million tons. At the same time, consumption of wastepaper is projected to triple between 1986 and 2040, to over 46 million tons. The woodpulp proportion of total fiber (79% in 1986) is projected to drop to 71% in 2040. This decline is due to technological developments that enable higher and more efficient use of recycled fiber while maintaining a high quality in the final product.

Consumption of woodpulp for nonpaper products, such as rayon, cellulose acetate, and plastics is projected to remain at its current level of about one million tons. Thus, total woodpulp consumption is projected to increase from 61 million tons in 1986 to over 116 million tons in 2040 (table 104). Imports of woodpulp are

[27] *The FPL Pulpwood Model is an economic model of the North American pulp and paper industry designed to project pulpwood consumption over the next five decades. The model is based in part on a general price-endogeneous linear programming system (PELPS) developed by Gilless and Boungiorno (1987). The FPL Pulpwood Model introduces various "processes" for manufacturing paper and board along with regional and product disaggregation found in previous applications of PELPS. The model incorporates 10 commodity groups, including 5 paper and board grades and 5 fiber input commodities. Projections are developed for paper and board consumption and price by grade and region, paper and board production by grade, process and region, and regional pulpwood consumption and price. Projections of woodpulp consumption and production, and projections for three paper and board grades not included in the FPL Pulpwood Model are developed by a spreadsheet model developed by Durbak (1988). Additional information on the FPL Pulpwood Model can be found in Ince et al. (in prep.).*

Table 102.—Paper and board consumption, exports, imports, and production in the United States, specified years 1952–1986, with projections to 2040.

Year	Consumption		Exports	Imports	Production
	Total	Per capita			
	Thousand tons	*Pounds*		*Thousand tons*	
1952	29,092	369	499	5,173	24,418
1962	42,360	454	1,003	5,820	37,543
1970	58,058	567	2,698	7,239	53,516
1976	63,952	586	3,195	7,249	59,898
1986	81,720	676	4,222	11,838	74,104
2000	100,358	730	5,300	10,300	95,358
2010	121,591	826	5,500	11,200	115,891
2020	141,702	908	5,700	12,000	135,402
2030	158,258	972	5,800	12,700	151,358
2040	173,055	1038	5,900	13,000	165,955

Note: Data may not add to totals because of rounding.

Table 103.—Fiber consumption in U.S. paper and board production, specified years 1952–1986, with projections to 2040.

Year	Total fiber	Woodpulp	Wastepaper	Other
		Thousand tons		
1952	26,378	17,286	7,881	1,211
1962	38,636	28,598	9,075	963
1970	54,614	43,192	10,594	828
1976	60,156	47,541	11,874	742
1986	75,940	60,049	15,491	400
2000	95,155	74,902	20,062	191
2010	114,467	88,584	25,672	211
2020	132,440	98,847	33,361	232
2030	147,718	107,324	40,394	0
2040	162,175	115,675	46,500	0

Note: Data may not add to totals because of rounding.

Table 104.—Woodpulp consumption, exports, imports and production in the United States, specified years 1952–1986, with projections to 2040.

Year	Consumption		Exports	Imports	Production
	Total	Per capita			
	Thousand tons	*Pounds*		*Thousand tons*	
1952	18,198	231	212	1,937	16,473
1962	29,511	316	1,186	2,789	27,908
1970	43,969	429	3,095	3,518	43,546
1976	48,930	449	2,518	3,727	47,721
1986	60,697	502	4,459	4,594	60,562
2000	75,595	550	4,500	4,636	75,459
2010	89,277	607	5,500	5,667	89,110
2020	99,540	638	6,000	6,182	99,358
2030	108,017	664	6,600	6,800	107,817
2040	116,368	698	7,200	7,418	116,150

Note: Data may not add to totals because of rounding.

projected to continue to exceed exports. Net trade (imports minus exports) is projected to increase from 135 thousand tons in 1986, to 218 thousand tons in the year 2040. Given the projected trends in woodpulp consumption and exports, total U.S. woodpulp production increases from 61 million tons in the year 1986 to 116 million tons in 2040.

Pulpwood

Pulpwood consumption in the United States is projected to increase at a slower rate between 1986 and 2040 than over the historical period 1952 to 1986. From 1986 to 2040, pulpwood consumption is projected to increase 72%, to 158 million cords (table 105). Exports of pulpwood are projected to exceed imports by 0.5 million cords in 2040. Thus, total demand for U.S. pulpwood (pulpwood produced for consumption in U.S. mills and for export) increases to 159 million cords by the year 2040.

A slowing in the projected growth in pulpwood consumption is due to technological developments resulting in greater use of wastepaper, higher yields from pulpwood, and lower overall fiber requirements in the U.S. pulp and paper industry.

Consumption of hardwood and softwood pulpwood in the production of woodpulp more than tripled between 1952 and 1986 (fig. 57). This follows closely the trend in woodpulp production, which also more than tripled during this time. The projections show hardwood pulpwood consumption increasing from 2.2 billion cubic feet in 1986 to 5.1 billion cubic feet by 2040—an increase of more than 130%. Softwood pulpwood consumption is projected to increase by 50% from 1986 to 2040. The higher rate of increase for hardwood pulpwood reflects a gradual shift in the industry toward use of high-yield mechanical pulps which use more hardwood and away from chemical pulps which primarily use softwoods.

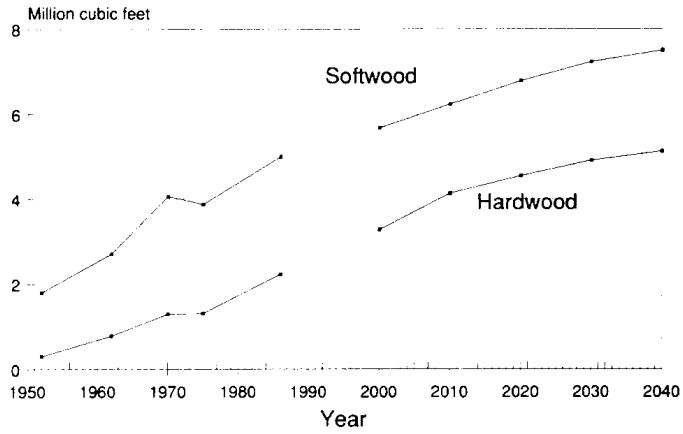


Figure 57.—Pulpwood consumption in the woodpulp industry by species group.

Pulpwood consumption is projected to more than double between 1986 and 2040 in the Northeast, North Central, and Pacific Northwest-East regions between 1986 and 2040 (table 106). Softwood pulpwood consumption increases the greatest in the Pacific Northwest-East, with the lowest rate of increase in the Pacific Northwest-West. Hardwood pulpwood consumption increases more than 140% in the Northeast, North Central, and the Southeast.

Other Industrial Timber Products

A variety of other industrial timber products; including poles, piling, posts, round mine timbers, bolts used for shingles, handles, and woodturnings, and chemical wood, is consumed in the United States. This total also includes roundwood used for oriented strand board and waferboard and particleboard not manufactured from byproducts. Total consumption of roundwood for these products amounted to an estimated 534 million cubic feet in 1986.

Table 105.—Pulpwood consumption, exports, imports, and production in the United States, specified years 1952–1986, with projections to 2040.

Year	Consumption	Exports	Imports	Production				
				Total	Roundwood	Softwood Roundwood	Hardwood Roundwood	Chips
				Thousand cords				
1952	27,155	15	2,125	25,045	23,475	20,000	3,475	1,570
1962	44,060	115	1,405	42,770	33,330	24,315	9,015	9,440
1970	69,620	1,965	1,120	70,460	50,220	36,660	13,560	20,240
1976	75,255	3,270	1,115	77,410	47,650	32,970	14,680	29,760
1986	92,060	1,945	630	93,380	57,130	35,290	21,840	36,250
2000	112,311	1,900	1,300	112,911	84,683	49,370	35,313	28,228
2010	129,992	1,700	1,200	130,492	101,784	56,388	45,396	28,708
2020	141,907	1,600	1,100	142,407	110,223	60,182	50,041	32,184
2030	152,147	1,500	1,000	152,647	118,607	63,929	54,678	34,040
2040	158,213	1,500	1,000	158,713	124,114	66,649	57,465	34,599

Note: Data may not add to totals because of rounding.

Table 106.—Pulpwood consumption by the woodpulp industry in the United States, by species group, roundwood and residue, and region, 1986, with projections to 2040.

	1986	Projections				
		2000	2010	2020	2030	2040
			Million cubic feet			
Northeast	672	885	1,098	1,276	1,372	1,444
Softwood	333	363	445	528	566	594
Roundwood	241	262	322	382	409	429
Residue	92	100	123	146	157	165
Hardwood	340	522	652	748	806	850
Roundwood	239	366	458	525	566	597
Residue	101	156	194	223	240	253
North Central[1]	593	852	1,062	1,224	1,319	1,390
Softwood	139	152	186	221	237	249
Roundwood	117	128	157	186	199	209
Residue	22	24	30	35	38	40
Hardwood	457	700	876	1,003	1,082	1,141
Roundwood	405	621	776	889	958	1,011
Residue	52	80	100	114	123	130
Southeast	2,143	2,722	3,080	3,324	3,663	3,791
Softwood	1,607	1,925	2,038	2,187	2,395	2,476
Roundwood	1,280	1,581	1,674	1,798	2,062	2,208
Residue	328	345	364	388	333	267
Hardwood	535	797	1,042	1,138	1,268	1,316
Roundwood	431	701	944	1,048	1,203	1,275
Residue	103	97	98	89	65	41
South Central	2,440	3,102	3,458	3,670	3,888	4,025
Softwood	1,624	1,941	2,014	2,143	2,274	2,350
Roundwood	1,154	1,526	1,747	1,735	1,690	1,655
Residue	470	415	267	408	584	695
Hardwood	816	1,161	1,445	1,526	1,614	1,675
Roundwood	683	1,033	1,329	1,409	1,500	1,558
Residue	133	129	116	118	114	116
Rocky Mountains[2]	182	171	258	279	284	310
Softwood	182	171	258	279	284	310
Roundwood	29	27	41	45	45	50
Residue	153	144	216	235	238	260
Pacific Southwest[3]	157	151	223	244	249	270
Softwood	146	139	206	227	231	251
Roundwood	15	22	100	133	157	208
Residue	131	117	107	94	74	44
Hardwood	10	12	16	17	18	19
Roundwood	([4])	([4])	([4])	([4])	([4])	([4])
Residue	10	12	15	17	18	19
Pacific Northwest-West	978	946	1,038	1,142	1,183	1,203
Softwood	907	865	932	1,028	1,061	1,076
Roundwood	297	304	372	444	460	482
Residue	610	561	559	584	601	594
Hardwood	68	81	106	114	122	127
Roundwood	53	66	91	98	106	112
Residue	15	15	15	15	16	15
Pacific Northwest-East	55	53	89	107	121	131
Softwood	55	53	89	107	121	131
Roundwood	1	1	1	1	1	1
Residue	54	52	88	106	119	130
United States	7,219	8,885	10,304	11,265	12,076	12,564
Softwood	4,994	5,609	6,168	6,720	7,167	7,437
Roundwood	3,134	3,851	4,414	4,724	5,023	5,242
Residue	1,860	1,758	1,754	1,996	2,144	2,195
Hardwood	2,225	3,276	4,136	4,545	4,909	5,127
Roundwood	1,811	2,787	3,598	3,969	4,333	4,553
Residue	414	489	538	576	576	574

[1]*Includes North Dakota, Nebraska, and Kansas.*
[2]*Excludes North Dakota, Nebraska, and Kansas.*
[3]*Excludes Hawaii.*
[4]*Less than 500 thousand cubic feet.*
Note: Data may not add to totals because of rounding.

The long downward trend in the use of miscellaneous roundwood products appears to have bottomed out in recent years. Since the mid-1970s, the amount of roundwood consumed in these products has been gradually increasing. In these projections, it has been assumed that this upward trend will continue; consumption of these products (including roundwood for oriented strand board and waferboard, and particleboard) will rise slowly to 1.4 billion cubic feet in 2040. Much of the increase is expected to come from expanding consumption of roundwood for these board products.

Imports of logs, both softwood and hardwood, are expected to be negligible. Exports of softwood logs, largely from the Pacific Northwest to Pacific Rim markets, are expected to continue. This trade flow has been the subject of controversy and restrictions in the past. Exports in 1988 amounted to about 3.7 billion board feet, an all time peak. Projections of future softwood log exports from Washington, Oregon, and California decline to roughly 2.5 billion board feet by 2000 and remain at that level through 2040. This outlook is consistent with expected decline in the future Japanese housing market being partly offset by increases in the demand for logs in South Korea, China, and Taiwan. Potential expansions of softwood supplies from Chile and New Zealand by the late 1990s and the Soviet Union after 2000 are assumed to impact fiber markets and low-grade lumber and log markets (Flora and Vlosky 1986). The ultimate impact of demand from the People's Republic of China, currently about half as large as shipments to Japan, is difficult to assess at this time. Another uncertainty is that supply constraints in the Douglas-fir region will affect both the quantity and quality of log exports. Exports of hardwood logs, about 30 million cubic feet in 1986, are projected to remain below 50 million over the projection period.

Fuelwood

Total fuelwood consumption in 1986 was an estimated 3.12 billion cubic feet. Of this total, 26% or 0.80 billion cubic feet came from growing stock volume. The remainder came from nonmerchantable portions of growing stock trees, nongrowing stock trees on timberland, and from trees on other timberland including fence rows, and urban areas. About 74% of the growing stock volume was from hardwoods.

The rapid growth of wood energy use in the 1970s and continued high levels of use are discussed in detail in Chapter 2. The marked reduction in oil prices after 1985 has, however, led to some reduction in residential fuelwood use and a slowing of the increase in industrial use.

Wood energy sources include: (1) chips, logs, and sticks from trees cut specifically for fuel; (2) chips, logs and sticks from logging residue; (3) mill residue of wood waste or bark; and (4) black pulp liquor left over from the pulping process. The models used to project wood energy demand consider all these sources because in some sectors they are partially interchangeable. The projections of wood demand for fuel given later in this section, however, include only the fuel derived from the first source above. Logging residue and pulp liquor, although derived from trees, are byproducts and the volumes harvested to produce them are included in the projections of nonfuelwood timber products given elsewhere in this chapter (High and Skog, in press).

Fuelwood Demand Projections

Both the residential[28] and industrial/commercial[29] models project fuelwood use for five regions (table 107). Each region is considered to have separate fuelwood supply and demand. This assumption is generally valid because the relatively low value of fuelwood makes it uneconomic to transport it out of a region.

As a result of a projected cost advantage of fuelwood over nonwood fuels in all regions, industrial/commercial and residential fuelwood use from all sources (both growing stock and nongrowing stock) is projected to increase from 3.1 billion cubic feet in 1986 to 5.1 billion cubic feet in 2040 with most of the increase occurring before 2010. Total fuelwood use declines after 2020 due to declines in residential use.

