# Appendix A. Correlation of U.S. Geological Survey and Oregon Water Resources Department Identifiers for Selected Wells.

[Location is USGS station identifier and contains township, range, section, and letter code for quarter location in section]

| Location | OWRD name | USGS name | Depth drilled, in feet below land surface |
|---|---|---|---|
| 01N/02W-03AAD01 | WASH 5090 | 453613122542901 | 305 |
| 01N/02W-03ABA | WASH 14 | 453618122544701 | 405 |
| 01N/02W-08BCA | WASH 5173 | 453514122575801 | 60 |
| 01N/02W-17ACC | WASH 5382 | 453417122572901 | 70 |
| 01N/02W-17DAB | WASH 5377 | 453414122571001 | 760 |
| 02N/03W-35CDD | WASH 5956 | 453628123012101 | 618 |
| 03N/01W-06BAA1 | COLU 3379 | 454645122512201 | 92 |
| 01S/01E-24BBC01 | MULT 63238 | 452827122382401 | 27 |
| 01S/01E-24BBC02 | MULT 63239 | 452827122382402 | 98 |
| 01S/02E-13CDA1 | None | 452840122302202 | 17 |
| 01S/02E-13CDA2 | None | 452840122302201 | 54 |
| 01S/02E-16BAA01 | MULT 63388 | 452921122340401 | 129 |
| 01S/02E-16BDA01 | MULT 50871 | 452912122340401 | 437 |
| 01S/01W-17CBD | WASH 8862 | 452845122502301 | 414 |
| 01S/01W-21CDD2 | WASH 8988 | 452751122485401 | 800 |
| 01S/01W-21DAD2 | WASH 8976 | 452757122482001 | 395 |
| 01S/01W-21DDD | WASH 8986 | 452751122466001 | 145 |
| 01S/01W-33CBC | WASH 9205 | 452619122492401 | 325 |
| 01S/02W-23ACB | WASH 10143 | 452817122561501 | 805 |
| 02S/01E-20CBD1 | CLAC 12346 | 452249122430801 | 238 |
| 02S/01E-20CBD2 | CLAC 3165 | 452249122430901 | 40 |
| 02S/01E-21CCC | CLAC 3246 | 452234122415901 | 330 |
| 02S/02E-29DD | CLAC 4396 | None | 560 |
| 02S/04E-05CBB | CLAC 5535 | 452528122205501 | 205 |
| 02S/04E-29DAD | CLAC 6388 | 452033122195901 | 190 |
| 02S/01W-04ACC | WASH 11449 | 452534122485101 | 494 |
| 02S/01W-04BAD | WASH 11436 | 452551122485801 | 600 |
| 02S/01W-32ADD | WASH 51903 | 452113122493001 | 1,030 |
| 02S/02W-34ACD | WASH 3443 | 452118122545001 | 277 |
| 02S/02W-34ADB | WASH 13210 | 452119122544001 | 160 |
| 03S/01E-16DDD | CLAC 9327 | 451815122405401 | 202 |
| 03S/01E-17ACA | CLAC 9340 | 451845122423101 | 292 |
| 03S/01W-15CAC | CLAC 8184 | 451747122484801 | 920 |
| 03S/01W-24BAA01 | CLAC 8491 | 451804122451201 | 620 |
| 03S/02W-36ABA | YAMH 2703 | 451626122522001 | 282 |

# Appendix A. Correlation of U.S. Geological Survey and Oregon Water Resources Department Identifiers for Selected Wells—Continued.

[Location is USGS station identifier and contains township, range, section, and letter code for quarter location in section]