The amount of fuelwood from growing stock volume is projected to increase from 0.8 billion cubic feet in 1986 to 1.2 billion cubic feet by 2020, then decline to 1.0 billion cubic feet by 2040. This smaller increase (compared to total fuelwood use) and eventual decline is due to the

[28] *The residential wood energy forecasting model (WOODSTOV-III) is a regionally desegregated model that represents the behavior of households. Its structure is discussed in papers by Marshall (1981, 1982) and Marshall et al. (1983). Demand for fuelwood depends on total energy needed for heating various types of residential buildings, the prices for competing residential fuels, and the price for residential fuelwood. The model calculates wood use separately for heating and esthetic fireplace use. The amount of wood used for heating is the product of the fuelwood use capacity installed and the proprotion used. Capacity is modified each successive period as a function of fuel cost savings, pay back period and retirement. Capacity utilization is a function of fuelwood cost savings relative to fossil fuel cost. Fireplace use is determined as a function of wood fuel cost savings. The proportion of hardwood used for fuelwood in each region in 1986 is from Waddell et al. 1989, table 30. The proportion changes with the relative cost of hardwood and softwood fuelwood chips as estimated by the industrial/commercial wood energy model (CHIPS).*

[29] *The industrial/commercial wood energy forecasting model (CHIPS) is a set of five independent regional models that represents the behavior of numerous energy using companies and fuelwood suppliers. Demand for fuelwood and mill residue depends on total energy demanded in various industrial/commercial sectors, the demand for nonfuel timber products, and the prices of competing fuels in the industrial/commercial sector. The price of fuelwood is determined within the model by the interaction of the fuelwood supply submodel with energy demand. The model has been calibrated for the period 1975 to 1985 primarily against fuelwood/mill residue consumption in the pulp and paper industry (the only sector for which consistent data on fuelwood/mill residue consumption is available). Fuelwood and mill residue demand is tracked separately for four sectors; pulp and paper companies, other forest products companies, large nonforest product industries, and small nonforest product industries together with commercial and institutional users. The fuelwood/mill residue supply submodel tracks inventories and consumption of (1) timber by hardwoods and softwoods, growing stock volume and nongrowing stock by timber size class; (2) mill residues; and (3) logging residues. Demand for nonfuel timber products is exogenous but is not included in the inventory accounting and price structure in the CHIPS model.*

Table 107.—Fuelwood consumed from timberland in the United States by species group, growing stock/nongrowing stock source, and end use, 1986, with projections to 2040.[1]

Year	All roundwood			Growing stock			Industrial and commercial fuelwood use	Residential fuelwood use
	Total	Hard-woods	Soft-woods	Total	Hard-woods	Soft-woods		
				Billion cubic feet				
				Northeast				
1986	0.98	0.89	0.09	0.13	0.12	0.01	0.02	0.96
2000	1.04	0.88	0.16	0.10	0.09	0.01	0.09	0.94
2010	1.33	1.13	0.20	0.09	0.10	0.01	0.09	1.24
2020	1.37	1.15	0.22	0.09	0.08	0.01	0.09	1.28
2030	1.28	1.07	0.21	0.09	0.08	0.01	0.09	1.19
2040	1.20	0.99	0.21	0.08	0.07	0.01	0.09	1.11
				North Central[2]				
1986	0.85	0.81	0.04	0.11	0.10	0.01	0.06	0.79
2000	1.05	0.93	0.12	0.12	0.10	0.02	0.12	0.94
2010	1.41	1.24	0.17	0.13	0.11	0.02	0.15	1.26
2020	1.33	1.15	0.18	0.11	0.08	0.02	0.15	1.18
2030	1.15	0.98	0.17	0.09	0.07	0.02	0.15	1.00
2040	1.02	0.85	0.17	0.08	0.06	0.02	0.15	0.87
				South				
1986	0.75	0.69	0.05	0.32	0.29	0.03	0.06	0.69
2000	1.41	1.31	0.09	0.58	0.53	0.05	0.26	1.14
2010	1.81	1.69	0.12	0.72	0.66	0.06	0.31	1.50
2020	1.90	1.78	0.12	0.73	0.67	0.06	0.32	1.57
2030	1.88	1.77	0.12	0.70	0.64	0.06	0.31	1.57
2040	1.88	1.76	0.12	0.68	0.61	0.06	0.29	1.59
				Rocky Mountains[3]				
1986	0.11	0.02	0.08	0.01	0.00	0.01	0.00	0.11
2000	0.22	0.05	0.17	0.01	0.00	0.01	0.01	0.21
2010	0.31	0.06	0.25	0.02	0.00	0.01	0.01	0.30
2020	0.34	0.06	0.28	0.02	0.00	0.02	0.01	0.33
2030	0.33	0.06	0.28	0.02	0.00	0.02	0.01	0.33
2040	0.33	0.05	0.28	0.02	0.00	0.02	0.01	0.32
				Pacific Coast[4]				
1986	0.44	0.16	0.28	0.22	0.08	0.15	0.03	0.41
2000	0.55	0.21	0.34	0.28	0.14	0.05	0.04	0.51
2010	0.74	0.27	0.47	0.24	0.18	0.07	0.04	0.70
2020	0.79	0.27	0.52	0.25	0.18	0.08	0.04	0.76
2030	0.74	0.25	0.49	0.22	0.16	0.07	0.03	0.71
2040	0.67	0.22	0.45	0.19	0.14	0.06	0.02	0.65
				United States[4]				
1986	3.12	2.57	0.55	0.80	0.59	0.21	0.16	2.96
2000	4.26	3.38	0.88	0.99	0.86	0.14	0.52	3.74
2010	5.60	4.39	1.21	1.20	1.05	0.18	0.60	5.00
2020	5.73	4.42	1.31	1.19	1.01	0.19	0.61	5.12
2030	5.38	4.11	1.27	1.12	0.95	0.18	0.59	4.80
2040	5.09	3.88	1.22	1.04	0.89	0.16	0.56	4.54

[1]*Excludes logging residue used for fuel.*
[2]*Includes North Dakota, Nebraska, and Kansas.*
[3]*Excludes North Dakota, Nebraska, and Kansas.*
[4]*Excludes Alaska and Hawaii.*
Note: Data may not add to totals because of rounding.

projected decline in proportion of fuelwood from growing stock volume. The proportion from growing stock is projected to decline from 26% in 1986 to 20% in 2040.

For residential fuelwood, growing stock makes up 20–25% of the total and is expected to remain low over the projection period. For industrial and commercial use, fuelwood from sources other than logging residues will be in the form of whole-tree chips. Chipping operations will take wood for both fuel and pulp from stands with below average growing stock. Thus, fuelwood chips for industrial/commercial uses will have a low growing stock content. As industrial and commercial use increases relative to residential use, the overall proportion of growing stock used is projected to decline.

Residential fuelwood use is currently much larger than industrial/commercial fuelwood use because most industrial/commercial wood boilers use mill waste or spent pulp liquor. Industrial/commercial fuelwood is expected to grow much more rapidly in the future than residential use (281% versus 73% between 1986 and 2020) as more nonforest products firms burn fuel from roundwood rather than mill waste. After 2020 residential fuelwood use is projected to decline as residential fossil fuel prices remain constant and residential fuelwood prices continue to increase.

Softwoods are projected to increase from 18% of all fuelwood in 1986 to 24% in 2040 as industrial/commercial use increases. Industrial/commercial users have less of a bias toward use of hardwood than residential users. The proportion of softwood roundwood use in 1986 varies from 73% and 64% for the Rocky Mountains and Pacific Coast regions to less than 10% in other regions.

The Northeast, North Central, and the South have the largest total fuelwood demand both currently and in 2040. The higher use in the Northeast and North Central results from the widespread availability of low-grade (inexpensive) wood and relative competitiveness of fuelwood due to higher than average fossil fuel prices in those regions. Demand in the South is expected to grow much more rapidly, and increase 150% between 1896 and 2040. Fuelwood use in the two western regions is lower than in the eastern regions. In both the Rocky Mountains and the Pacific Coast regions residential use dominates fuelwood use. This is expected to continue through 2040 by which time total consumption is expected to nearly double to 1.0 billion cubic feet.

Product Price Projections

The general increases in product prices shown in table 108 are largely due to increases in stumpage prices. Higher raw material costs raise production costs and affect timber product (lumber, plywood, paper and board) prices, demand, trade, and domestic production (demand on domestic forests). They are also the driving force behind interregional shifts in mill capacity since they are the only components of costs whose relative levels among regions change significantly over time. Other production costs such as labor, materials, and capital change, but the relationships among regions and products remain much the same.

Softwood lumber prices are relatively flat after 2010 (table 108). The rate of increase is most rapid in the 1986–2010 period, averaging about 1.2% per year. This reflects upward pressure on stumpage prices resulting from diminishing softwood sawtimber inventories on private timberlands in the West and South.

The projected rate of increase in equilibrium real softwood lumber prices is consistent with the long historical trend in lumber prices. Since 1900, the price of lumber measured in constant dollars has been rising at

Table 108.—Price[1] indexes for selected timber products in the United States, by softwoods and hardwoods, specified years 1952–1986, with projections to 2040.

Product, unit & species group	1952	1962	1970	1976	1986	Projections 2000	2010	2020	2030	2040
				Index of price per unit - 1982 = 100						
Lumber (1,000 board feet)										
Softwoods	99.8	88.3	95.3	126.0	114.3	132.1	151.2	159.8	164.6	160.7
Hardwoods	104.7	103.7	118.6	109.9	126.2	133.6	147.0	163.8	182.6	201.1
Structural panels (1,000 square feet, 3/8-inch basis)										
Plywood	172.0	119.0	109.2	143.6	121.1	112.8	133.1	146.4	154.1	140.5
OSB-waferboard				163.0	92.7	77.6	82.6	100.5	85.1	88.7
Nonstructural panels (1,000 square feet, 3/8-inch basis)										
Plywood	184.5	174.5	153.4	110.6	90.7	88.4	86.7	85.0	83.3	81.6
Other panels[2]		151.4	115.0	92.1	107.1	107.1	107.1	107.1	107.1	107.1
Paper & board (tons)	100.2	105.3	101.5	101.5	115.8	107.6	105.7	102.9	100.3	98.9

[1]*Prices are measured in constant (1982) dollars and are net inflation or deflation. They measure price changes relative to the general price level and most competing materials.*
[2]*Hardboard, particleboard, and fiberboard products.*

an average rate of 1.4% per year. In addition, the historical increases have not been evenly spread. Typically, there have been periods of a decade or two when prices showed little change (the 1950s). This has been followed by periods such as the 1940s and 1970s when prices rose rapidly. Similar price movements are expected over the projection period, with rapid increases from 1990 to 2010 and then near stability through 2040.

Equilibrium hardwood lumber prices rise at an average annual rate of about .9% per year. This reflects continuous growth in major shipping uses and a steady decline in the availability of larger timber for higher quality lumber grades. The increases in hardwood lumber prices are more evenly spread over the projection period than are the increases in softwood lumber prices.

The equilibrium projections for structural panel prices (table 108) also show rising real prices for plywood but roughly constant prices for oriented strand board and waferboard. Like softwood lumber, softwood plywood prices are relatively stable in the last three decades of the projection. For the entire projection period, softwood plywood prices increase at about .3% per year. The price projections for the other structural panel products (oriented strand board and waferboard) show little growth. This is the consequence of the greater dependence of these products on residential construction markets and slower growth in wood costs due to lower quality requirements.

As with lumber, the projected changes in softwood plywood prices largely reflect changes in stumpage costs: stumpage costs rise nearly four times faster than processing costs in the Douglas-fir subregion and nearly five times faster in the South Central region.

In contrast to structural panels, there is little change in the projected prices for nonstructural panels. Prices for hardwood plywood are expected to continue to decline in real terms throughout the projection period. Prices for the other board products are expected to remain constant in real terms for the next several decades.

The projected decreases in paper and board prices, shown in table 108, largely reflect efficiency improvements in the manufacture of paper and board. The expectation is that future price decreases will mirror the experience of the period 1962 to 1976. Prices for other timber products such as posts, poles, piling, mine timbers, and cooperage logs are expected to be similar to the price increases for lumber shown in table 108. As for lumber, panels, and paper and board, the projections will depend on the demand levels for the various products and the importance of stumpage costs relative to product selling prices.

Projected Demands for Timber

The projections of demand for timber products discussed in preceding sections have been presented, for the most part, in standard units of measure such as board feet of lumber, square feet of panel products, cords of pulpwood and fuelwood, and cubic feet of miscellaneous industrial roundwood products. In order to compare demand for these products with projections of timber supplies, these projections are converted to a common unit of measure—cubic feet of roundwood.

Demands for Roundwood

In 1986, total U.S. consumption of timber products in terms of roundwood volume was 20.5 billion cubic feet, including fuelwood obtained from nongrowing stock sources (table 109).[30] Total consumption will continue to grow throughout the next five decades at .6% per year. Growth in hardwood consumption is expected to be nearly three times as fast as growth in softwood consumption. Total consumption of timber products increases to 22.9 billion cubic feet in 2000 and 28.6 billion cubic feet in 2040. Although demand for each of the products (except veneer) is higher in 2040 than in 1986, fuelwood and pulpwood show the largest increases in volume. By 2040, these two products account for 56% of the timber consumed in the United States. In terms of percentages, miscellaneous products exhibits the largest increase because of the increase in roundwood used for oriented strand board and waferboard.

Part of this total consumption is met by trade with other producing countries. The scale of this trade can be illustrated when the various product trade projections are converted to roundwood equivalent. In 1986, nearly 25% of total demand was filled by imports (table 110). Total imports in 1986 amounted to 4.4 billion cubic feet, triple the volume imported in 1952. Over the same period, exports rose more than 9 times, to 1.9 billion cubic feet.

Projected levels of total imports, currently at about 4.4 billion cubic feet, roundwood equivalent, are expected to fall in the next two decades but rise again around 2020 (table 110). This trend is the result of increasing softwood product imports around 2020. Total hardwood imports are projected to increase slowly throughout the next five decades to the equivalent of 0.5 billion cubic feet by 2040. Projected total exports increase about 32% to 2.5 billion cubic feet in 2040 as a result of general increases in exports of all products. Exports of hardwood products are projected to rise 75%, to about 0.7 billion cubic feet over the projection period.

The trade situation differs between the hardwood and softwood sectors. The softwood sector is expected to remain a net importer of timber products. The primary imports are expected to remain softwood lumber and newsprint, both from Canada. The hardwood sector, on the other hand, is a net exporter of timber products. These projections of timber products imports and exports show only a modest overall decline in net imports into the United States, from 2.5 billion cubic feet in 1986 to 1.5 billion cubic feet in 2040.

[30] *This assumption is consistent with past Assessments but differs from the assumptions in the 1983 Assessment Supplement (Haynes and Adams 1985) and the South's Fourth Forest Study (USDA FS 1988) that did not include fuelwood obtained from nongrowing stock sources in the estimates of total consumption.*

Table 109.—Roundwood consumption in the United States, by species group and product, specified years 1952–1986, with projections of demand to 2040.

Species group and product	Historical					Projections					
	1952	1962	1970	1976	1986	1990	2000	2010	2020	2030	2040
	Billion cubic feet, roundwood equivalent										
Softwoods											
Sawlogs	5.0	4.8	4.9	5.5	7.6	7.0	6.4	6.9	7.4	7.4	7.4
Veneer logs	0.2	0.7	0.9	1.2	1.6	1.3	1.1	1.1	1.2	1.3	1.4
Pulpwood[1]	2.4	2.6	3.4	3.3	4.2	4.0	4.8	5.5	5.9	6.3	6.6
Miscellaneous products[2]	0.3	0.2	0.2	0.2	0.3	0.3	0.5	0.6	0.7	0.8	0.9
Fuelwood	0.2	0.1	0.1	0.1	0.6	0.7	0.9	1.2	1.3	1.3	1.2
Total[3]	8.1	8.4	9.5	10.5	14.3	13.4	13.7	15.3	16.6	17.1	17.5
Hardwoods											
Sawlogs	1.1	1.1	1.1	1.3	1.5	1.5	1.8	2.0	2.1	2.2	2.2
Veneer logs	0.2	0.2	0.3	0.3	0.2	0.2	0.3	0.3	0.3	0.3	0.3
Pulpwood[1]	0.3	0.7	1.0	1.1	1.7	1.9	2.6	3.3	3.7	4.0	4.2
Miscellaneous products[2]	0.4	0.2	0.2	0.1	0.2	0.3	0.4	0.4	0.5	0.5	0.5
Fuelwood	0.7	0.4	0.3	0.3	2.7	2.9	3.4	4.4	4.4	4.1	3.9
Total[3]	2.7	2.6	2.9	3.1	6.2	6.9	8.3	10.4	11.0	11.1	11.1
All species											
Sawlogs	6.1	5.9	6.0	6.8	9.0	8.6	8.2	8.9	9.5	9.6	9.6
Veneer logs	0.4	0.9	1.2	1.5	1.8	1.6	1.3	1.4	1.5	1.6	1.7
Pulpwood[1]	2.7	3.3	4.4	4.4	5.8	5.9	7.4	8.8	9.6	10.3	10.8
Miscellaneous products[2]	0.7	0.5	0.4	0.4	0.5	0.7	0.8	1.0	1.2	1.3	1.4
Fuelwood	1.0	0.5	0.3	0.3	3.3	3.6	4.3	5.6	5.7	5.4	5.1
Total[3]	10.9	11.1	12.3	13.5	20.5	20.3	22.9	25.7	27.6	28.2	28.6

[1]*Includes both pulpwood and the pulpwood equivalent of the net imports of pulp, paper, and board.*
[2]*Includes cooperage logs, poles, piling, fence posts, round mine timbers, box bolts, shingle bolts, roundwood used in waferboard, oriented strand board, and particleboard manufacture, and other miscellaneous items.*
[3]*Includes imported logs not shown by product use.*

Table 110.—Timber demand, exports, imports, and demand on timberland in the United States, by species group, specified years 1952–1986, with projections to 2040.

Species group and product	Historical[1]					Projections					
	1952	1962	1970	1976	1986	1990	2000	2010	2020	2030	2040
	Billion cubic feet										
Softwoods											
Total demand[2]	8.1	8.4	9.5	10.5	14.3	13.4	13.7	15.3	16.6	17.1	17.5
Exports	0.1	0.4	1.3	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.8
Imports	1.3	1.7	2.1	2.5	4.1	3.8	3.2	3.7	3.9	3.6	3.5
Demand on U.S. forest land	6.9	7.1	8.7	9.5	11.7	11.3	12.1	13.4	14.5	15.3	15.8
Hardwoods											
Total demand[2]	2.7	2.6	2.9	3.1	6.2	6.9	8.3	10.5	11.0	11.1	11.1
Exports	([3])	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.6	0.7	0.7
Imports	0.1	0.2	0.3	0.3	0.3	0.3	0.4	0.5	0.5	0.5	0.5
Demand on U.S. forest land	2.6	2.5	2.8	3.0	6.3	7.0	8.4	10.5	11.1	11.3	11.3
All species											
Total demand[2]	10.9	11.1	12.3	13.5	20.5	20.3	22.0	25.7	27.6	28.7	28.6
Exports	0.2	0.5	1.5	1.9	1.9	2.1	2.2	2.3	2.4	2.5	2.5
Imports	1.4	1.9	2.4	2.8	4.4	4.2	3.7	4.1	4.4	4.1	4.0
Demand on U.S. forest land	9.7	9.7	11.4	12.6	18.0	18.2	20.5	23.9	25.6	26.5	27.1

[1]*Data are estimates of actual consumption and harvests.*
[2]*Total demand for products converted to a roundwood equivalent basis.*
[3]*Less than 50 million cubic feet.*

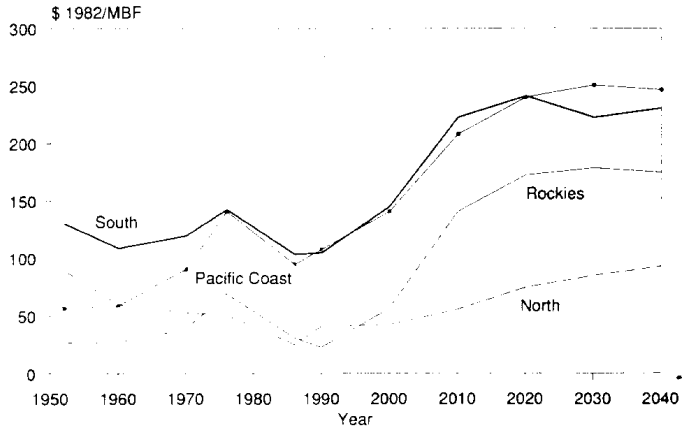
Demands on U.S. Timberland

Given the projections of total demands and net trade (shown in tables 96, 99, and 101), demands on U.S. timberland increase sharply over the next five decades, rising about 50%, from 18.0 billion cubic feet in 1986 to 27.1 billion in 2040 (table 110). Demands for both softwoods and hardwoods increase; in line with projected trends discussed above, however, hardwood demand rises somewhat more rapidly. Between 1986 and 2040, demand on U.S. timberland for hardwoods is projected to increase about 79%, to 11.3 billion cubic feet. Demands on U.S. timberland for softwoods during the same period is expected to grow about 35%, to 15.8 billion cubic feet.

In summary, demands on U. S. timberland will grow fairly rapidly over the next five decades. These demands increase about 50%, to 27.1 billion cubic feet, roundwood equivalent, in 2040. At the same time, prospective imports are projected to be only slightly smaller than current levels. Consequently, in the future the United States will look to its domestic timber resources to meet a larger proportionate share of its demands for timber products.

THE STUMPAGE MARKET

The preceding section of this chapter has been largely concerned with assessing the situation in the product market and with the development of the demand for timber from domestic forests. This section focuses on the supply of timber needed to meet that demand, the associated stumpage prices, and the levels of timber inventories.



NOTE--Pacific Coast excludes Alaska and Hawaii

Figure 58.—Softwood stumpage prices, 1952–1986, with projections 1990–2040.

Projections of the regional sawtimber[31] softwood stumpage prices[32] are summarized in table 111 and shown for selected regions in figure 58. These projections show softwood sawtimber stumpage prices rising substantially in all regions. There are, however, marked differences among the various regions. Stumpage prices in the South rise at an annual rate of about 1.5% between 1986 and 2040. Stumpage prices in the North rise at about 2.5% per year. The Rocky Mountain Region is expected to experience the most rapid increase in stumpage prices averaging 3.2% per year between 1986 and

[31] *That part of harvest being used in the manufacture of lumber, plywood, and miscellaneous products and as log exports.*

[32] *All stumpage prices are measured in 1982 dollars. This excludes the effect of general price inflation or deflation. The increases shown, therefore, measure change relative to the general prices of most competing materials.*

Table 111.—Softwood sawtimber stumpage prices[1] in the contiguous states, by region, specified years 1952–1986, with projections to 2040.

Region	1952	1962	1970	1976	1986	Projections 2000	2010	2020	2030	2040
	Price per thousand board feet, Scribner log rule									
North	90	60	54	51	25	42	55	74	85	93
South	129	108	120	141	103	145	222	242	222	231
Rocky Mountain	27	27	39	69	31	56	141	172	178	175
Pacific Northwest[2]										
Douglas-fir subregion (Western Washington & Western Oregon)	54	63	105	156	99	147	215	249	251	244
Ponderosa Pine subregion (Eastern Washington & Eastern Oregon)	66	39	60	105	93	127	204	216	257	267
Pacific Southwest[3]	54	39	66	114	82	134	187	236	241	234

[1] *Prices are measured in constant (1982) dollars and are net of inflation or deflation. They measure price changes relative to the general price level and most competing materials.*

[2] *Excludes Alaska.*

[3] *Excludes Hawaii.*

Sources: Data for 1952, 1962, 1970, 1976, and 1986 based on information published by the U.S. Department of Agriculture and summarized by Adams et al. 1988.

Cost competition will force the use of appropriate technologies including horse logging, here being used in a thinning operation.

2040. The Pacific Coast Region (composed of the Douglas-fir, Ponderosa Pine, and Pacific Southwest subregions) is expected to experience rates of increase of roughly 1.7–2.0% per year.

Rates of stumpage price increase also vary greatly over time. During the next two decades, rapid price escalation is expected in the Rocky Mountain Region and in the Douglas-fir subregion. In the Douglas-fir subregion, this is the consequence of fairly rapid declines in sawtimber harvest. In the Rocky Mountains, price growth accompanies a major expansion in regional lumber processing capacity to absorb increases in national forest harvest.

These different rates of price growth do not materially change the relationships in stumpage prices among regions over the projection period. The regional variations in the rates of increase are caused by a number of complex forces. In general, however, they reflect the degree of competition for available timber, differences in stumpage quality characteristics, and variations in regional logging, manufacturing, and transportation costs.

These computed rates of price growth depend heavily on the choice of the initial time point (1986) used for comparison. This is particularly the case for the two northern subregions (the Northeast and the North Central subregions) and for the Rocky Mountain Region where low prices in 1986 sharply raise rates of increase expressed in percentage terms.

Hardwood sawtimber prices are expected to increase at about 1.4% per year as illustrated in the following tabulation:

Price index (1982 = 100) per thousand board feet	
1986	123
2000	135
2010	163
2020	194
2030	229
2040	263

Hardwood stumpage prices are expected to grow relatively slowly over the next 15 years as hardwood inventories continue to expand. After 2000, the growth rate for hardwood stumpage prices increases because of slowing growth in hardwood inventories and increased demand, especially for pulpwood.

Price projections for sawtimber harvested by Forest Service region are shown in table 112. These price projections, except for Alaska (Region 10), were developed from those in table 111. Price projections for Alaska were developed from those for the Region 6-Westside and assume declining private (Native corporation) harvest and roughly stable national forest harvests (Haynes and Brooks, in press).

Projected regional national forest harvest generally follows the projections of allowable sale quantity shown in tables 77 and 78 except for the four Rocky Mountain regions where the softwood sold volumes average 150–180 million cubic feet less than the offered volumes throughout the projection period. The majority of this unsold volume is in Region 1.

Table 112.—Price projections for sawtimber harvested in each Forest Service region.

Region	1986	2000	2010	2020	2030	2040
	1982 dollars per MBF					
1	69	68	171	210	217	213
2	24	23	59	72	74	73
3	85	84	210	258	267	261
4	32	32	79	97	100	98
5	85	134	187	235	241	234
6–Westside	123	146	215	249	251	243
6–Eastside	101	127	204	216	256	267
8–Hardwoods	69	81	106	134	166	197
8–Softwoods	129	145	223	241	217	230
9–Hardwoods	97	107	129	154	182	209
9–Softwood	35	42	55	66	85	93
10[1]	34	34	56	66	67	65

[1]*Price projections for Region 10 (Alaska) are for timber sold rather than timber harvested.*

Delivered prices (stumpage price plus logging costs and transportation cost to the mill) are projected to increase for sawtimber, pulpwood and fuelwood (table 113). The most rapid increase in delivered prices is for softwood sawtimber, which increase over the period 1986 to 2040 at 1.2% a year in the South, 1.6% per year in the Rocky Mountains, and 1.4% a year in the Pacific Coast. Delivered prices for hardwood pulpwood increase at 0.9% a year in the North and 1.1% a year in the South, or about twice as fast as softwood pulpwood delivered prices in the South. Hardwood fuelwood prices in the North increase at 0.8% a year. Both fuelwood and pulpwood remain far below the delivered prices for softwood sawtimber (fig. 59).

There are significant changes in the demands and supplies of timber associated with the projected increases in softwood and hardwood stumpage prices (table 114). In terms of total (both softwood and hardwood) harvest, there are also some changes in regional shares of total supply as shown in figure 60. The projections shown in tables 111 and 114 indicate impending limitations on softwood timber harvest in the 1990–2000 decade in the Douglas-fir subregion and between 2000 and 2010 in the South. Harvest in the Douglas-fir subregion falls by 2000 driving up stumpage prices and leading to retrenchments in the forest products industry. In the South, after increasing at roughly 0.8% per year until 2000, timber harvests grow at only 0.1–0.2% per year during the next decade. Stumpage prices rise and growth in regional solid-wood product output stalls as a result. After 2010, softwood harvest grows more rapidly, reflecting both the maturing of large areas of young growth in both the South and the Douglas-fir subregion and the investments in forest management during the 1980s and 1990s. This increase in harvest slows the rates of stumpage price increases in both the South and in the Douglas-fir subregion.

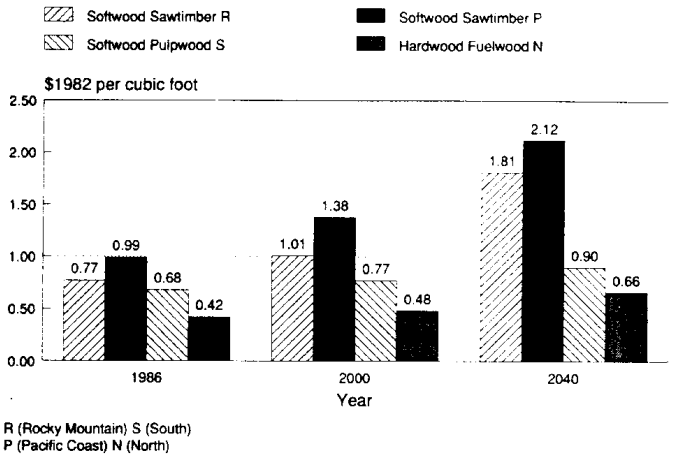


Figure 59.—Delivered prices for timber by product and region.

Only modest softwood harvest shifts are expected in the relative importance of the various regions. The Southern and the Pacific Coast regions will continue to dominate. Specific regional shares do change during the projection period. For example, the shares of the total softwood roundwood supplies originating in the eastern regions, Rocky Mountain Region, and the Ponderosa Pine subregion increase over the projection period. The share originating in the Douglas-fir subregion, on the other hand, drops from 27% of the total in 1986 to 19% by 2040. There is also a small decline in the share coming from the Pacific Southwest.

Hardwood harvest is expected to increase in all regions although not uniformly. The largest increases are in the South where both growth in fuelwood and

Table 113.—Delivered prices for sawtimber, pulpwood, and fuelwood, by section and region, and species group, 1986, with projections to 2040.

Section and region	1986	Projections				
		2000	2010	2020	2030	2040
	1982 dollars per cubic foot, log scale					
Softwood sawtimber						
South	0.79	1.01	1.40	1.52	1.46	1.55
Rocky Mountain[1]	0.77	1.01	1.48	1.69	1.73	1.81
Pacific Coast[2]	0.99	1.38	1.76	1.98	2.04	2.12
Softwood pulpwood						
South	0.68	0.77	0.82	0.82	0.88	0.90
Hardwood pulpwood						
North[3]	0.45	0.56	0.71	0.71	0.73	0.75
South	0.49	0.71	0.83	0.81	0.86	0.90
Hardwood fuelwood						
North[3]	0.42	0.48	0.56	0.61	0.65	0.66
South	0.38	0.39	0.39	0.42	0.42	0.39

[1]*Excludes North Dakota, Nebraska, and Kansas.*
[2]*Excludes Alaska and Hawaii.*
[3]*Includes North Dakota, Nebraska, and Kansas.*

Table 114.—Timber harvests (roundwood supplies) from forest land in the contigous states, by region, specified years 1952–1986, with projections through 2040.

Item	1952[1]	1962[1]	1970[1]	1976[1]	1986[1]	Projections 2000	2010	2020	2030	2040
					Billion cubic feet					
Softwoods										
Northeast	0.48	0.37	0.38	0.43	0.60	0.74	0.91	1.05	1.10	1.13
North Central[2]	.17	.20	.17	.21	.24	.38	.50	.59	.64	.66
Southeast	1.65	1.40	1.63	1.72	2.33	2.81	3.06	3.27	3.42	3.48
South Central	1.21	1.16	1.96	2.28	2.80	3.18	3.27	3.70	4.12	4.49
Rocky Mountain	.47	.61	.79	.85	1.01	1.18	1.35	1.40	1.40	1.41
Pacific Northwest[3]										
Douglas-fir subregion (Western Washington and Western Oregon)	1.85	2.01	2.44	2.69	3.14	2.56	2.77	2.88	2.97	3.00
Ponderosa pine subregion (Eastern Washington and Eastern Oregon)	.38	.50	.48	.54	.60	.59	.69	.73	.75	.76
Pacific Southwest[4]	.68	.86	.85	.78	.78	.75	.84	.85	.85	.85
Softwoods total harvests	6.89	7.11	8.70	9.50	11.50	12.19	13.39	14.47	15.25	15.78
Hardwoods										
Northeast	.55	.55	.54	.52	1.52	1.79	2.25	2.44	2.48	2.49
North Central	.98	.80	.75	.81	1.93	2.25	2.81	2.91	2.86	2.82
Southeast	.77	.62	.63	.64	1.35	1.83	2.31	2.47	2.58	2.60
South Central	1.27	.96	.89	.84	1.58	2.10	2.60	2.74	2.83	2.91
West	.03	.07	.09	.09	.29	.38	.48	.49	.46	.43
Hardwoods total harvests	3.60	3.00	2.90	2.90	6.67	8.35	10.45	11.05	11.21	11.25

[1]*Data are estimates of actual consumption or harvests and differ somewhat from the "trend" estimates shown in the preceding section on timber supplies.*
[2]*Includes the Great Plains States—Kansas, Nebraska, North Dakota, and eastern South Dakota.*
[3]*Excludes Alaska.*
[4]*Excludes Hawaii.*
Note: Data may not add to totals because of rounding.
Sources: The historial data is published in Adams et al. 1988.

pulpwood demands push up harvest. The lowest rate of growth in the east is in the Northcentral subregion.

Associated with these changes in harvest are changes in the size of harvested trees. The average diameters of timber harvested on private timberlands in the various Assessment regions are shown in table 115. The largest changes are expected for softwoods on the Pacific Coast where the average diameter of harvested trees is expected to drop 20%. Decreasing sizes of future harvests are expected in most regions and for both hardwoods and softwoods.

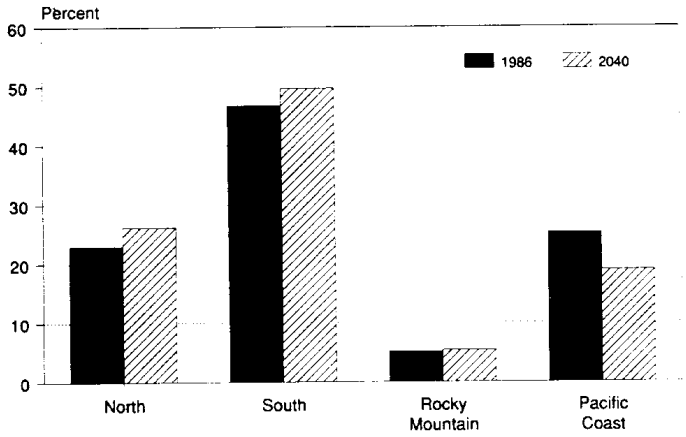


Figure 60.—Regional percentage of total roundwood supply, 1986 and 2040.

EFFECTS OF EQUILIBRIUM LEVELS OF TIMBER HARVESTS ON INVENTORIES

The higher timber harvests expected in the future accelerate various trends in net annual growth and inventories. These projections for private timberlands are shown in tables 116–119. Similar figures for the public timberlands as shown in tables 77–80. This data is summarized for all owners and all regions in tables 120 and 121 and figure 61. Essentially, changes in inventories are the result of harvest levels and assumptions regarding forest management and investment. As a result of declining growth, increasing harvests, and conversion of forest land to other uses, total softwood inventories remain constant through 2000 (table 120). However, by 2040, softwood inventories are projected to expand to roughly the same level as they were in the mid-1970s. Net growth falls by 2000 but increases rapidly afterwards as older, slow growing stands are replaced by younger stands. The trend in softwood inventory for the entire United States (roughly flat over the period 1970 to 2040)

Table 115.—Average diameter[1] of timber harvested on private timberlands in the Assessment regions.