| Location | OWRD name | USGS name | Depth drilled, in feet below land surface |
|---|---|---|---|
| 03S/02W-36ACA | YAMH 2685 | 451611122522601 | 545 |
| 04S/01W-05CDC | MARI 308 | 451447122502101 | 120 |
| 04S/01W-06ADD | MARI 50403 | 451514122504401 | 365 |
| 04S/01W-11ADA01 | MARI 53023 | 451429122455301 | 1,097 |
| 04S/01W-15BDD | CLAC 1952 | 451333122474901 | 245 |
| 04S/01W-19ACA01 | MARI 56530 | 451237122510601 | 613 |
| 04S/01W-19ACD01 | MARI 54896 | 451235122510401 | 350 |
| 04S/02W-01CDD01 | None | 451444122524701 | 12.6 |
| 04S/02W-01CDD02 | None | 451444122524601 | 3.9 |
| 04S/02W-02BBD | MARI 1044 | 451528122541301 | 166 |
| 05S/01W-28CCD01 | None | 450603122491601 | 2.83 |
| 05S/01W-28CCD02 | None | 450603122491602 | 17.7 |
| 05S/02W-01DDA | MARI 2218 | 450939122520901 | 200 |
| 05S/02W-08CBC01 | MARI 18414 | 450856122580201 | 270 |
| 05S/02W-08CCA2 | MARI 52504 | 450851122575801 | 106 |
| 05S/02W-08CCB1 | MARI 52597 | 450851122580101 | 203 |
| 05S/02W-19DCC | MARI 2541 | 450758122590201 | 130 |
| 05S/03W-34CBB | YAMH 50041 | 450531123025901 | 57 |
| 05S/03W-36DAA | MARI 17239 | 450535122593201 | 109 |
| 06S/01W-06CCC | MARI 3054 | 450423122514701 | 165 |
| 06S/01W-08DAC01 | MARI 55014 | 450341122493701 | 49 |
| 06S/01W-08DAC03 | MARI 55016 | 450341122493702 | 35 |
| 06S/01W-08DAD01 | MARI 53920 | 450340122493401 | 115 |
| 06S/01W-08DAD02 | MARI 54951 | 450340122493403 | 53.6 |
| 06S/01W-08DAD03 | MARI 54952 | 450340122493402 | 69.5 |
| 06S/01W-08DAD04 | MARI 54953 | 450339122492801 | 55.1 |
| 06S/01W-08DAD05 | MARI 55015 | 450339122492802 | 68.9 |
| 06S/01W-08DAD06 | MARI 55017 | 450340122493404 | 45.2 |
| 06S/01W-09DCA | MARI 50456 | 450332122483801 | 850 |
| 06S/01W-15ABD01 | MARI 3179 | 450313122472401 | 700 |
| 06S/01W-16AAB01 | MARI 3197 | 450324122482801 | 830 |
| 06S/01W-16ABC01 | MARI 51339 | 450312122484401 | 188 |
| 06S/01W-21CAD | MARI 3266 | 450200122485301 | 120 |
| 06S/01W-21CDC01 | MARI 3280 | 450140122490701 | 323 |
| 06S/01W-21CDC02 | MARI 51006 | 450141122490601 | 566 |
| 06S/01W-22AAA01 | MARI 19510 | 450231122470401 | 630 |
| 06S/01W-36BBC | MARI 3653 | 450036122454101 | 176 |
| 06S/01W-36DBC1 | MARI 3657 | 450013122450001 | 226 |

# Appendix A. Correlation of U.S. Geological Survey and Oregon Water Resources Department Identifiers for Selected Wells—Continued.

[Location is USGS station identifier and contains township, range, section, and letter code for quarter location in section]

| Location | OWRD name | USGS name | Depth drilled, in feet below land surface |
|---|---|---|---|
| 06S/01W-36DDC | MARI 3652 | 445959122445001 | 526 |
| 06S/02W-06DAD | MARI 17263 | 450432122582001 | 120 |
| 06S/02W-17DAD | MARI 4160 | 450246122564801 | 136 |
| 06S/02W-17DBC | MARI 4092 | 450248122572601 | 315 |
| 06S/03W-04ACD | MARI 4816 | 450451123031901 | 70 |
| 06S/03W-06CBC | YAMH 1907 | 450435123063101 | 205 |
| 06S/04W-03ABD | YAMH 3189 | 450502123092501 | 382 |
| 07S/01W-02CAA01 | MARI 5904 | 445923122462501 | 583 |
| 07S/02W-28ADD | MARI 7883 | 445606122554101 | 130 |
| 07S/02W-28ADD01 | MARI 55258 | 445604122554501 | 304 |
| 07S/03W-18AB1 | POLK 841 | 445808123055601 | 440 |
| 07S/03W-18BAD | POLK 1777 | 445803123060701 | 303 |
| 07S/03W-18BAD01 | POLK 1781 | 445804123061201 | 323 |
| 08S/01W-30DDB1 | MARI 8999 | 445032122505001 | 40 |
| 08S/01W-30DDB2 | MARI 8971 | 445033122505101 | 160 |
| 08S/02W-12CDB01 | MARI 9917 | 445306122524501 | 248 |
| 08S/02W-12CDB02 | MARI 56786 | 445307122524701 | 425 |
| 08S/02W-13BAD01 | MARI 10176 | 445244122523701 | 105 |
| 08S/03W-10DC | MARI 19624 | None | 332 |
| 08S/03W-11CCC | MARI 11727 | 445304123014101 | 270 |
| 08S/03W-35DDD | MARI 12984 | 444935123003701 | 264 |
| 09S/01W-14DCA | LINN 2705 | 444700122460701 | 326 |
| 09S/01W-15DCB01 | LINN 50629 | 444704122473001 | 141 |
| 09S/01W-15DCB03 | LINN 51763 | 444704122472801 | 406 |
| 11S/04W-28BDD1 | LINN 4146 | 443512123105001 | 54 |
| 11S/04W-28CAA | LINN 14280 | 443500123105001 | 60 |
| 11S/04W-34CDA | LINN 8753 | 443358123093601 | 60 |
| 11S/04W-34DDC | LINN 8756 | 443352123090401 | 104 |
| 11S/05W-35DDD | LINN 10841 | 443349123150501 | 45 |
| 12S/02W-19CCB1 | LINN 8054 | 443028122590901 | 47.5 |
| 12S/03W-07BCC2 | LINN 50852 | 443234123063101 | 51 |
| 12S/03W-07CCB | LINN 50103 | 443211123062901 | 80 |
| 12S/03W-09BDC2 | LINN 10510 | 443232123034501 | 80 |
| 12S/03W-12BAA | LINN 10391 | 443252122595301 | 65 |
| 12S/04W-01ABB | LINN 50097 | 443343123070501 | 65 |
| 12S/04W-35CDC | LINN 10817 | 442838123083001 | 115 |
| 12S/05W-02AAA | LINN 12120 | 443348123150201 | 260 |
| 15S/03W-19ACD1 | LINN 14047 | 441508123053001 | 98 |