	Pacific Coast		Rockies		North		South	
	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood
				inches				
1986	16.6	18.7	18.9	9.6	14.2	12.0	12.4	9.9
2000	17.2	16.0	14.1	9.3	13.4	11.9	11.4	9.0
2040	16.5	15.2	12.7	9.3	13.1	12.3	10.8	8.8

[1]*Diameter measured at breast height.*

masks changes in regional softwood timber stocks. This, and the fact that the projected inventory in 2040 is composed of a larger number of younger trees, contributes to the relatively rapid increase in softwood stumpage prices shown in table 111.

The trends in inventory differ between ownerships and are compounded by land area changes (particularly on the farmer and other private ownership). Softwood inventories for both the national forest and forest industry ownerships decline by 2000 while, over the same period, inventories for the other two ownerships are projected to increase. Some of the decline of national forest inventories is due to changes in definitions regarding forest lands that are considered as suitable for timber production. Inventories on forest industry timberlands increase after 2000 and by 2010, are projected to exceed current levels.

Trends in hardwood inventories present a very different picture. Hardwood inventories are expected to increase in the North and the Pacific Coast (table 120). Until 2000, decreases in the South are more than offset by increases in hardwood inventories in the North; after 2010 declines in Southern inventories accelerate.

Net annual growth for hardwoods, after stabilizing between 1976–86, starts to drop early in the projection period because of increasing stand age and the shift from hardwood types to softwood types in the South. This trend is most prominent for the forest industry ownership (see table 117).

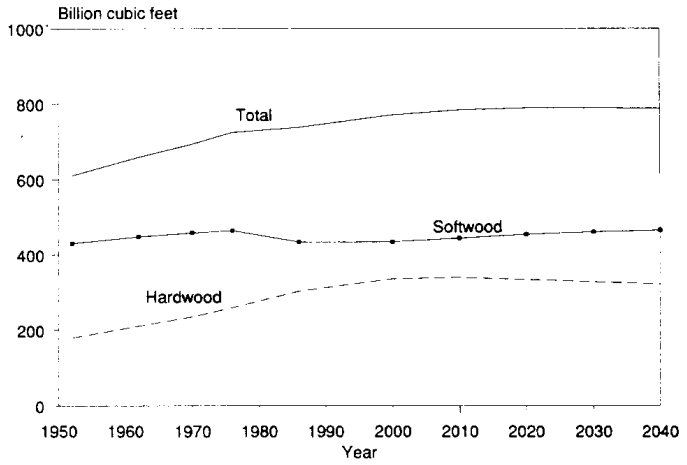


Figure 61.—Growing stock inventories on timberland, 1952–1986, with projections to 2040.

Regional shares for total softwood and hardwood harvest, derived from tables 120 and 121, are shown in the following tabulation:

	1986	2000	2040
		Percent	
North	23.0	25.0	26.1
South	46.7	48.0	49.6
Rocky Mountains	5.1	5.9	5.3
Pacific Coast	25.2	21.2	18.9

These data illustrate that nearly all of the near-term increase in both softwood and hardwood harvest comes in the East. In the longer term, the Pacific Coast Region continues to lose share of harvest in spite of modest harvest increases in the Douglas-fir subregion.

Table 121 illustrates that nearly all of the increase in timber harvest comes from other private and forest industry ownerships. Supply from the national forests, and supply from other public ownerships in all regions is determined by various planning efforts that are not, for the most part, affected by expected future prices. National forest harvests (as distinct from the volume of timber offered for sale) in the Rocky Mountains are an exception. There harvest levels initially fall below projected offerings, because industry capacity is unable to absorb the prospective increase over current levels. As capacity expands, unsold volume falls and harvests rise toward projected public supply.

The ownership pattern of the increases in harvest differs between the hardwood and softwood sectors (table 121). The increase in softwood harvest is shared between the two types of private timberland owners. Increase in hardwood harvest, on the other hand, is concentrated on the other private ownership. This ownership accounts for 77% of the hardwood harvest in 1986 and by 2040 their share is expected to increase to 82%. This increase is the result of declining harvests from forest industry timberlands due to conversion of hardwood forest types to softwood plantations.

IMPLICATIONS OF THE BASE PROJECTIONS

The projections suggest that forest industry timberlands in the South and in the Pacific Northwest will be approaching a roughly regulated state within the next three decades. In a regulated forest, growth and harvest are nearly equal and there is a roughly uniform distri-

Table 116.—Softwood removals, harvest, net annual growth, and growing stock inventory on forest industry timberlands[1] in the contiguous states, specified years 1952–1986, with projections to 2040.

Item	1952	1962	1970	1976	1986	Projections 2000	2010	2020	2030	2040
					Million cubic feet					
Northeast										
Removals	105	92	138	182	273	239	185	183	178	178
Timber harvest	99	87	128	168	356	310	287	285	273	268
Net growth	179	236	339	377	188	177	169	172	176	178
Inventory	5,246	6,427	9,753	10,824	9,232	8,251	8,043	7,905	7,846	7,817
North Central[2]										
Removals	34	23	28	33	37	41	45	50	54	59
Timber harvest	30	22	25	28	41	62	71	76	80	82
Net growth	43	44	63	55	50	52	52	55	56	54
Inventory	917	1,314	1,521	1,690	1,653	1,669	1,732	1,765	1,770	1,715
Southeast										
Removals	325	262	458	518	821	1,121	1,267	1,531	1,597	1,511
Timber harvest	318	252	430	473	740	984	1,210	1,393	1,433	1,503
Net growth	375	411	558	688	789	1,206	1,462	1,484	1,532	1,539
Inventory	6,469	7,455	8,286	8,737	10,264	10,962	12,510	13,437	12,633	12,463
South Central										
Removals	494	341	564	898	1,088	1,082	1,457	1,807	1,891	2,065
Timber harvest	484	328	530	893	1,045	1,038	1,532	1,664	1,827	2,094
Net growth	707	971	889	894	829	1,500	1,878	1,910	2,122	2,106
Inventory	9,738	13,087	13,501	14,430	13,515	14,533	20,444	21,416	23,655	24,979
Pacific Southwest										
Removals	456	449	318	344	435	309	235	187	134	151
Timber harvest	393	385	294	321	452	300	291	255	300	323
Net growth	90	108	135	139	205	189	167	167	178	158
Inventory	11,268	9,639	8,244	7,457	7,918	5,207	4,353	3,930	4,206	4,143
Douglas-fir subregion										
Removals	1,150	909	1,272	1,302	1,222	1,059	1,003	1,004	1,034	1,114
Timber harvest	1,244	976	1,234	1,268	1,244	1,178	1,303	1,383	1,496	1,530
Net growth	337	393	455	606	915	949	1,052	1,162	1,254	1,273
Inventory	32,725	27,399	23,767	21,978	20,137	17,779	18,308	19,873	22,038	23,530
Ponderosa pine subregion										
Removals	103	95	120	162	179	104	128	135	145	148
Timber harvest	100	94	117	151	166	97	116	120	128	132
Net growth	62	71	84	85	115	147	139	149	139	153
Inventory	3,975	3,972	4,038	3,849	4,279	5,355	5,423	5,518	5,439	5,482
United States total										
Removals	2,666	2,171	2,898	3,439	4,055	3,955	4,320	4,897	5,033	5,226
Timber harvest	2,668	2,144	2,758	3,302	4,043	3,969	4,810	5,176	5,537	5,932
Net growth	1,793	2,234	2,523	2,844	3,091	4,220	4,919	5,099	5,457	5,461
Inventory	70,338	69,293	69,110	68,965	66,998	63,756	70,813	73,844	77,587	80,129

[1]*The forest industry timberlands in the Rocky Mountains are included with the farmer and other private timberlands for that region.*

[2]*Data for the Great Plains are included in the Rocky Mountains for the historical period and in the North Central subregion for the projection period.*

Note: Supply data for 1952, 1962, 1970, 1976, and 1986 are estimates of the trend level of harvests and differ somewhat from the estimates of actual consumption shown in some tables. For the projection years, the data shows the volume that would be harvested given the assumptions of the study. Inventory data for 1952 and 1962 are as of December 31. Inventory data for 1970 and the projection years are as of Janaury 1. Inventory data shown under 1976 and 1986 are as of January 1 of following year.

Table 117.—Hardwood removals, harvest, net annual growth, and growing stock inventory on forest industry timberlands[1] in the contiguous states, specified years 1952–1986, with projections to 2040.

Item	1952	1962	1970	1976	1986	Projections 2000	2010	2020	2030	2040
					Million cubic feet					
Northeast										
Removals	47	51	91	121	110	116	136	157	174	188
Timber harvest	44	45	69	89	216	231	289	316	323	328
Net growth	129	156	193	226	230	211	207	207	206	206
Inventory	4,742	5,554	6,819	7,636	8,835	11,039	11,739	12,230	12,540	12,702
North Central[2]										
Removals	74	45	64	69	142	119	124	125	121	117
Timber harvest	73	41	57	55	201	200	223	207	187	169
Net growth	99	100	118	118	105	99	95	98	102	96
Inventory	2,048	2,673	3,129	3,376	3,430	2,909	2,596	2,291	2,075	1,843
Southeast										
Removals	169	158	161	147	185	241	279	288	289	289
Timber harvest	127	96	108	107	176	239	286	291	296	304
Net growth	171	174	230	259	271	193	175	179	190	194
Inventory	5,149	5,801	6,738	7,080	7,781	7,217	6,192	4,948	3,817	2,860
South Central										
Removals	211	375	202	213	322	379	401	391	385	380
Timber harvest	157	227	213	184	323	394	430	423	412	415
Net growth	203	285	379	453	348	317	261	306	333	343
Inventory	5,656	7,753	8,086	9,661	9,594	9,751	7,793	6,535	5,641	5,302
Pacific Southwest										
Removals	3	4	5	4	4	3	3	4	4	5
Timber harvest	2	3	3	3	24	28	27	26	24	26
Net growth	11	15	24	19	46	41	43	38	30	26
Inventory	336	449	717	679	1,374	1,427	1,585	1,709	1,777	1,777
Douglas-fir subregion										
Removals	18	24	44	44	44	144	142	79	78	74
Timber harvest	18	22	37	34	57	107	126	137	139	134
Net growth	75	98	124	145	154	135	127	121	116	112
Inventory	1,889	2,663	3,264	3,336	3,872	3,480	3,061	3,312	3,684	4,031
Ponderosa pine subregion										
Removals	0	0	0	0	0	0	0	0	0	0
Timber harvest	0	0	0	0	0	(3)	(3)	(3)	(3)	(3)
Net growth	0	0	0	0	0	0	0	0	0	0
Inventory	11	12	18	19	16	8	6	5	4	3
United States total										
Removals	522	657	567	597	807	1,002	1,085	1,044	1,051	1,053
Timber harvest	421	434	487	472	998	1,197	1,379	1,398	1,379	1,373
Net growth	688	828	1,068	1,220	1,154	996	908	949	977	977
Inventory	19,831	24,905	28,771	31,787	34,902	35,831	32,972	31,030	29,538	28,518

[1]*The forest industry timberlands in the Rocky Mountains are included with the farmer and other private timberlands for that region.*
[2]*Data for the Great Plains are included in the Rocky Mountains for the historical period and in the North Central subregion for the projection period.*
[3]*Less than .5 million cubic feet.*
Note: Supply data for 1952, 1962, 1970, 1976, and 1986 are estimates of the trend level of harvests and differ somewhat from the estimates of actual consumption shown in some tables. For the projection years, the data shows the volume that would be harvested given the assumptions of the study. Inventory data for 1952 and 1962 are as of December 31. Inventory data for 1970 and the projection years are as of Janaury 1. Inventory data shown under 1976 and 1986 are as of January 1 of following year.

Table 118.—Softwood removals, harvest, net annual growth, and growing stock inventory on farmer and other private timberlands in the contiguous states, specified years 1952–1986, with projections to 2040.

Item	1952	1962	1970	1976	1986	Projections 2000	2010	2020	2030	2040
					Million cubic feet					
Northeast										
Removals	358	274	263	300	226	210	321	418	487	523
Timber harvest	338	258	244	278	296	402	582	717	775	809
Net growth	433	538	510	623	441	468	464	462	456	453
Inventory	13,438	16,031	16,214	17,976	18,985	24,119	25,445	25,607	25,066	24,177
North Central[1]										
Removals	59	61	72	79	109	121	153	209	258	286
Timber harvest	62	63	70	74	99	194	271	348	391	405
Net growth	128	152	170	196	250	221	220	222	226	233
Inventory	2,610	3,382	4,010	4,899	6,246	8,251	8,893	8,978	8,616	8,054
Southeast										
Removals	1,444	1,234	1,235	1,365	1,821	1,835	1,831	1,866	1,966	2,027
Timber harvest	1,414	1,189	1,157	1,247	1,693	1,644	1,652	1,677	1,778	1,768
Net growth	1,349	1,567	1,882	2,130	1,904	1,626	1,765	1,740	1,745	1,769
Inventory	23,857	26,687	30,665	34,487	34,397	33,907	32,796	32,101	30,247	27,725
South Central										
Removals	606	787	1,117	1,278	1,569	2,003	1,606	1,712	2,068	2,164
Timber harvest	584	748	1,129	1,264	1,507	1,899	1,464	1,756	2,012	2,105
Net growth	792	1,182	1,668	2,000	1,762	1,646	2,013	2,103	2,023	2,062
Inventory	11,273	16,128	23,646	28,760	31,555	26,666	27,001	33,199	33,920	32,986
Rocky Mountains[2]										
Removals	226	241	280	287	299	397	472	491	468	441
Timber harvest	207	219	256	262	305	502	630	652	625	609
Net growth	293	341	388	388	440	387	343	336	344	366
Inventory	19,610	20,097	20,336	19,601	18,372	18,692	17,378	15,800	14,535	13,761
Pacific Southwest										
Removals	542	271	178	145	34	110	147	176	160	133
Timber harvest	468	230	163	136	120	115	209	245	199	167
Net growth	178	192	211	197	238	263	245	225	192	180
Inventory	15,256	12,900	9,608	9,337	9,931	12,526	12,912	12,747	12,388	12,138
Douglas-fir subregion										
Removals	302	201	259	200	203	292	327	344	332	333
Timber harvest	317	207	245	195	250	371	443	473	451	449
Net growth	265	308	358	340	409	393	373	363	358	361
Inventory	9,510	9,520	10,304	8,458	10,171	12,008	12,169	12,135	12,214	12,404
Ponderosa pine subregion										
Removals	103	68	49	65	70	52	112	156	180	179
Timber harvest	100	67	48	60	91	64	113	148	160	155
Net growth	109	136	148	121	122	160	158	162	150	148
Inventory	4,495	4,319	4,725	4,604	3,896	5,440	5,875	5,904	5,588	5,269
Alaska										
Removals			4	2	61	42	32	28	26	26
Timber harvest			5	2	65	44	34	30	28	28
Net growth		1	2	2	3	37	69	102	143	165
Inventory	218	284	323	666	8,018	9,125	9,676	10,643	11,922	13,319
United States total										
Removals	3,640	3,137	3,457	3,721	4,392	5,062	5,001	5,400	5,945	6,112
Timber harvest	3,490	2,981	3,317	3,518	4,426	5,235	5,398	6,046	6,419	6,495
Net growth	3,548	4,418	5,337	5,998	5,603	5,233	5,683	5,756	5,659	5,739
Inventory	100,267	109,348	119,831	128,788	141,571	150,734	152,145	157,114	154,496	149,833

[1]*Data for the Great Plains are included in the Rocky Mountains for the historical period and in the North Central subregion for the projection period.*
[2]*The forest industry timberlands in the Rocky Mountains are included with the farmer and other private timberlands for that region.*
Note:Supply data for 1952, 1962, 1970, 1976, and 1986 are estimates of the trend level of harvests and differ somewhat from the estimates of actual consumption shown in some tables. For the projection years, the data shows the volume that would be harvested given the assumptions of the study. Inventory data for 1952 and 1962 are as of December 31. Inventory data for 1970 and the projection years are as of Janaury 1. Inventory data shown under 1976 and 1986 are as of January 1 of following year.

Table 119.—Hardwood removals, harvest, net annual growth, and growing stock inventory on farmer and other private timberlands in the contiguous states, specified years 1952–1986, with projections to 2040.