# Appendix A. Correlation of U.S. Geological Survey and Oregon Water Resources Department Identifiers for Selected Wells—Continued.

[Location is USGS station identifier and contains township, range, section, and letter code for quarter location in section]

| Location | OWRD name | USGS name | Depth drilled, in feet below land surface |
|---|---|---|---|
| 16S/05W-26AAD | LANE 8725 | 440915123145601 | 30 |
| 17S/01W-29ACC | LANE 10127 | 440354122495501 | 43 |
| 17S/02W-30CAA1 | LANE 10761 | 440341122584001 | 249 |
| 17S/02W-30CAA2 | LANE 10762 | 440341122584002 | 50 |
| 17S/05W-02BAC1 | LANE 12676 | 440736123154701 | 105 |
| 17S/05W-02BAC2 | LANE 3203 | 440735123154601 | 25 |

# Appendix B. Chlorofluorocarbon-Based Model Ages for Ground Water in the Willamette Basin, Oregon

By Stephen R. Hinkle

## Introduction

Twenty-one wells were sampled for chlorofluorocarbons (CFCs) in October 1996 as part of the Willamette Ground-Water Project. Samples were analyzed for three CFCs: $CCl_3F$, $CCl_2F_2$, and $C_2Cl_3F_3$. Measurement of CFCs allows determination of CFC-model ages for ground water, where a CFC-model age is defined to be an estimate of the time-of-travel for water particles from their points of recharge at the water table to the open or screened interval of a well. CFC-dating techniques allow water recharged as far back as 1940 to be dated. CFC-dating theory, techniques and limitations are described in Busenberg and Plummer (1992), Busenberg and others (1998), and Plummer and Busenberg (2000).

## Methods

Methods of CFC sample collection and analysis in this project were essentially identical to those used by Hinkle and Snyder (1997), with one important exception. Many wells chosen for sampling by Hinkle and Snyder (1997) had long open or screened intervals, and the resulting samples often probably represented mixtures of water of widely varying age. In contrast, in the present work, particular emphasis was placed on sampling wells with short open or screened intervals to minimize well-bore mixing of ground-water components. The resulting CFC-model ages are more meaningful than are CFC-model ages determined from wells with long open or screened intervals.

CFC-model ages are based upon CFC concentrations, temperature of water at the time of recharge, and the altitude of the water table at the time of recharge. The mean recharge temperature in the Portland Basin (which lies at the mouth of the Willamette Basin) was determined to be 8°C (degrees Celsius) (Hinkle and Snyder, 1997). Thus, the mean recharge temperature used in this study was assumed to be 8°C. A 2°C error in the estimate of recharge temperature would result in an error of 0 to 1 years for water recharged in the 1940s-1970s and 2 years for water recharged in the early to mid-1980s. The temperature dependence of CFC-model ages becomes more significant for water recharged since the late 1980s (errors of several years), but as will be seen later, none of the wells sampled in this project were open or screened close enough to the water table to yield such young water. Thus, uncertainty in recharge temperatures are not a significant source of error for these samples.

Recharge elevations were approximated by assuming that they were equal to the elevations of the static water levels in the wells. A 2,000-foot error in recharge elevation generally results in a difference of 0 to 1 year. Thus, although recharge elevations will be higher than elevations of static water levels in wells, the uncertainty associated with this approximation is negligible.

Degradation of CFCs will affect the CFC-based model ages. Degradation may occur in reducing environments. To evaluate redox conditions, dissolved oxygen and methane in ground-water samples were measured. Dissolved oxygen was measured electrometrically in a flow-through chamber in the field. Probes were calibrated daily and were periodically checked against anoxic solutions (deionized water with sodium sulfite added to chemically reduce oxygen). Dissolved methane was measured by gas chromatography (Busenberg and others, 1998).

## Results

For each site, two to three samples were analyzed for CFCs. CFC concentrations, CFC-model recharge dates, dissolved-oxygen (DO) concentrations, selected physical data, and assigned CFC-model ages are presented in table B1. Figure B1 shows the CFC-model ages of water from the sampled wells.

Reducing conditions were widespread. DO concentrations at 16 sites were less than 0.3 mg/L (milligrams per liter), and even the site with the highest DO concentration (3.3 mg/L) cannot be assumed to represent only oxic water, as a sample with such a low DO concentration could represent a mixture of well-oxygenated and anoxic water. CFC dating in reducing environments requires consideration of redox conditions because microbial degradation of CFCs can occur in reducing environments. Degradation of $CCl_3F$ is considerably faster (generally by at least an order of magnitude) than degradation of $CCl_2F_2$, and measurable degradation of $CCl_2F_2$ apparently does not occur until methanogenic conditions become well established (Plummer and Busenberg, 2000). Observed $CCl_3F$-model recharge dates generally are older than $CCl_2F_2$-model recharge dates (table B1), suggesting that some microbial degradation of $CCl_3F$

has occurred. Dissolved-methane concentrations were measured in samples from 10 of the 21 sites; all concentrations were <0.05 mg/L, indicating non-methanogenic or minimally methanogenic conditions. Thus, although $CCl_3F$-model recharge dates appear to be biased low (too old), $CCl_2F_2$-model recharge dates are reliable.

$C_2Cl_3F_3$ data are difficult to interpret in reducing environments. $C_2Cl_3F_3$, like $CCl_3F$, tends to undergo biodegradation in anoxic environments. Also, the abundant organic carbon that likely serves as an electron donor in these reducing environments also may serve to sorb $C_2Cl_3F_3$; $C_2Cl_3F_3$ sorbs to a much greater extent than do $CCl_3F$ and $CCl_2F_2$ (Plummer and Busenberg, 2000). For these reasons, $C_2Cl_3F_3$-model recharge dates can be biased too old. $C_2Cl_3F_3$ is a liquid at common environmental temperature, whereas $CCl_3F$ and $CCl_2F_2$ are gases; so in some respects, $C_2Cl_3F_3$ contamination can more easily occur than contamination by $CCl_3F$ and $CCl_2F_2$. The result is that $C_2Cl_3F_3$-model recharge dates can be biased young due to contamination. Thus, for the data for this study area, $CCl_2F_2$-model recharge dates were considered more reliable than $C_2Cl_3F_3$-model recharge dates, and $C_2Cl_3F_3$-model recharge dates were not interpreted.

For 17 of the 21 sites sampled, the oldest $CCl_2F_2$-model recharge date for each site was used to assign the CFC-model age. The oldest $CCl_2F_2$-model recharge date was chosen to minimize potential influence of any minor contamination during sampling or analysis, and is consistent with the approach used by Hinkle and Snyder (1997). Assigned CFC-model ages ranged from 23 to >57 years.

Assignment of CFC-model ages for 3 of the 21 sites was complicated by the presence of contaminant-level concentrations of CFCs. For samples collected in 1996, a contaminant-level concentration of a CFC is defined to be a concentration greater than the concentration that would be in equilibrium with 1996 air. Contaminant-level concentrations result from introduction of CFCs to the aquifer by processes other than air-water equilibrium. Where contaminant-level concentrations of CFCs were detected in one or more samples for a given site, the water was considered to have been recharged earlier than the oldest apparent $CCl_2F_2$-model recharge date, but more recently than 57 years (limit of method for samples collected in late 1996). Thus, for each of the three sites with contaminant levels of CFCs, ranges of ages were assigned.

Assignment of a CFC-model age for the remaining site (well 06S/04W-03ABD) was less straightforward than it was for the other sites. The oldest $CCl_3F$-model recharge date for site 06S/04W-03ABD was more recent than the oldest $CCl_2F_2$-model recharge date. This pattern was observed at only two other sites (wells 06S/01W-36DDC and 06S/02W-06DAD). Water from these two wells is estimated to be older than 57 years because ages from $CCl_2F_2$ and $C_2Cl_3F_3$ analysis indicate the water is old and does not contain those CFCs. (In the case of 06S/01W-36DDC and 06S/02W-06DAD, small concentrations (few pg/kg or less) of $CCl_3F$ detected in samples of