Item	1952	1962	1970	1976	1986	Projections 2000	2010	2020	2030	2040
					Million cubic feet					
Northeast										
Removals	424	503	591	623	630	737	877	1,024	1,125	1,211
Timber harvest	404	438	448	462	1,241	1,484	1,881	2,040	2,074	2,096
Net growth	1,018	1,296	1,465	1,491	1,620	1,481	1,466	1,438	1,389	1,355
Inventory	32,669	39,863	44,751	49,457	54,938	70,842	76,287	79,066	80,587	81,133
North Central[1]										
Removals	629	661	797	793	932	1,032	1,222	1,401	1,502	1,572
Timber harvest	751	685	738	737	1,326	1,852	2,366	2,464	2,404	2,384
Net growth	961	980	1,084	1,137	1,377	1,428	1,424	1,426	1,443	1,476
Inventory	24,385	29,009	31,821	35,636	42,884	52,871	54,067	53,558	52,378	50,951
Southeast										
Removals	817	861	843	801	1,096	1,525	1,879	2,031	2,089	2,079
Timber harvest	617	523	566	586	1,043	1,508	1,935	2,075	2,166	2,181
Net growth	1,020	1,175	1,439	1,715	1,701	1,368	1,339	1,345	1,388	1,330
Inventory	29,227	32,794	36,543	41,962	48,153	45,497	41,833	35,254	27,955	20,527
South Central										
Removals	1,396	1,313	1,012	948	1,208	1,495	1,847	1,990	2,075	2,108
Timber harvest	937	730	848	713	1,212	1,579	2,031	2,169	2,260	2,322
Net growth	1,424	1,459	1,845	2,117	1,800	1,495	1,448	1,610	1,813	1,969
Inventory	37,669	39,691	42,243	45,836	53,471	57,444	54,182	49,311	45,553	43,631
Rocky Mountains[2]										
Removals	30	24	21	20	18	10	14	14	12	5
Timber harvest	1	1	2	2	44	32	47	47	41	36
Net growth	48	54	59	62	85	45	50	42	34	35
Inventory	2,354	2,514	2,701	2,784	3,495	2,772	3,129	3,396	3,611	3,905
Pacific Southwest										
Removals	4	7	10	8	1	12	18	21	20	17
Timber harvest	2	4	7	7	8	10	10	11	12	13
Net growth	29	30	40	36	95	92	80	73	77	65
Inventory	998	1,050	1,562	1,598	3,352	4,124	4,457	4,663	4,891	5,003
Douglas-fir subregion										
Removals	8	29	22	47	7	104	132	153	141	118
Timber harvest	6	24	16	37	9	186	253	250	226	206
Net growth	98	130	154	146	186	184	168	158	150	143
Inventory	3,135	3,902	4,634	3,728	5,099	6,015	6,157	6,050	6,004	6,190
Ponderosa pine subregion										
Removals	0	0	0	0	0	1	1	2	1	1
Timber harvest	0	0	0	0	0	(3)	(3)	(3)	(3)	(3)
Net growth	1	1	2	2	3	0	2	1	3	1
Inventory	62	70	77	79	102	79	88	81	93	90
Alaska										
Removals						1	1	1	1	(3)
Timber harvest						1	2	1	1	(3)
Net growth					27	43	46	39	25	13
Inventory	39	83	102	121	1,397	1,906	2,408	2,890	3,221	3,423
United States total										
Removals	3,308	3,398	3,296	3,240	3,892	4,917	5,991	6,637	6,966	7,111
Timber harvest	2,718	2,405	2,625	2,544	4,883	6,650	8,523	9,055	9,182	9,235
Net growth	4,599	5,125	6,088	6,706	6,894	6,136	6,023	6,132	6,322	6,387
Inventory	130,538	148,976	164,434	181,201	212,891	241,550	242,608	234,269	224,293	214,853

[1]*Data for the Great Plains are included in the Rocky Mountains for the historical period and in the North Central subregion for the projection period.*
[2]*The forest industry timberlands in the Rocky Mountains are included with the farmer and other private timberlands for that region.*
[3]*Less than .5 million cubic feet.*
Note: Supply data for 1952, 1962, 1970, 1976, and 1986 are estimates of the trend level of harvests and differ somewhat from the estimates of actual consumption shown in some tables. For the projection years, the data shows the volume that would be harvested given the assumptions of the study. Inventory data for 1952 and 1962 are as of December 31. Inventory data for 1970 and the projection years are as of Janaury 1. Inventory data shown under 1976 and 1986 are as of January 1 of following year.

Table 120.—Softwood and hardwood timber harvest and growing stock inventory in the contiguous states, by region, specified years 1952–1986, with projections to 2040.

Item	1952	1962	1970	1976	1986	Projections 2000	2010	2020	2030	2040
					Million cubic feet					
North[1]										
Softwoods										
Timber harvest	596	501	549	636	888	1,125	1,411	1,638	1,740	1,791
Inventory	27,053	33,661	38,817	43,850	47,400	56,166	59,429	60,832	61,174	60,516
Hardwoods										
Timber harvest	1,381	1,329	1,465	1,502	3,190	4,041	5,058	5,351	5,337	5,310
Inventory	76,695	94,627	106,867	119,158	139,640	174,937	187,016	194,210	199,021	202,246
South										
Softwoods										
Timber harvest	3,036	2,707	3,527	4,251	5,370	5,996	6,325	6,971	7,544	7,973
Inventory	58,737	73,203	87,047	98,896	103,798	100,895	108,484	116,840	118,694	118,316
Hardwoods										
Timber harvest	1,933	1,662	1,840	1,707	2,930	3,931	4,913	5,215	5,412	5,513
Inventory	84,099	94,617	103,635	116,488	134,236	134,423	124,130	109,827	97,333	86,683
Rocky Mountains										
Softwoods										
Timber harvest	497	684	814	773	849	1,184	1,350	1,399	1,398	1,409
Inventory	87,546	93,223	94,560	95,111	100,298	102,353	102,033	101,745	102,049	103,045
Hardwoods										
Timber harvest	10	13	13	5	57	33	48	48	42	37
Inventory	5,074	5,596	6,035	6,138	7,681	3,928	4,425	4,812	5,117	5,511
Pacific Coast[2]										
Softwoods										
Timber harvest	3,393	3,430	3,805	3,849	4,329	4,029	4,424	4,581	4,697	4,731
Inventory	256,821	247,892	237,754	226,924	182,968	175,391	174,126	175,140	179,141	183,811
Hardwoods										
Timber harvest	37	62	87	102	145	352	443	451	427	402
Inventory	14,099	16,419	19,197	18,441	22,446	23,286	24,639	26,050	27,320	28,305
United States										
Softwoods										
Timber harvest	7,522	7,322	8,698	9,510	11,436	12,336	13,511	14,589	15,380	15,904
Inventory	430,157	447,979	458,178	464,781	434,464	434,805	444,072	454,557	461,058	465,688
Hardwoods										
Timber harvest	3,361	3,066	3,405	3,316	6,322	8,357	10,462	11,065	11,217	11,263
Inventory	179,967	211,259	235,734	260,225	304,003	336,574	340,210	334,899	328,792	322,744

[1]*Great Plains states included in North.*

[2]*Historical data may not match information in Chapter 3 due to changes in Alaska data.*

Note: Supply data for 1952, 1962, 1970, 1976, and 1986 are estimates of the trend level of harvests and differ somewhat from the estimates of actual consumption shown in some tables. For the projection years, the data shows the volume that would be harvested given the assumptions of the study. Inventory data for 1952 and 1962 are as of December 31. Inventory data for 1970 and the projection years are as of Janaury 1. Inventory data shown under 1976 and 1986 are as of January 1 of following year.

Table 121.—Softwood and hardwood timber harvest and growing stock inventory in the contiguous states, by ownership, specified years 1952–1986, with projections to 2040.

Item	1952	1962	1970	1976	1986	Projections 2000	2010	2020	2030	2040
					Million cubic feet					
National forest										
Softwoods										
Timber harvest	961	1,635	1,918	1,867	2,153	2,156	2,263	2,311	2,357	2,404
Inventory	204,354	213,605	211,818	207,977	169,173	161,441	158,921	158,004	159,355	161,477
Hardwoods										
Timber harvest	100	97	123	101	166	204	224	243	262	260
Inventory	13,253	16,851	18,784	21,044	24,712	19,982	19,983	19,858	19,962	19,686
Other public										
Softwoods										
Timber harvest	403	562	702	822	814	974	1,040	1,056	1,067	1,073
Inventory	55,198	55,733	57,419	59,051	56,722	58,875	62,193	65,596	69,621	74,249
Hardwoods										
Timber harvest	122	130	170	199	276	306	336	369	394	394
Inventory	16,345	20,527	23,745	26,193	31,498	39,211	44,647	49,742	54,999	59,687
Forest industry										
Softwoods										
Timber harvest	2,668	2,144	2,758	3,302	4,044	3,969	4,810	5,176	5,537	5,932
Inventory	70,338	69,293	69,110	68,965	66,998	63,756	70,813	73,844	77,587	80,129
Hardwoods										
Timber harvest	421	434	487	472	998	1,197	1,379	1,398	1,379	1,373
Inventory	19,831	24,905	28,771	31,787	34,902	35,831	32,972	31,030	29,538	28,518
Farm and other private										
Softwoods										
Timber harvest	3,490	2,981	3,317	3,518	4,426	5,235	5,398	6,046	6,419	6,495
Inventory	100,267	109,348	119,831	128,788	141,571	150,734	152,145	157,114	154,496	149,833
Hardwoods										
Timber harvest	2,718	2,405	2,625	2,544	4,883	6,650	8,523	9,055	9,182	9,235
Inventory	130,538	148,976	164,434	181,201	212,891	241,550	242,608	234,269	224,293	214,853
United States[1]										
Softwoods										
Timber harvest	7,522	7,322	8,698	9,510	11,436	12,336	13,511	14,589	15,380	15,904
Inventory	430,157	447,979	458,178	464,781	434,464	434,805	444,072	454,557	461,058	465,688
Hardwoods										
Timber harvest	3,361	3,066	3,405	3,316	6,322	8,357	10,462	11,065	11,217	11,263
Inventory	179,967	211,259	235,734	260,225	304,003	336,574	340,210	334,899	328,792	322,744

[1]*Historical data may not match information in Chapter 3 due to change in Alaska data.*

Note: Supply data for 1952, 1962, 1970, 1976, and 1986 are estimates of the trend level of harvests and differ somewhat from the estimates of actual consumption shown in some tables. For the projection years, the data shows the volume that would be harvested given the assumptions of the study. Inventory data for 1952 and 1962 are as of December 31. Inventory data for 1970 and the projection years are as of Janaury 1. Inventory data shown under 1976 and 1986 are as of January 1 of following year.

bution of forest land across age classes. Projections for forest industry timberlands show this happening after 2005 in the South and roughly 2010 in the Douglas-fir region.

There are (at least) three other ways to view the base projections. The first is in terms of employment associated with harvesting and processing timber. The Southern Timber Study (USDA FS 1988b), an analysis comparable to this study, found that employment in the forest sector is likely to decline as productivity per employee increases faster than production. This conclusion reflects a new awareness of employment implications of long-term projections, and an interest in the employment impacts associated with current forest policy issues such as log export restrictions and old-growth retention.

A second view of the base projections considers the broad environmental effects of projected developments in the U.S. forest sector. Chief among these broad-based concerns is substitution between materials derived from renewable resources (such as timber) and materials derived from nonrenewable resources (such as minerals). At issue here are the environmental effects of increased production, consumption, and disposal of nonrenewable materials.

Finally, the base projections must be examined in terms of the likely impact on wildlife, fish, forage, and water resources. These concerns are addressed in detail in other resource Assessments. In this chapter, for nontimber resources, we will review only the broad implications of projected changes in timber harvests and timber inventories.

Employment

Projected employment in U.S. forest products industries is shown in table 122. There are significant differences in trends in employment within the projection period, across industries, and across regions. For example, between 1985 and 2000, employment in the softwood lumber industry declines in the Pacific Northwest-West and the Pacific Southwest, but increases elsewhere. In the softwood plywood industry, employment declines in all regions between 1985 and 2000. By 2040, employment in both industries is down significantly in all regions (Lange et al., in press). Total employment in the lumber and wood products industries (all regions) decreases 5% between 1986 and 2000, and 13% between 1986 and 2040.

Two factors contribute to these declines in employment. First, reduction in timber harvest and timber processing (in the Pacific Northwest-West and Pacific Southwest lumber and wood products industries, for example) result in direct reductions in employment. The second factor is the employment impact of technological change. Even in those regions where the long-term trend is nondeclining levels of harvest and processing, employment may decrease as a result of labor-saving technological change in processing industries. Competitive firms in the forest products industry have generally been those that utilize technology in place of labor and raw material as modernization takes place. The historical trend—that we expect will continue—is increased productivity of labor in new mills that more than offsets increases in employment that might have resulted from higher levels of production. Expected increases in labor productivity are clear when total employment (table 122) is compared to production (tables 97, 100, and 102).

The character of technological change is a consequence of a long-term trend of increasing wage rates (relative to other costs of production), and the fact that labor costs comprise a major component of total production costs. Changes in the cost and physical characteristics of raw material (in particular, decreasing average size of logs) are also factors that motivate the development and implementation of new, more mechanized production processes. In addition to providing some control over increasing costs, technological improvements also facilitate changes in product mix (Keegan and Polzin 1987).

Table 123 shows trends in wages and salaries (in constant dollars). As a result of trends in wage rates, these trends are less pronounced and, in some cases, are counter to the trends in employment. Here, too, there are considerable differences between regions, and between industry groups within the broad categories shown in table 123. For example, workers in the softwood plywood industries earn roughly 40% more than those in the lumber industry. Between 2000 and 2040, wages and salaries are lower in the softwood lumber industry and constant to substantially higher in the softwood plywood industry.

Projected increases in forest products prices can be expected to increase the use of substitute materials in the housing, nonresidential construction, manufacturing and shipping sectors. Through these changes, declines in production and employment in the forest products industry would induce increased activity in the industries producing substitute materials. Higher production levels in these industries would increase employment, mitigating at least some of the jobs lost in the forest products industry. However, jobs created through expansion in these industries will be in different regions of the country and will require different skills. In addition, increased demand for nonwood products will lead, in turn, to higher prices and possible environmental problems associated with these industries.

Environmental Effects

The broad-based environmental impacts of these forest products industry projections cannot be viewed in isolation because forest products compete with a variety of materials in most end-use markets. An assessment of the environmental impact of changes in forest products production and consumption must take into consideration the wide range of materials that can be substituted for forest products, and the fact that each of the industries producing substitute materials has its own set of environmental impacts.

Table 122.—Employment in the softwood lumber and plywood industries, by section and region, 1986, with projections to 2040.

Section and region	1986	Projections				
		2000	2010	2020	2030	2040
		Thousand employees				
Softwood lumber industry						
South	36.0	39.9	43.3	44.8	41.3	37.0
Rocky Mountain	13.2	15.0	13.6	14.3	12.6	11.1
Pacific Coast						
Pacific Northwest						
Pacific Northwest-West	20.8	20.3	18.9	18.2	16.1	13.6
Pacific Northwest-East	9.2	9.8	10.6	10.9	10.6	9.8
Pacific Southwest[1]	12.0	10.9	10.3	8.5	7.3	5.8
Softwood plywood industry						
South	17.3	13.5	15.5	17.0	18.4	19.9
Rocky Mountain	1.7	1.3	1.4	1.6	1.7	1.8
Pacific Coast						
Pacific Northwest						
Pacific Northwest-West	16.6	10.4	9.2	9.6	10.0	10.4
Pacific Northwest-East	1.2	0.9	1.0	1.2	1.3	1.5

[1]*Excludes Hawaii.*

Table 123.—Wages and salaries in the softwood lumber and plywood industries, by section and region, 1986, with projections to 2040.

Section and region	1986	Projections				
		2000	2010	2020	2030	2040
		Millions of 1982 dollars				
Softwood lumber industry						
South	411	455	494	511	471	422
Rocky Mountain	223	253	230	241	213	187
Pacific Coast						
Pacific Northwest						
Pacific Northwest-West	410	401	373	359	318	269
Pacific Northwest-East	180	193	208	216	210	193
Pacific Southwest[1]	232	210	199	164	141	113
Softwood plywood industry						
South	486	380	436	477	518	559
Rocky Mountain	48	36	40	43	47	51
Pacific Coast						
Pacific Northwest						
Pacific Northwest-West	467	294	259	270	282	293
Pacific Northwest-East	35	26	29	33	38	42

[1]*Excludes Hawaii.*

Rising prices for forest products are likely to induce greater consumption and production of other industrial commodities. In construction, for example, steel, aluminum, plastic, and concrete can be used in place of wood products in structural and nonstructural applications. In manufacturing, plastics and metal products have proven to be viable substitutes for wood used in furniture, and in a variety of other uses. In shipping, increased use of containers in cargo handling has resulted in greater use of steel in place of wood; a variety of plastics have also been substituted for wood and paper products used in packaging and materials handling. Based on analysis of historical data we expect similar substitution to take place in the future (Alexander and Greber 1988).

Industrial materials generate environmental problems at each of four stages in the material's life cycle: (a) raw material extraction, (b) manufacturing, (c) material use, and (d) disposal. At each stage, the environmental impacts can be categorized as soil, air, water, and health and miscellaneous problems. Soil problems include general soil scarification and disturbance, disposal of displaced soils, and landfill problems associated with disposal of waste material. Air quality problems include

production of particulates, production of pollutant gasses (such as sulphur dioxide and sulfides), and the production of so-called "greenhouse gasses" (such as carbon dioxide). Water quality problems include acid runoff from exposing low pH materials (during mining operations), pollution resulting from disposal of materials used in manufacturing, pollution resulting from biological and chemical processes that deplete aquatic oxygen, and problems with suspended solids (including sedimentation).