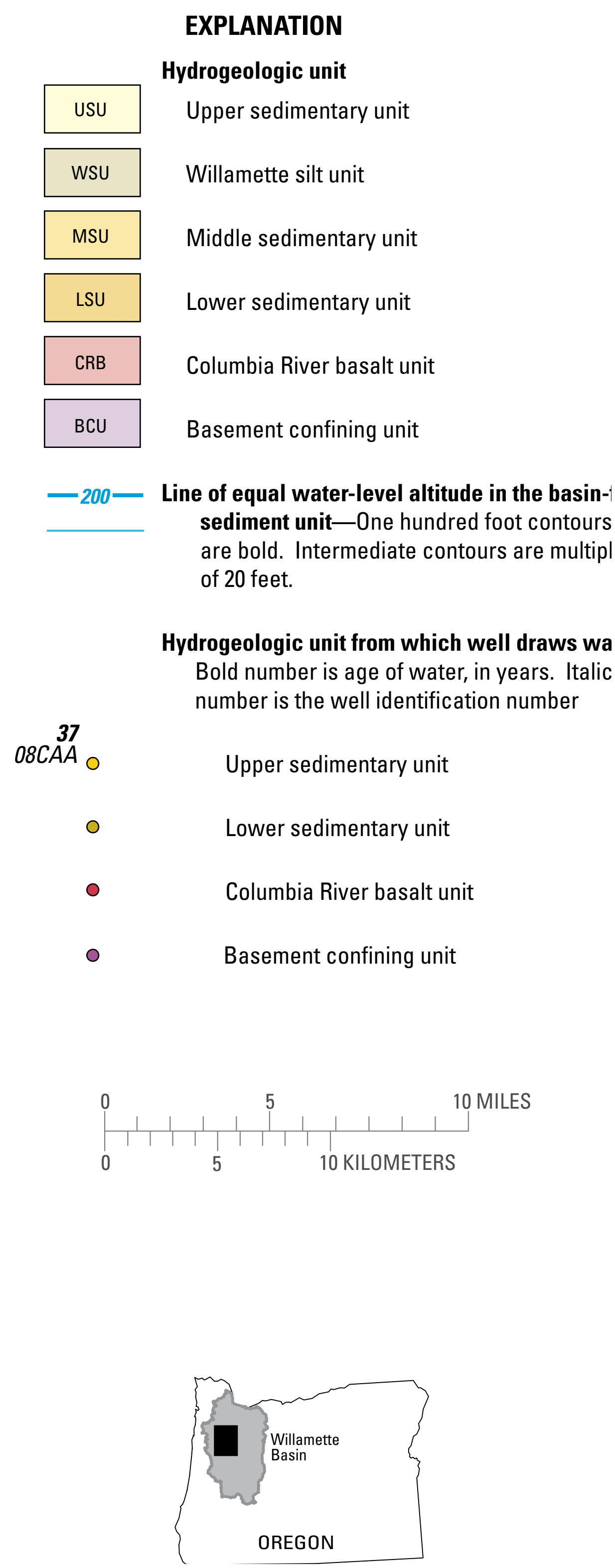
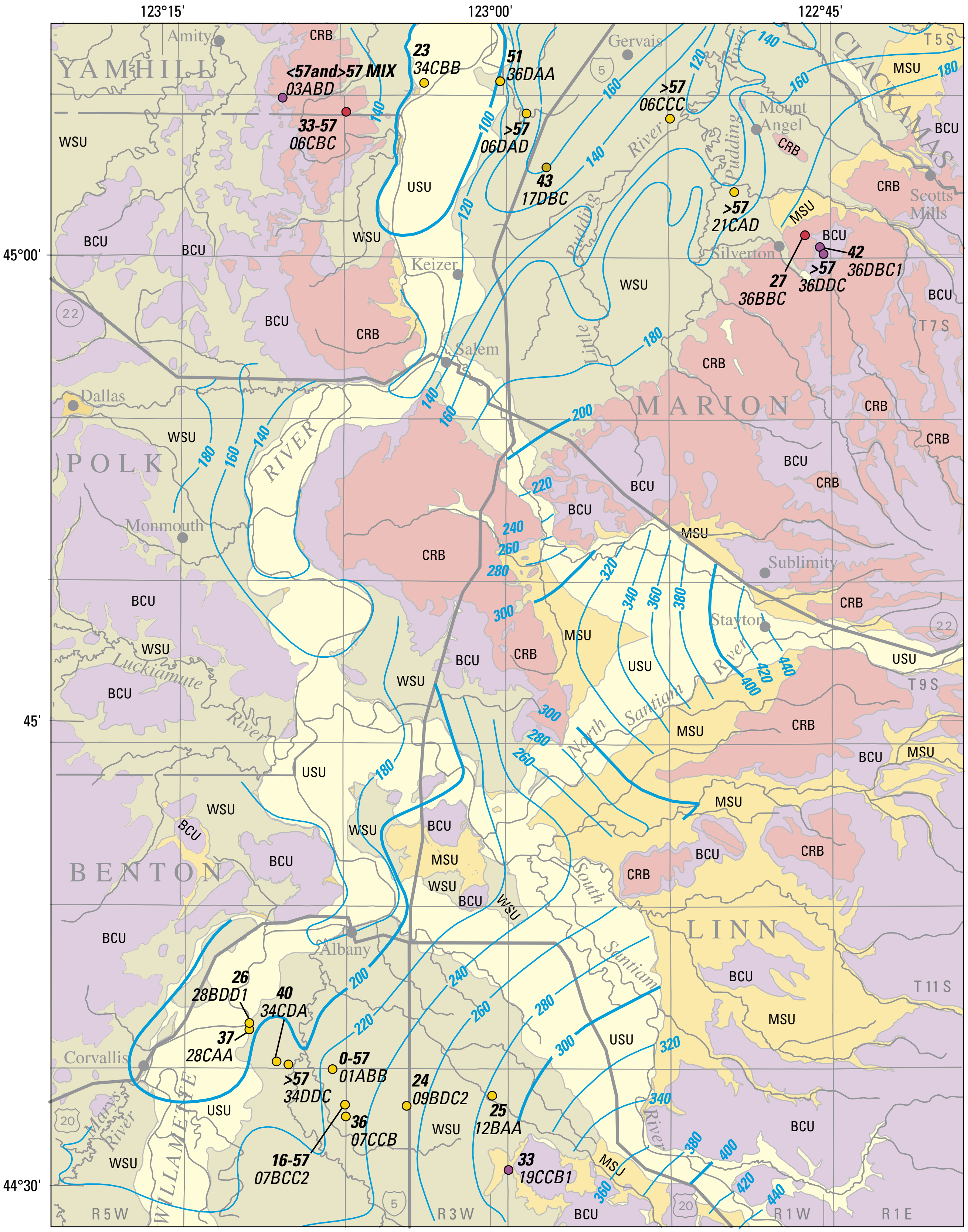



**Figure B1.** CFC-model ages for ground-water along two




See Table of Contents for mapping sources

transects and water-table contours in the basin-fill sediments, Willamette Basin, Oregon.

**Table B1.** Chlorofluorocarbon data for ground-water samples collected October 7–24, 1996

[Duplicate or triplicate samples were run for samples from each site. OWRD, Oregon Water Resources Department; ft NGVD 29, feet above NGVD 29; pg/kg, picograms per kilogram; mg/L, milligrams per liter; yrs, years; *, samples contain chlorofluorocarbon (CFC) concentrations greater than would be found in water at equilibrium with average global 1996 air; <, less than; >, greater than]

| Location | OWRD name | USGS name | Sample date | Dissolved oxygen (mg/L) | Recharge elevation[1] (ft NGVD 29) | $CCl_3F$ concentration (pg/kg) | $CCl_2F_2$ concentration (pg/kg) | $C_2Cl_3F_3$ concentration (pg/kg) | $CCl_3F$ model recharge date | $CCl_2F_2$ model recharge date | $C_2Cl_3F_3$ model recharge date | CFC model age of water (yrs) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 05S/03W-34CBB | YAMH 50041 | 450531123025901 | 10/15/1996 | 1.8 | 90 | 235.6 | 146.7 | 36.0 | 1971.0 | 1974.0 | 1981.0 | 23 |
| 05S/03W-34CBB | YAMH 50041 | 450531123025901 | 10/15/1996 | | 90 | 246.0 | 149.8 | 39.6 | 1971.5 | 1974.0 | 1981.5 | |
| 05S/03W-34CBB | YAMH 50041 | 450531123025901 | 10/15/1996 | | 90 | 250.4 | 149.2 | 37.0 | 1971.5 | 1974.0 | 1981.0 | |
| 05S/03W-36DAA | MARI 17239 | 450535122593201 | 10/7/1996 | <0.1 | 104 | 0.0 | 1.6 | 0.0 | <1945.0 | 1946.0 | <1954.5 | 51 |
| 05S/03W-36DAA | MARI 17239 | 450535122593201 | 10/7/1996 | | 104 | 2.4 | 4.3 | 0.0 | 1950.5 | 1949.0 | <1954.5 | |
| 06S/01W-06CCC | MARI 3054 | 450423122514701 | 10/8/1996 | <0.1 | 128 | 2.0 | 0.4 | 0.0 | 1950.0 | 1941.5 | <1954.5 | >57 |
| 06S/01W-06CCC | MARI 3054 | 450423122514701 | 10/8/1996 | | 128 | 0.0 | 0.0 | 0.0 | <1945.0 | <1940.0 | <1954.5 | |
| 06S/01W-06CCC | MARI 3054 | 450423122514701 | 10/8/1996 | | 128 | 0.6 | 0.0 | 0.0 | 1947.5 | <1940.0 | <1954.5 | |
| 06S/01W-21CAD | MARI 3266 | 450200122485301 | 10/8/1996 | <0.1 | 142 | 0.0 | 0.0 | 0.0 | <1945.0 | <1940.0 | <1954.5 | >57 |
| 06S/01W-21CAD | MARI 3266 | 450200122485301 | 10/8/1996 | | 142 | 0.0 | 0.0 | 0.0 | <1945.0 | <1940.0 | <1954.5 | |
| 06S/01W-36BBC | MARI 3653 | 450036122454101 | 10/9/1996 | 0.1 | 210 | 34.2 | 100.5 | 4.3 | 1960.0 | 1970.5 | 1965.5 | 27 |
| 06S/01W-36BBC | MARI 3653 | 450036122454101 | 10/9/1996 | | 210 | 18.3 | 95.2 | 0.0 | 1956.5 | 1970.0 | <1954.5 | |
| 06S/01W-36BBC | MARI 3653 | 450036122454101 | 10/9/1996 | | 210 | 17.5 | 88.4 | 6.9 | 1956.5 | 1969.5 | 1969.0 | |
| 06S/01W-36DBC1 | MARI 3657 | 450013122450001 | 10/11/1996 | <0.1 | 339 | 7.6 | 12.4 | 0.0 | 1953.5 | 1955.0 | <1954.5 | 42 |
| 06S/01W-36DBC1 | MARI 3657 | 450013122450001 | 10/11/1996 | | 339 | 7.1 | 14.1 | 0.0 | 1953.0 | 1955.5 | <1954.5 | |
| 06S/01W-36DBC1 | MARI 3657 | 450013122450001 | 10/11/1996 | | 339 | 6.0 | 14.2 | 0.0 | 1952.5 | 1955.5 | <1954.5 | |
| 06S/01W-36DDC | MARI 3652 | 445959122445001 | 10/11/1996 | <0.1 | 233 | 2.8 | 0.0 | 0.0 | 1950.5 | <1940.0 | <1954.5 | >57 |
| 06S/01W-36DDC | MARI 3652 | 445959122445001 | 10/11/1996 | | 233 | 3.4 | 4.3 | 0.0 | 1951.5 | 1949.0 | <1954.5 | |
| 06S/01W-36DDC | MARI 3652 | 445959122445001 | 10/11/1996 | | 233 | 2.4 | 0.0 | 0.0 | 1950.5 | <1940.0 | <1954.5 | |