Some general health and ecological concerns that have been associated with the production and use of various industrial materials include production (as byproducts) of heavy metals (such as chromium), and production or use of toxic chemicals such as cyanide, radon, dioxins, formaldehyde, and poly-chlorinated bi-phenols (PCBs). All of these contaminants may be harmful to production workers, to users of the materials, or to the broader environment. Assessments of the likely damage, and the acceptability of risks associated with these materials and, even more broadly, with particular industries, often depend on perceptions of opportunities to gain, or likelihood of loss (of employment, income, or health). Uncertain, diffuse risks are frequently outweighed in the social balance by certain, concentrated gains.

Finally, the durability of disposed materials presents a variety of environmental problems. All industrial materials present disposal problems, even taking into account differentiation between industrial and municipal (household) wastes. Industrial wastes from steel, pulp and paper, and plastic manufacture include waste waters, that often contain toxic contaminants, and solid waste whose chief problem is its quantity. Wastes from aluminum manufacture present landfill space problems, as do industrial wastes from panel product manufacture. Municipal waste contains a large proportion of metal, plastic, and aluminum products. These materials can be recycled (reducing disposal impacts, and decreasing requirements for virgin raw material); unfortunately, recycling is not widespread and the material endures when buried. Wood products (other than panel products), and concrete products pose the fewest long-term disposal problems for both industries and municipalities because they will break down over time.

The environmental impacts of the forest products industries, or those industries producing substitute materials, are not easily summarized and cannot be easily translated into comparable terms. In general, forest products, steel, plastics, aluminum, and cement all give rise to substantial environmental impacts through harvesting or raw material extraction. Raw material production for steel, cement, and aluminum manufacturing generally results in impacts on soil that are relatively greater—or at least more concentrated—than is the case with timber production. Steel manufacturing has a significant (negative) impact on local and regional air quality, and the cement and plastics industries have significant impacts on water quality. On the other hand, timber production and forest products industries have been associated with extensive changes in forest-based wildlife habitat, damage to productivity of anadromous fisheries, and reductions in local air quality.

Clearly, the magnitude, type, and duration of environmental impacts differ across these industries. In addition, the location of production (of both raw materials and processed products) differs widely for forest products and industries producing substitute materials. As a result, the concentration of environmental impacts will shift as materials use patterns change. In many cases, shifts in the use of industrial materials will have environmental impacts that are multinational in scope. The lack of empirical methods and the absence of a national environmental policy, or a national materials policy make it impossible to provide unambiguous measures of the environmental consequences of projected developments in the forest products sector.

Effects on Wildlife and Fish, Forage and Water

The projected changes in timber production will lead to structural changes in the Nation's forest resources. These changes will affect wildlife and fish habitat, forage availability, and watershed outputs. Changes in harvest levels, changes in the type and intensity of forest management, and changes in the pattern of land uses are important determinants of the short- and long-term impacts on nontimber forest resources.

Over the next five decades the United States will continue to reduce its dependence on timber produced from the old-growth, softwood forests of the Pacific Northwest. Timber production will increase from the private forests in the North and South. The pressures placed on forest owners in the West (both public and private) to maintain, or increase the nontimber benefits of forests will be felt increasingly by owners and managers in the North and South.

Because total (national) timber production is projected to increase, and because forests in the North and South are, on average, less densely stocked than those in the West, the total area harvested will increase by more than 25%. Between 2030 and 2040, an average of 5.4 million acres will be harvested each year in U.S. private forests. In 1986, approximately 4.3 million acres were harvested from these forests. A 16% decline in harvested area in the West will be more than offset by a 30% increase in the North, and a 33% increase in the South. The biggest relative change is a doubling of the area of softwood stands harvested in the North.

Projections of timber harvests, timber growth, and timber inventories incorporate assumptions regarding changes in forest management. Most of these changes (and the most significant changes) take place in the industrial forests in the Northwest and in the South. It is difficult to quantify the likely impact on nontimber resources of the broad array of management activities that will be undertaken. These management activities include controlling the species composition of forest stands, the use of genetically "improved" seed stock, efforts to manage stand density, and shortening the aver-

age age of harvested stands. Some of the most noticeable changes bear mentioning.

In the South, for example, the rate of harvest and likely management strategies will combine to nearly eliminate natural pine stands on industrial lands by the year 2040. In their place will be a considerable area of pine plantations, many of which will reflect "managed" genetic characteristics. These plantation forests will have a more balanced age-class structure than existing forests in the region, and few stands will be allowed to reach the age of the stands of natural origin that they replace. A similar—and even more dramatic—replacement of older stands with younger, more actively managed stands will take place in the West. Forest type transitions will not be as significant in the West (or in the North), but managed forests on private lands in the West in the future will also provide a different blend of nontimber benefits.

The area of timberland in the United States is projected to decline by 21 million acres by the year 2040 (table 70). This is slightly more than half of the timberland area reduction that occurred between 1962 and 1987 (37.3 million acres), and roughly 4% of the current timberland area. The largest portion of this reduction is expected to occur by the year 2000.

The impacts of these changes in timberland on nontimber resources will vary across regions, and depend largely on the causes of the changes within each region. In the South, for example, where most timberland is privately owned, and the majority of timberland is nonindustrial, most timberland conversion is to agricultural and urban uses. This implies a significant change in, if not elimination, of the forest cover and associated resources. Roughly 40% of the total (national) timberland reduction occurs in the South. In the Pacific Coast region (including Alaska), where one-fourth of the reduction occurs, some of the reduction is the result of conversion to urban and other uses; however, much of the land that is no longer classified as timberland will remain forested. The impact on nontimber resources will be considerably less in this case.

Projected changes in timber harvests, forest management practices, and timberland area will have both direct and indirect impacts on nontimber resources that can be either detrimental or beneficial. Direct, negative impacts include those associated with the conversion of timberland to nontimber uses. The replacement of existing forests with forests composed of younger stands, or different species will have direct, but mixed impacts that will depend on the resource being considered. The quantity and type of wildlife supported, forage production, and watershed production will adjust to the new forest environment.

CHAPTER 8. ALTERNATIVE FUTURES

Chapter 7 was concerned with one view of the future based on the complex set of assumptions about determinants of timber demands and supplies described in Chapter 6. These projections of long-run demands and supplies are strongly influenced by short-run conditions at the time they are made,[33] but views of the future may differ from those assumed in the basic assumptions. In addition, the U.S. forest sector appears to be verging on several major shifts (changes in public harvests, assumptions about recycling, etc.) from past conditions of supply and demand for both products and stumpage. Acting in concert, such changes could lead to future trends that differ significantly from traditional expectations. This chapter examines some of these potential shifts and their impacts on the forest sector.

These futures differ from the base projection with respect to key assumptions about timber supply and demand. Eight alternative futures will be examined. Most were derived from reviews of, and public comments on, past Assessments. The following descriptions highlight key points in each.

1. **Increased productivity.**—An alternative view of the future where the rates of softwood lumber and plywood product yield improvement for western regions rise faster than those assumed in the base Assessment projection.
2. **Higher exports of timber products.**—An alternative view of the future where projected exports of pulpwood (including pulpwood and the pulpwood equivalent of pulp, paper, and board) lumber, and plywood double by 2040.
3. **Lower rates of timber growth.**—An alternative view of the future where the net annual growth for softwoods and hardwoods in the East is reduced. This future is intended to reflect the potential impacts of air pollutants on major U.S. forest ecosystems.
4. **Greater forest management.**—An alternative view of the future where all intensive management opportunities on timberland in private ownerships (that yield a 10% rate of return or more, net of inflation or deflation) would be implemented. Details on the various opportunities are described in Chapter 9.
5. **Reforestation of surplus crop and pastureland.**—An alternative view of the future where all surplus crop and pastureland (some 32.5 million acres) projected in the review draft of the Second RCA Appraisal (SCS 1988) is assumed to revert to natural cover with a 10-year time lag.
6. **Reduced timber harvests on national forests.**—Two alternative views of timber harvests levels on the national forests. First, timber harvests on national forests are assumed to drop from 2.3 to 2.1 billion cubic feet per year by 2000 and remain at that level to 2040. Second, timber harvests on national forests in the Douglas-fir subregion are reduced by 25% to represent protection for old-growth and old-growth dependent species such as the northern spotted owl.
7. **Increased use of recycled fiber.**—An alternative view of the future where the use of recycled fiber in paper and board production rises to 39% of total fiber furnished by 2040.
8. **Higher housing starts.**—An alternative view of the future where replacement rates for single-family homes in the housing stock increase by 2040 to maintain the average age of the housing stock at roughly its current level.

[33] *The base projections were made in the spring of 1989. Most data series had been revised through 1987 and some were revised for 1988.*

SELECTED FUTURES

This section examines the important differences in product and stumpage markets of each of these selected futures from those shown in the base projections. In their own way, each of these futures is a potential alternative to the base Assessment projection. The objective here is to demonstrate both the sensitivity of the base projections to changes in input assumptions and to provide a basis for assessing the robustness[34] of policy conclusions drawn from the base Assessment projections.

Increased Productivity

In the base Assessment projection, softwood lumber recovery was projected to increase in all sections and regions (see Chapter 6 for details). The rates of increase were greatest in the South and in the Ponderosa Pine subregion where decreases in log diameters were the smallest. The rates of increase were the least in the Douglas-fir subregion where expected decreases in log diameters offset improvements resulting from the adoption of new technology.

In this future, the rate of change for western regions is assumed to be roughly the same as the rate used in the base Assessment projection for the southern subregions. The rationale is that producers in the western sections and regions, facing more rapid increases (than southern producers) in stumpage prices during the next two decades, will adopt technology that will overcome shrinking log sizes. For example, the average lumber recovery factor for the Pacific Coast states is assumed to rise from 7.2 to 8.7 (rather than 8.4) board feet (lumber scale) per cubic foot (log input) by 2040. Changes in rates of recovery improvement were made also for the Canadian regions.

In this future there is very little change from the base projections in softwood harvest levels (timber supplies) and timber inventories on private timberlands (table 124). Although harvests are little changed, production

[34] *Robustness is used in the context of flexibility. A robust policy conclusion is one that leads the forest sector into more acceptable final states.*

Table 124.—Simulated effects of selected futures on projected consumption, production, prices, and harvest, by region, selected years 1986–2040.

	Base	Increased solidwood recovery	Higher exports	Reduced growth	Increased forest management	Surplus cropland	Reduced USFS harvest	Spotted owl protection	Increase recycle fiber	Higher housing starts
	Softwood lumber consumption			Million board feet						
1986	46,283	46,283	46,283	46,283	46,283	46,283	46,283	46,283	46,283	46,283
2000	47,610	47,853	47,653	47,281	47,645	47,667	47,317	47,118	47,652	47,608
2010	49,564	50,036	49,588	49,212	49,745	49,582	49,211	49,435	49,950	49,579
2020	53,783	54,176	53,638	52,905	54,066	53,842	53,241	53,475	54,473	54,646
2030	55,008	55,447	54,693	53,921	55,501	55,192	54,446	54,678	56,140	56,758
2040	56,094	56,522	55,510	54,806	56,678	56,281	55,563	55,908	57,622	58,743
	Softwood lumber production									
1986	33,889	33,889	33,889	33,889	33,889	33,889	33,889	33,889	33,889	33,889
2000	39,118	39,285	39,119	38,277	39,128	39,138	38,392	38,379	39,136	39,134
2010	40,049	41,497	40,459	37,822	40,656	40,563	38,237	38,818	41,465	40,120
2020	43,612	45,387	44,053	38,890	44,991	44,473	41,339	42,528	46,480	43,686
2030	46,805	48,608	47,037	41,862	48,594	47,590	44,604	45,912	52,888	47,420
2040	49,173	51,003	49,375	44,095	51,553	50,175	46,804	48,086	56,186	50,033
	Softwood lumber imports									
1986	14,363	14,363	14,363	14,363	14,363	14,363	14,363	14,363	14,363	14,363
2000	10,962	11,038	11,004	11,474	10,987	10,999	11,396	11,210	10,987	10,944
2010	12,021	11,046	11,684	13,896	11,595	11,524	13,479	13,123	10,992	11,964
2020	12,764	11,383	12,985	16,609	11,668	11,963	14,496	13,541	10,586	13,553
2030	10,804	9,439	11,956	14,659	9,507	10,203	12,442	11,366	6,194	11,938
2040	9,521	8,119	11,245	13,311	7,726	8,706	11,359	10,421	4,036	11,311
	Softwood plywood consumption			Million square feet						
1986	19,766	19,766	19,766	19,766	19,766	19,766	19,766	19,766	19,766	19,766
2000	17,752	17,890	17,820	17,561	17,764	17,775	17,635	17,560	17,653	17,755
2010	17,977	18,184	17,997	17,627	18,026	17,986	17,704	17,817	18,282	17,936
2020	19,812	19,940	19,743	19,215	19,888	19,891	19,576	19,622	20,168	20,088
2030	21,117	21,344	20,975	20,783	21,358	21,304	20,927	21,070	21,606	21,550
2040	22,612	22,757	22,244	21,981	22,938	22,741	22,289	22,510	22,952	23,150
	All softwood lumber price index			(1982 = 100)						
1986	111.6	111.6	111.6	111.6	111.6	111.6	111.6	111.6	111.6	111.6
2000	146.3	143.5	146.2	152.1	146.1	145.7	150.7	152.1	145.7	146.6
2010	155.0	150.9	156.6	161.4	153.4	154.4	161.4	154.8	148.9	155.5
2020	162.7	158.8	165.9	175.7	159.5	160.9	168.6	165.4	153.2	164.9
2030	159.8	156.0	165.0	174.1	154.9	157.9	166.6	163.7	140.7	165.1
2040	157.7	154.5	164.8	176.7	150.8	155.5	167.2	159.4	140.4	166.7
	All softwood plywood price index									
1986	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6	109.6
2000	128.1	125.4	127.0	134.7	128.3	128.0	132.4	133.9	127.2	128.6
2010	139.8	135.2	140.1	151.6	138.0	140.4	149.3	143.6	128.3	141.8
2020	142.2	141.0	145.7	161.4	140.7	139.5	151.1	147.9	130.6	141.9
2030	144.5	138.7	148.3	153.1	134.1	136.0	148.2	142.4	126.4	147.3
2040	142.2	143.3	156.9	163.1	131.4	139.6	152.5	145.4	129.3	155.8
	All hardwood lumber price index									
1986	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.3	120.3
2000	132.6	143.1	132.7	134.5	133.1	132.0	132.6	132.6	132.7	143.1
2010	146.3	146.2	146.5	149.1	147.2	144.0	146.4	146.3	146.2	146.3
2020	163.0	162.9	163.6	166.8	164.4	157.1	163.2	163.0	162.3	163.0
2030	181.7	181.7	182.9	186.5	179.7	146.2	182.0	181.7	180.1	181.7
2040	198.5	198.5	200.0	203.4	200.4	150.0	198.9	198.5	196.0	198.7
	United States softwood demand			Billion cubic feet						
1986	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
2000	12.1	12.1	12.1	12.1	12.1	12.2	12.0	12.1	11.8	12.1
2010	13.4	12.4	13.3	13.2	13.4	13.4	13.2	13.2	13.0	13.3
2020	14.5	14.6	14.5	14.1	14.6	14.5	14.3	14.4	14.1	14.5
2030	15.3	15.3	15.4	14.8	15.4	15.4	15.0	15.2	14.8	15.4
2040	15.8	15.9	15.9	15.3	14.8	15.9	15.5	15.7	15.3	15.9