**Table B1.** Chlorofluorocarbon data for ground-water samples collected October 7–24, 1996—Continued.

[Duplicate or triplicate samples were run for samples from each site. OWRD, Oregon Water Resources Department; ft NGVD 29, feet above NGVD 29; pg/kg, picograms per kilogram; mg/L, milligrams per liter; yrs, years; *, samples contain chlorofluorocarbon (CFC) concentrations greater than would be found in water at equilibrium with average global 1996 air; <, less than; >, greater than]

| Location | OWRD name | USGS name | Sample date | Dissolved oxygen (mg/L) | Recharge elevation[1] (ft NGVD 29) | $CCl_3F$ concentration (pg/kg) | $CCl_2F_2$ concentration (pg/kg) | $C_2Cl_3F_3$ concentration (pg/kg) | $CCl_3F$ model recharge date | $CCl_2F_2$ model recharge date | $C_2Cl_3F_3$ model recharge date | CFC model age of water (yrs) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 06S/02W-06DAD | MARI 17263 | 450432122582001 | 10/7/1996 | <0.1 | 144 | 0.9 | 1.0 | 0.0 | 1948.5 | 1944.0 | <1954.5 | >57 |
| 06S/02W-06DAD | MARI 17263 | 450432122582001 | 10/7/1996 | | 144 | 0.5 | 0.0 | 0.0 | 1947.0 | <1940.0 | <1954.5 | |
| 06S/02W-17DBC | MARI 4092 | 450248122572601 | 10/21/1996 | <0.1 | 137 | 1.0 | 16.6 | 0.0 | 1948.5 | 1957.0 | <1954.5 | 43 |
| 06S/02W-17DBC | MARI 4092 | 450248122572601 | 10/21/1996 | | 137 | 0.9 | 10.6 | 0.0 | 1948.5 | 1954.0 | <1954.5 | |
| 06S/02W-17DBC | MARI 4092 | 450248122572601 | 10/21/1996 | | 137 | 1.1 | 16.8 | 0.0 | 1949.0 | 1957.0 | <1954.5 | |
| 06S/03W-06CBC | YAMH 1907 | 450435123063101 | 10/15/1996 | 3.3 | 282 | 42.9 | 44.9 | 8.2 | 1961.0 | 1964.0 | 1970.0 | 33–57[2] |
| 06S/03W-06CBC | YAMH 1907 | 450435123063101 | 10/15/1996 | | 282 | 523.9 | 851.7 | 181.1 | 1979.0 | * | * | |
| 06S/03W-06CBC | YAMH 1907 | 450435123063101 | 10/15/1996 | | 282 | 2825.4 | 305.8 | 84.7 | * | 1986.5 | 1988.0 | |
| 06S/04W-03ABD | YAMH 3189 | 450502123092501 | 10/10/1996 | <0.1 | 739 | 5.6 | 5.8 | 0.0 | 1952.5 | 1950.5 | <1954.5 | <57&>57[3] |
| 06S/04W-03ABD | YAMH 3189 | 450502123092501 | 10/10/1996 | | 739 | 3.5 | 3.6 | 0.0 | 1951.5 | 1948.5 | <1954.5 | |
| 06S/04W-03ABD | YAMH 3189 | 450502123092501 | 10/10/1996 | | 739 | 3.2 | 3.1 | 0.0 | 1951.0 | 1948.0 | <1954.5 | |
| 11S/04W-28BDD1 | LINN 4146 | 443512123105001 | 10/24/1996 | 1.0 | 194 | 110.9 | 114.9 | 18.3 | 1966.5 | 1971.5 | 1976.0 | 26 |
| 11S/04W-28BDD1 | LINN 4146 | 443512123105001 | 10/24/1996 | | 194 | 96.3 | 106.1 | 11.1 | 1965.5 | 1971.0 | 1972.0 | |
| 11S/04W-28BDD1 | LINN 4146 | 443512123105001 | 10/24/1996 | | 194 | 98.6 | 106.8 | 12.7 | 1965.5 | 1971.0 | 1973.0 | |
| 11S/04W-28CAA | LINN 14280 | 443500123105001 | 10/17/1996 | 0.2 | 197 | 9.6 | 26.3 | 0.0 | 1954.0 | 1960.0 | <1954.5 | 37 |
| 11S/04W-28CAA | LINN 14280 | 443500123105001 | 10/17/1996 | | 197 | 9.1 | 27.2 | 0.0 | 1954.0 | 1960.5 | <1954.5 | |
| 11S/04W-28CAA | LINN 14280 | 443500123105001 | 10/17/1996 | | 197 | 9.8 | 28.2 | 0.0 | 1954.0 | 1960.5 | <1954.5 | |
| 11S/04W-34CDA | LINN 8753 | 443358123093601 | 10/16/1996 | <0.1 | 215 | 1.3 | 17.0 | 0.0 | 1949.0 | 1957.0 | <1954.5 | 40 |
| 11S/04W-34CDA | LINN 8753 | 443358123093601 | 10/16/1996 | | 215 | 1.4 | 17.5 | 0.0 | 1949.5 | 1957.0 | <1954.5 | |
| 11S/04W-34CDA | LINN 8753 | 443358123093601 | 10/16/1996 | | 215 | 0.0 | 16.6 | 0.0 | <1945.0 | 1957.0 | <1954.5 | |
| 11S/04W-34DDC | LINN 8756 | 443352123090401 | 10/17/1996 | <0.1 | 209 | 0.0 | 0.0 | 0.0 | <1945.0 | <1940.0 | <1954.5 | >57 |
| 11S/04W-34DDC | LINN 8756 | 443352123090401 | 10/17/1996 | | 209 | 0.0 | 0.0 | 0.0 | <1945.0 | <1940.0 | <1954.5 | |
| 11S/04W-34DDC | LINN 8756 | 443352123090401 | 10/17/1996 | | 209 | 0.0 | 0.0 | 0.0 | <1945.0 | <1940.0 | <1954.5 | |