Table 124.—Continued

	Base	Increased solidwood recovery	Higher exports	Reduced growth	Increased forest management	Surplus cropland	Reduced USFS harvest	Spotted owl protection	Increase recycle fiber	Higher housing starts
	United States hardwood demand									
1986	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
2000	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
2010	10.5	10.4	10.6	10.5	10.5	10.5	10.5	10.5	10.3	10.5
2020	11.1	11.1	11.3	11.1	11.1	11.1	11.1	11.1	10.8	11.1
2030	11.3	11.3	11.6	11.3	11.3	11.3	11.3	11.3	10.9	11.3
2040	11.3	11.3	11.7	11.3	11.3	11.4	11.3	11.4	10.9	11.4
	North stumpage prices			(1982 $/MBF)						
1986	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7	34.7
2000	42.9	42.9	43.1	46.0	42.2	43.2	43.7	42.9	42.4	42.9
2010	55.2	55.1	56.7	64.7	53.5	55.7	56.6	55.1	51.3	55.2
2020	73.6	73.4	76.3	87.7	69.9	72.4	75.6	73.5	65.2	73.6
2030	84.2	84.0	88.0	103.2	78.1	81.0	87.1	84.1	70.3	84.3
2040	91.5	91.3	96.1	114.2	83.3	85.6	95.3	91.4	75.8	91.8
	South stumpage prices									
1986	123.6	123.6	123.6	123.6	123.6	123.6	123.6	123.6	123.6	123.6
2000	169.4	155.3	166.7	204.5	167.1	165.0	188.3	191.1	152.5	169.5
2010	218.4	205.4	237.5	325.4	206.5	210.6	253.8	236.6	171.5	221.1
2020	243.1	231.0	264.0	334.9	233.3	232.1	276.8	261.3	200.3	247.2
2030	222.3	208.9	265.8	299.5	177.3	188.4	258.1	229.5	138.8	251.6
2040	232.4	223.1	295.1	335.0	176.8	194.5	260.7	230.5	175.5	275.1
	Rockies stumpage prices									
1986	43.3	43.3	43.3	43.3	43.3	43.3	43.3	43.3	43.3	43.3
2000	89.9	67.4	89.5	101.9	88.5	88.1	99.3	91.2	88.1	89.9
2010	145.1	140.5	145.0	171.8	139.3	144.1	174.8	149.1	122.6	148.4
2020	184.3	179.2	197.6	222.2	177.7	181.6	213.3	200.5	144.3	187.5
2030	189.0	181.7	202.9	234.1	168.6	174.8	218.7	197.3	119.6	207.9
2040	184.4	174.7	219.7	236.0	153.7	169.2	211.9	193.2	88.9	233.2
	Pacific Coast stumpage prices									
1986	113.5	113.5	113.5	113.5	113.5	113.5	113.5	113.5	113.5	113.5
2000	160.2	134.7	145.5	176.5	157.0	155.2	198.6	185.3	153.5	160.1
2010	211.8	181.5	187.2	238.4	206.3	207.2	253.7	219.6	192.4	211.3
2020	240.0	222.4	228.8	298.0	222.4	232.5	277.2	249.8	199.4	246.8
2030	248.5	226.4	243.3	306.5	224.7	235.0	283.5	259.8	187.8	263.8
2040	244.9	216.3	246.7	299.0	209.8	229.5	282.6	251.2	178.8	279.7
	Hardwood sawtimber stumpage prices									
1986	179.4	179.4	179.4	179.4	179.4	179.4	179.4	179.4	179.4	179.4
2000	203.6	203.6	203.7	207.4	204.6	202.3	203.7	203.6	203.8	203.6
2010	245.6	245.6	246.1	251.6	247.6	240.7	245.8	245.6	245.5	245.6
2020	292.6	292.5	293.9	301.0	295.7	283.8	293.0	292.5	291.2	292.6
2030	344.6	344.5	347.5	355.9	349.2	331.5	345.3	344.6	340.6	344.7
2040	391.9	391.7	395.7	404.5	396.9	374.7	392.8	391.9	385.2	392.2
	Softwood North harvest			Million cubic feet						
1986	879	879	879	879	879	879	879	879	879	879
2000	1,142	1,142	1,149	1,142	1,142	1,142	1,142	1,142	1,124	1,142
2010	1,421	1,419	1,435	1,327	1,420	1,421	1,418	1,419	1,398	1,421
2020	1,641	1,639	1,666	1,641	1,641	1,641	1,641	1,640	1,603	1,644
2030	1,750	1,750	1,785	1,733	1,750	1,750	1,750	1,751	1,704	1,755
2040	1,803	1,802	1,849	1,805	1,799	1,801	1,803	1,801	1,755	1,811
	Softwood South harvest									
1986	5,237	5,237	5,237	5,237	5,237	5,237	5,237	5,237	5,237	5,237
2000	6,163	6,134	6,208	6,051	6,166	6,159	6,157	6,185	5,905	6,164
2010	6,327	6,337	6,428	6,090	6,378	6,350	6,289	6,329	6,267	6,324
2020	7,017	6,999	7,132	6,513	7,136	7,083	6,959	6,993	6,804	7,032
2030	7,610	7,618	7,777	7,179	7,762	7,675	7,567	7,619	7,728	7,653
2040	7,997	7,997	8,182	7,563	8,216	8,083	7,933	7,999	7,872	8,041

Table 124.—Continued

	Base	Increased solidwood recovery	Higher exports	Reduced growth	Increased forest management	Surplus cropland	Reduced USFS harvest	Spotted owl protection	Increase recycle fiber	Higher housing starts
	Softwood Rockies harvest									
1986	877	877	877	877	877	877	877	877	877	877
2000	1,083	1,066	1,083	1,091	1,081	1,081	1,089	1,092	1,054	1,083
2010	1,237	1,238	1,238	1,252	1,233	1,237	1,255	1,237	1,218	1,240
2020	1,306	1,306	1,317	1,322	1,303	1,306	1,317	1,312	1,281	1,307
2030	1,310	1,308	1,316	1,321	1,299	1,303	1,316	1,308	1,269	1,317
2040	1,318	1,315	1,336	1,327	1,304	1,314	1,319	1,317	1,272	1,340
	Softwood Pacific Coast harvest									
1986	4,086	4,086	4,086	4,086	4,086	4,086	4,086	4,086	4,086	4,086
2000	4,023	4,052	3,949	4,039	4,023	4,032	3,940	3,953	3,979	4,024
2010	4,369	4,439	4,269	4,385	4,381	4,391	4,222	4,283	4,203	4,370
2020	4,490	4,615	4,440	4,584	4,496	4,507	4,342	4,438	4,356	4,495
2030	4,569	4,659	4,510	4,650	4,582	4,578	4,420	4,349	4,290	4,597
2040	4,607	4,686	4,545	4,587	4,590	4,610	4,465	4,536	4,398	4,657
	Hardwood North harvest									
1986	3,355	3,355	3,355	3,355	3,355	3,355	3,355	3,355	3,355	3,355
2000	4,093	4,091	4,109	4,095	4,093	4,095	4,091	4,092	4,098	4,093
2010	5,043	5,038	5,081	5,039	5,044	5,055	5,035	5,038	4,997	5,043
2020	5,362	5,358	5,428	5,367	5,367	5,387	5,362	5,361	5,288	5,370
2030	5,367	5,367	5,466	5,377	5,379	5,402	5,367	5,371	5,268	5,379
2040	5,368	5,368	5,483	5,377	5,370	5,405	5,369	5,366	5,240	5,388
	Hardwood South harvest									
1986	2,694	2,694	2,694	2,694	2,694	2,694	2,694	2,694	2,694	2,694
2000	3,953	3,954	3,988	3,952	3,952	3,953	3,954	3,954	3,979	3,953
2010	4,904	4,903	4,988	4,905	4,899	4,902	4,905	4,906	4,782	4,903
2020	5,230	5,230	5,353	5,230	5,219	5,225	5,227	5,216	5,011	5,233
2030	5,429	5,428	5,594	5,416	5,410	5,421	5,426	5,428	5,148	5,435
2040	5,529	5,527	5,727	5,510	5,514	5,527	5,525	5,532	5,231	5,543
	Hardwood Rockies harvest									
1986	32	32	32	32	32	32	32	32	32	32
2000	52	52	52	52	52	52	52	52	52	52
2010	66	66	66	66	66	66	66	66	66	66
2020	67	67	67	67	67	67	67	67	67	67
2030	61	61	61	61	61	61	61	61	61	61
2040	58	58	58	58	58	58	58	58	58	58
	Hardwood Pacific Coast harvest									
1986	279	279	279	279	279	279	279	279	279	279
2000	331	331	331	331	331	331	331	328	327	331
2010	415	415	416	415	415	415	415	390	392	415
2020	426	426	430	426	426	426	426	426	393	426
2030	409	410	416	409	409	409	410	420	376	409
2040	389	389	397	389	389	389	389	389	353	389
	Softwood North Inventory									
1986	38,175	38,175	38,175	38,175	38,175	38,175	38,175	38,175	38,175	38,175
2000	42,301	42,301	42,278	40,603	43,152	42,263	42,275	42,300	42,316	42,301
2010	44,190	44,199	44,094	41,648	45,943	44,872	44,078	44,197	44,345	44,190
2020	44,366	44,387	44,124	41,009	47,001	45,960	44,153	44,383	44,769	44,362
2030	44,393	43,424	42,935	39,274	46,985	45,890	43,069	43,406	44,092	43,370
2040	42,029	42,060	41,308	37,243	46,480	45,352	41,583	42,040	43,070	41,969
	Softwood South Inventory									
1986	91,417	91,417	91,417	91,417	91,417	91,417	91,417	91,417	91,417	91,417
2000	86,894	86,986	86,623	79,703	87,326	87,476	86,673	86,620	87,341	86,897
2010	92,718	92,903	92,005	82,571	94,590	94,585	92,264	92,496	94,680	92,713
2020	100,160	100,182	98,880	88,408	103,287	102,040	99,837	100,065	102,811	100,141
2030	101,107	101,280	98,462	88,436	106,268	102,823	100,589	101,095	106,494	100,703
2040	98,967	98,997	95,125	84,595	106,312	100,290	98,183	98,802	104,441	97,974

Table 124.—Continued

	Base	Increased solidwood recovery	Higher exports	Reduced growth	Increased forest management	Surplus cropland	Reduced USFS harvest	Spotted owl protection	Increase recycle fiber	Higher housing starts
	Softwood Rockies Inventory									
1986	18,967	18,967	18,967	18,967	18,967	18,967	18,967	18,967	18,967	18,967
2000	18,617	18,701	18,622	18,560	18,622	18,630	18,586	18,540	18,639	18,616
2010	17,374	17,575	17,394	17,209	17,405	17,420	17,253	17,230	17,489	17,380
2020	15,848	16,001	15,829	15,434	15,925	15,931	15,522	15,651	16,124	15,780
2030	14,614	14,773	14,447	13,980	14,756	14,758	14,171	14,371	15,158	14,439
2040	13,832	13,994	13,561	13,087	14,117	14,061	13,313	12,902	14,817	13,536
	Softwood Pacific Coast Inventory									
1986	57,022	57,022	57,022	57,022	57,022	57,022	57,022	57,022	57,022	57,022
2000	58,747	59,066	58,958	58,538	59,032	59,232	58,310	58,344	58,867	58,767
2010	59,591	60,105	60,044	59,101	60,261	60,273	58,625	59,430	59,905	59,600
2020	60,491	60,822	60,761	59,693	61,772	61,164	59,649	56,778	61,227	60,424
2030	62,140	62,182	61,933	60,901	64,273	63,029	61,426	62,038	64,429	61,828
2040	63,359	63,535	62,738	62,254	66,541	64,706	62,735	57,307	65,368	62,392
	Total Softwood Inventory									
1986	205,581	205,581	205,581	205,581	205,581	205,581	205,581	205,581	205,581	205,581
2000	206,559	207,053	206,481	197,403	208,131	207,600	205,843	205,804	207,154	206,580
2010	213,873	214,781	213,537	200,530	218,199	217,150	212,220	213,353	216,418	213,882
2020	220,865	221,391	219,594	204,543	227,984	225,094	219,160	216,877	224,931	220,707
2030	221,254	221,659	217,776	202,591	232,282	226,500	219,255	220,910	229,993	220,341
2040	218,188	218,585	212,733	197,179	233,449	224,409	215,814	211,050	227,696	215,871
	Hardwood North Inventory									
1986	119,748	119,748	119,748	119,748	119,748	119,748	119,748	119,748	119,748	119,748
2000	137,985	137,986	137,924	134,378	137,495	138,854	137,933	137,982	137,943	137,985
2010	145,130	145,171	144,873	139,795	144,311	150,203	144,946	145,162	145,226	145,130
2020	147,789	147,872	147,129	140,814	146,778	157,224	147,454	147,857	148,377	147,770
2030	148,101	148,212	146,809	139,540	146,851	161,159	147,594	148,153	149,414	148,016
2040	147,311	147,419	145,226	137,269	145,761	163,455	146,599	147,352	149,456	147,108
	Hardwood South Inventory									
1986	115,184	115,184	115,184	115,184	115,184	115,184	115,184	115,184	115,184	115,184
2000	120,299	120,298	120,136	115,216	119,392	121,316	120,251	120,298	119,979	120,298
2010	110,319	110,319	109,543	103,521	108,361	113,833	110,094	110,305	110,265	110,332
2020	96,297	96,312	94,472	87,890	93,109	101,306	95,916	96,258	98,126	96,300
2030	83,167	83,193	79,977	73,127	78,612	89,326	82,626	83,127	87,902	83,086
2040	73,252	73,307	69,555	63,478	68,854	80,363	72,626	73,223	80,561	73,063
	Hardwood Rockies Inventory									
1986	2,199	2,199	2,199	2,199	2,199	2,199	2,199	2,199	2,199	2,199
2000	2,803	2,803	2,803	2,802	2,803	2,802	2,800	2,802	2,803	2,803
2010	3,144	3,146	3,145	3,143	3,145	3,144	3,134	3,143	3,145	3,144
2020	3,411	3,412	3,411	3,409	3,411	3,410	3,392	3,410	3,412	3,410
2030	3,633	3,678	3,632	3,631	3,678	3,678	3,654	3,633	3,677	3,632
2040	3,873	3,947	3,873	3,877	3,947	3,947	3,920	3,858	3,940	3,873
	Hardwood Pacific Coast Inventory									
1986	12,894	12,894	12,894	12,894	12,894	12,894	12,894	12,894	12,894	12,894
2000	15,845	15,854	15,849	15,840	14,998	16,858	15,832	15,836	15,843	15,845
2010	16,029	16,043	16,042	16,013	14,694	17,345	15,980	15,075	16,058	16,029
2020	16,162	16,170	16,171	16,152	14,617	17,780	16,101	16,154	16,228	16,161
2030	16,716	16,714	16,711	16,711	14,939	18,678	16,660	16,710	16,818	16,713
2040	17,368	17,356	17,349	17,358	15,335	19,690	17,313	17,358	17,502	17,357
	Total Hardwood Inventory									
1986	250,024	250,024	250,024	250,024	250,024	250,024	250,024	250,024	250,024	250,024
2000	276,931	276,941	276,711	268,236	274,687	279,831	276,816	276,917	276,567	276,931
2010	274,622	274,678	273,602	262,472	270,510	284,526	274,154	273,686	274,694	274,635
2020	263,659	263,766	261,182	248,264	257,914	279,720	262,863	263,680	266,142	263,642
2030	251,617	251,798	247,130	233,009	244,080	272,841	250,534	251,622	257,811	251,447
2040	241,804	242,028	236,002	221,981	233,896	267,455	240,458	241,792	251,457	241,402

of softwood lumber and plywood is up in most producing regions, particularly in the later projection years. Consumption of softwood roundwood pulpwood is also higher in the South because improved product recovery in the West shifts some lumber and plywood production from the South to the West, reducing the volumes of byproducts from mill operations available to southern pulpmills.

Lower harvests early in the projection period result in reductions in softwood stumpage and softwood lumber prices relative to the base projections in the near term. In the longer term, lumber prices remain lower than in the base Assessment projection but stumpage prices outside of the Pacific Coast region rise slightly because of increased product production in those regions.

The effects of industry adoption of the technologies identified by Haygreen and others (1986) have been estimated by Skog and Haynes (1987). They found that, just as this future suggests, the outlook for timber could be changed by actions that improved processing efficiency. The effects of a variety of specific technological changes are explored in Chapter 10.

Higher Exports

In the last 3 years, exports of forest products have been at near record levels, reawakening interest in the potential of export markets (see Chapter 5 for details). Realizing the potential for expanded trade also depends on the willingness of domestic firms to enter new markets, elimination of currently restrictive trade barriers (in importing countries), and the ability of U.S. producers to capture a larger export market share in the face of price and other kinds of competition from other world supplies.

In this future, the projected exports of lumber, plywood, and pulp products (including pulpwood and the roundwood equivalent of pulp, paper, and board) are assumed to increase by 20% per decade for the next five decades. Exports of lumber and plywood start to rise after 2010 when domestic product prices start to stabilize. Log exports in the Douglas-fir subregion are assumed to fall as lumber and plywood exports rise.

A doubling of exports of the major timber products (except softwood logs) over the projection years has the obvious effect of increasing demands and harvests (timber supplies) over the base projections for softwoods and hardwoods (see table 124). After 2010, softwood log exports in the Douglas-fir subregion were assumed to be replaced by exports of softwood lumber and plywood. The impacts vary by product, however, because doubled exports of some products are small in comparison to production. Impacts also vary by region because of the location of export markets and comparative cost differences. For example, production of softwood lumber and plywood drops below the base Assessment projection in the South, but rises substantially above them in the Pacific Northwest where reductions in log exports increases the availability of logs for domestic processing. Consumption of softwood roundwood pulpwood shows the reverse pattern, much above the base in the South (650 million cubic feet above the base by 2040), and below it in the Pacific Northwest.

There are also regional differences in the impact of this future on timber inventories. Softwood inventories in the South are lower in this future because of higher pulp production than those in the base Assessment projection. Hardwood inventories drop below the base Assessment projection in both the North and South because of increases in hardwood pulpwood use.

Prices for softwood stumpage and/or products made from softwoods are generally higher than those in the base. This reflects the volumes involved. There are large increases in pulpwood consumption while doubled lumber exports are still small relative to total lumber production. Hardwood sawtimber stumpage prices are not impacted as there is little change in hardwood lumber production and prices.

Lower Rates of Timber Growth

This decade of the 1980s has seen the emergence of a number of concerns centered first around declining forest growth possibly caused by acid rain or other air pollutants, and more recently due to global climate change. These concerns have evoked public apprehension and led to large scale research programs such as the Forest Response Program (FRP) (Schroeder and Kiester 1989) and the National Acid Precipitation Assessment Programs (NAPAP).[35]

The purpose of this future is to illustrate the economic impacts associated with the types of growth declines found by deSteigner and Pye (in press). They summarized a survey of expert opinion about quantitative estimates of the damage caused by air pollutants to major U.S. forest ecosystems, and found in general that eastern hardwood types would experience a 5% decline while eastern softwood types would experience a 10% decline. These growth reductions were simulated by lowering both current and future yield functions by the specified percentages for all stand age classes. This approach lowers what growth stands can attain. Because of stocking-level adjustments and growth of softwood components of hardwood stands and hardwood components of softwood stands, however, the simulated reductions in aggregate stand growth differ somewhat from the initial adjustments in yields.

Inventories change more slowly. By 2000, inventories in the Northeast and Southeast (except for softwoods in the Southeast) are only 3–4% less than in the base Assessment projection (table 125). Softwood inventories in the Southeast, for example, are 9% lower than in the base Assessment projection. This reflects the strong markets for softwood stumpage in the Southeast and the close balance between harvest and growth in the base Assessment projection. Hardwood inventories decline

[35] *The final NAPAP Assessment is due in 1990 (NAPAP 1988). This assessment includes the causes and effects of acidic deposition and related control and mitigation strategies.*

Table 125.—Growth, inventory, and harvest reductions.[1]

	Growth		Inventory		Harvest[2]	
	Hardwood	Softwood	Hardwood	Softwood	Hardwood	Softwood
			Northeast			
2000	.94	.90	.97	.96	1.00	1.00
2020	.94	.91	.95	.92	1.00	1.00
2040	.95	.92	.94	.89	1.00	1.00
			Southeast			
2000	.94	.91	.97	.91	1.00	.94
2020	.94	.92	.91	.85	1.00	.82
2040	.92	.92	.90	.79	1.00	.79

[1]*Measured as the ratio of the growth reduction future divided by the base Assessment projection.*
[2]*Sawtimber harvest only.*

by 2040 to 6% less than the base in the Northeast and 10% less in the Southeast (see table 125). Changes in harvest reflect shifts in product markets. In the South, there are changes in both softwoods and hardwoods but sawtimber harvest impacts are only large for softwoods. Softwood sawtimber harvest in the Southeast, for example, drops 6% by 2000 and 21% by 2040. This harvest trajectory is the consequence of the market model including the specification of the stumpage supply functions that relate harvest to inventory and price levels.

The market determines the economic impacts. These vary between species, regions, product and stumpage markets, and over time. Impacts in the near term are modest except for softwoods in the South where stumpage prices increase by 27% by 2000. They rise most rapidly in the near term as slow, downward capacity adjustments (modeled as a function of profitability) lead to tight stumpage markets. Overall, the price impacts for this future are the most severe of all of the futures in the softwood sector.

The biological and economic impacts associated with growth declines differ. The biological impacts, other than for growth, are slow to develop. Reduced growth rates eventually lower timber inventories (which lower harvests) and could, in the longer term, affect the mix of species. The most severe economic impacts are in the South, and especially in the Southeast where declines in growth further aggravate expected declines in softwood inventories shown in the base Assessment projection. Economic impacts for both the North and for hardwoods, in general, are more modest.

Another way to gauge the economic impacts is to look at which groups (consumers, producers, and stumpage owners) gain or lose because of growth reductions associated with acidic deposition. Sample impacts are shown as follows:

	Consumer expenditures	Southeast lumber producers' revenues*	Southeast stumpage owners' revenues
		billion 1982 dollars	
2000	.57	−.15	.03
2020	2.82	−.06	—
2040	2.16	−.03	.06

*Computed as profit per thousand board feet times production.

As a group, consumers are the most impacted as increased lumber prices due to reduced growth raise consumer expenditures. Changes in consumer expenditures for softwood lumber average $15 (1982 dollars) per household by 2040. In the near term (during the next two decades), potential changes in consumer expenditures are partially reduced by increased production in other regions including those in Canada. By 2020, the opportunities for this offsetting production are exhausted, increasing total impacts. Producers generally lose revenue as stumpage prices increase in affected regions faster than final product prices. In the South, these losses are greatest in the next decade but fall after 2000 as producers reduce lumber capacity in response to lower harvest levels and higher stumpage prices. One interesting note is that reduced growth leads to increased plywood profits and production levels in the Southeast. As less timber becomes available, there is a shift from lumber to plywood production in the Southeast resulting from the availability of alternative sources for lumber relative to those for plywood.

In spite of lower harvest levels (because of reduced timber inventories), stumpage owners see increased revenues in the long run derived from the sale of sawtimber because of higher stumpage prices.

Greater Forest Management

As described in Chapter 9, there are economic opportunities to increase timber inventories on private timberlands. In this future, the impact of increasing investment levels above those in the base Assessment projection were analyzed. Specifically, investment levels were increased to include those economic opportunities whose average rates of return were 10% or greater.

As shown in table 124 the impacts of increased investments on private timberlands are substantial. Softwood timber harvests, net annual growth, and inventories are all higher than in the base projection. Softwood timber inventories are 8.1% greater in 2040 for private timberlands in the South. This pattern in growth, inventories, and harvests illustrates how timber markets function. Growth increases are noticeable first. These lead to increases in inventories and finally (in later decades) to increases in harvest. The impacts on the softwood forest

resource are primarily felt in the South where the bulk of private timberland is located.

The economic impacts associated with this future are explained in Chapter 9.

Reforestation of Surplus Cropland

Important factors that influence the amount of cropland—such as changes in the domestic and international demand for agricultural products and changes in agricultural production technologies—are difficult to project and result in uncertainties regarding their possible impact on future land reallocation. These factors may have unanticipated effects on the amount of land needed for agricultural production. This future examines the effect of reducing the acres of cropland in production on the availability of timberland acres. This future assumes that all surplus cropland[36] projected by the Second RCA Appraisal (USDA SCS 1987) will revert to natural vegetation, either range or forest. It tests the sensitivity of future natural resource production to changes in the agricultural land base.

Idle cropland area was determined from the 2030 intermediate scenario projections in the 1988 RCA Appraisal (USDA SCS 1987). The Second Appraisal projects the availability of 386.8 million acres of cropland in 2030. Of this total, 218.5 million acres are assumed to be used for crop production, 39.8 million are assumed to be enrolled in the Conservation Reserve Program, and 128.5 million acres are assumed to be idle (land that will not be needed for agricultural production).

Of the 128.5 million idle acres, most is projected to revert to range (96 million acres). An additional 15.6 million acres is projected to revert to hardwoods, 15.4 million to hardwood/softwood, and 1.5 million acres to softwood types. Roughly 40% of the idle cropland available for reversion to forest was accounted for in the initial base timberland assumption. The remaining acres are expected to add 19.1 million acres to the timberland base over the next 20 years. In this future most of these acres consist of hardwood and hardwood/softwood types and occur primarily in the North and the South.

The effect of these increases in timberland area by 2040 is to raise private timberland inventories 2.9% and 10.8%, respectively, for softwoods and hardwoods (table 124). The largest increases are for hardwoods in the North and in the Pacific Coast. While these changes in timber inventories are large, they have limited market impacts since most of the increase involves hardwood types where there is already abundant supplies. Stumpage prices, by 2040, in the North are 6% less and in the South 11% less than those in the base run. These lower stumpage prices lead only to a small (less than 1%) change in hardwood timber demand.

[36]*Surplus cropland as defined in the RCA Appraisal are those acres that are currently cropped that would be in surplus (i.e., not needed to meet projected demands) in the future if a least cost method is used to meet food and fiber demands in the United States, under "intermediate" supply and demand assumptions.*

Changes in National Forest Timber Harvests

In the last two decades, it has become increasingly clear that the future of timber production on the national forests depends in part on (1) success in finding suitable ways to integrate timber production with other uses of forest land, and (2) the need to protect and maintain the forest environment, including endangered and threatened species. The controversy surrounding habitat protection for the spotted owl illustrates the increasing constraints on timber production on the national forests. In this section, two futures are presented to address these two issues. The total national forest harvest levels for each case are shown as follows:

	Base assessment projection	Reduced national forest harvest	Spotted owl
		billion cubic feet	
1986	2.07	2.07	2.07
2000	2.00	1.70	1.86
2010	2.17	1.85	2.03
2020	2.23	1.90	2.09
2030	2.28	1.95	2.13
2040	2.32	1.99	2.18

The reduced national forest harvest level was initially specified to be a 20% reduction, but in the actual simulations the reduction is roughly 15% because of the difference between sales offered and sold in the Rocky Mountains. In this simulation, some of the reduction in national forest harvest is assumed to come from those sales that while offered, would not be sold. Consequently, harvest reductions come primarily in the Pacific Coast states and in the South.

Reduced National Forest Harvest

The first future illustrates a future where national forest harvest levels are reduced from 2.3 billion cubic feet per year to 2.1 billion. This decrease in national forest harvest is partly offset by changes in harvests of other owners or in other regions. In regions, where there are sufficient private timber supplies, decreases in national forest harvest lead to higher stumpage prices that, in turn, increase timber harvests from private timberlands. For example, the national forest harvest in the Douglas-fir subregion is reduced by 96 million cubic feet per year. Total harvest, however, is reduced by only 40 million cubic feet by 2000—private harvests having increased by 56 million cubic feet per year. In the Douglas-fir subregion, these offsetting changes cannot be sustained after 2000 because of a worsening timber inventory situation. In other sections, such as the Rocky Mountains, the reduction in national forest harvest is partly offset throughout the projection period.

Under this future, declines in timber inventories are reflected in intensified competition for the available timber and higher prices for softwood stumpage prices. Those in the Pacific Northwest, for example, are 17% above the base by 2040.

Softwood lumber prices are 2.4% higher in 2040 than in the base Assessment projection (table 124). Because of the lumber price increases, total lumber consumption is down 1.2% and lumber imports from Canada are up 21% by 2040. The increase in lumber imports comes progressively after 2000 because domestic production is reduced as a consequence of the lower timber inventories and the associated higher prices. By 2040, domestic lumber production is 5.2% less than the base Assessment projection. There are different impacts among regions. The largest impacts are in the western states, particularly the Pacific Northwest with its large national forest resources.

There are no significant impacts on the hardwood resource associated with this future, further illustrating the small role of national forests in the hardwood sector.

The Northern Spotted Owl

The recent national forest and Bureau of Land Management controversy over old-growth retention and proper forest management practices has centered in the Douglas-fir subregion. This issue concerns further retention of old-growth forests than was planned to ensure survival of species such as the Northern Spotted Owl.[37] Exact acreage reductions and the affects on timber harvest are unclear until a protection policy is adopted. However, a mid-range harvest level from the Spotted Owl Environmental Impact Statement (USDA FS 1988a) suggests that national forest harvest in the Douglas-fir subregion could be reduced by 25%, assuming that 25% of the region's harvest came from old-growth stands.

Figure 62 shows the total harvest. National forest harvest was reduced over the next 3 years by 150 million cubic feet in the Douglas-fir subregion leading to roughly a 5% reduction in the total harvest for the subregion. This leads to higher stumpage prices and higher harvest on private lands. In 2000, harvest increases of 49 million cubic feet on forest industry timberlands and 20 million cubic feet on nonindustrial timberlands offsets the 150 million cubic feet decline. The actual harvest decline in 2000 following these changes is 73 million cubic feet.

Nationally, the effects of this future are modest relative to other futures (see table 124). It raises softwood product and stumpage prices and lowers U.S. consumption and production. Its impacts are most severe in the Douglas-fir subregion where higher stumpage prices lead to lower harvest and production levels.

[37] *The various viewpoints are summarized in publications such as "Pacific Northwest Lumber and Wood Products: An Industry in Transition" (Olson 1988) and "Spotted Owls, Old Growth and the Economy of the Northwest" (Northwest Forest Resource Council 1989).*

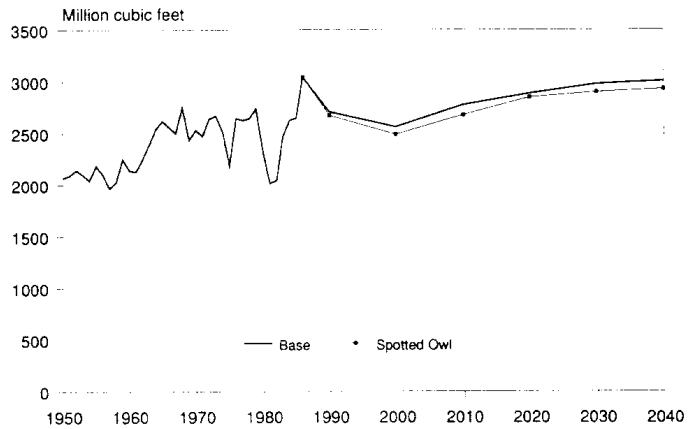


Figure 62.—Impacts of spotted owl reductions on total Pacific Northwest-West national forest harvest.

Increased Recycling

This future examines the impacts of further increases in recycling in the forest sector. There is a growing interest in the impact of increased use of wastepaper as raw material for paper and board production. Producers in other developed countries (e.g., Japan and European countries) use about twice as much wastepaper as raw material for the production of paper and board as U.S. producers. In the United States this recent interest seems to stem largely from concerns about waste disposal rather than concerns about raw material availability. In this future, the impacts of increasing wastepaper use to 39% of total fiber furnish are examined (see table 91 for the assumptions used in the base projection).

Increased recycling leads to a 3.7% reduction in total demand for forest products by 2040 (table 124). Consumption by sawtimber and pulpwood is shown in the following tabulation:

	Sawlogs		Pulpwood	
	Base	Recycle	Base	Recycle
	billion cubic feet			
1986	9.0	9.0	5.8	5.8
2000	8.2	8.2	7.4	7.1
2020	9.5	9.6	9.6	8.4
2040	9.6	9.9	10.8	8.9

By 2040, we are using 17.6% less pulpwood as a result of increased use of wastepaper. Some of the wood that would have been used as pulp is being used for the manufacture of other products especially lumber (note that sawlog consumption is increased). U.S. softwood lumber consumption rises 2.7%, imports of softwood lumber from Canada drop by 57.6%, and U.S. softwood lumber production rises by 14.3%.

Table 124 shows the reductions in harvest for both softwoods and hardwoods. The largest harvest reductions are for softwoods, particularly in the Pacific coast states where harvest falls both because of lower pulpwood use and because lumber and plywood production falls as a result of increased product production in the South. Reductions in the South are larger for hardwoods than for softwoods. Another way to look at this is in terms of reductions in acres harvested because of increased recycling. As the use of wastepaper increases, fewer acres are harvested each year (440,000 acres less in 2010). The bulk of these acres are in the South and are evenly split between hardwoods and softwoods.

Changes in wood prices are another way to gauge the impact of increased use of wastepaper. In the South, the

two decades it will almost entirely come from stands that are now considered to be at minimum harvest age. This raises questions about the quality of that timber and the ability to supply markets that have specific size, ring count, and limb size requirements.

Projections for the nonindustrial ownership show a different future (as illustrated for the Southeast in fig. 66). No forest regulation scheme will characterize this ownership and the change in harvest age is not expected to be as severe. Consequently, this ownership will still hold older and presumably more valuable timber. The nonindustrial ownership also faces a problem of age class imbalance but it is not expected to be resolved until late in the projection period (see the plots of 2010 and 2040 in fig. 66).

SUMMARY

The softwood lumber price index is often used as a general measure of the overall economic situation in the U.S. forest sector. In the base Assessment projection, it is projected to increase at an annual rate of 1.2% between 1986 and 2010 and .2% between 2010 and 2040. In the sense of an overview, which future affects the softwood lumber price index most? Figure 67 shows the softwood lumber price index from the base Assessment projection and four other futures that trace the bounds of the effects on the index. Two futures result in lower projected increases in the softwood lumber price index: increased

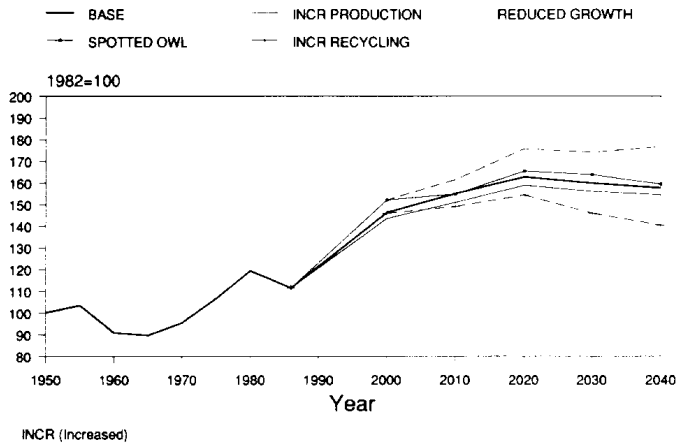


Figure 67.—Softwood lumber price index, 1950–1986, with projections to 2040.

productivity through improvements in processing efficiency, and increased recycling. Both of these futures reduce the demand for roundwood, lower wood costs, and finally total costs. The Spotted Owl and reduced growth futures lead to higher rates of projected price increases. The Spotted Owl future affects timber supplies immediately while the lower growth rates future impacts timber inventory levels only in the longer term. Both of these futures also illustrate how regional issues (the Spotted Owl issue is centered in the Douglas-fir subregion and lower rates of timber growth focuses on the East) can impact the entire forest sector.