**Table B1.** Chlorofluorocarbon data for ground-water samples collected October 7–24, 1996—Continued.

[Duplicate or triplicate samples were run for samples from each site. OWRD, Oregon Water Resources Department; ft NGVD 29, feet above NGVD 29; pg/kg, picograms per kilogram; mg/L, milligrams per liter; yrs, years; * samples contain chlorofluorocarbon (CFC) concentrations great than would be found in water at equilibrium with average global 1996 air; <, less than; >, greater than]

| Location | OWRD name | USGS name | Sample date | Dis-solved oxygen (mg/L) | Recharge elevation[1] (ft NGVD 29) | $CCl_3F$ concen-tration (pg/kg) | $CCl_2F_2$ concen-tration (pg/kg) | $C_2Cl_3F_3$ con centra-tion (pg/kg) | $CCl_3F$ model recharge date | $CCl_2F_2$ model recharge date | $C_2Cl_3F_3$ model recharge date | CFC model age of water (yrs) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12S/02W-19CCB1 | LINN 8054 | 443028122590901 | 10/23/1996 | <0.1 | 315 | 3.1 | 44.0 | 0.0 | 1951.0 | 1964.0 | <1954.5 | 33 |
| 12S/02W-19CCB1 | LINN 8054 | 443028122590901 | 10/23/1996 | | 315 | 7.2 | 42.5 | 0.0 | 1953.5 | 1964.0 | <1954.5 | |
| 12S/02W-19CCB1 | LINN 8054 | 443028122590901 | 10/23/1996 | | 315 | 5.1 | 47.6 | 0.0 | 1952.5 | 1964.5 | <1954.5 | |
| 12S/03W-07BCC2 | LINN 50852 | 443234123063101 | 10/22/1996 | <0.1 | 231 | 0.0 | 231.5 | 0.0 | <1945.0 | 1981.0 | <1954.5 | 16–57[2] |
| 12S/03W-07BCC2 | LINN 50852 | 443234123063101 | 10/22/1996 | | 231 | 1.0 | 352.9 | 0.0 | 1948.5 | 1990.0 | <1954.5 | |
| 12S/03W-07BCC2 | LINN 50852 | 443234123063101 | 10/22/1996 | | 231 | 8.1 | 456.1 | 0.0 | 1953.5 | * | <1954.5 | |
| 12S/03W-07CCB | LINN 50103 | 443211123062901 | 10/22/1996 | <0.1 | 231 | 9.9 | 41.3 | 0.0 | 1954.0 | 1963.5 | <1954.5 | 36 |
| 12S/03W-07CCB | LINN 50103 | 443211123062901 | 10/22/1996 | | 231 | 15.4 | 37.2 | 0.0 | 1956.0 | 1963.0 | <1954.5 | |
| 12S/03W-07CCB | LINN 50103 | 443211123062901 | 10/22/1996 | | 231 | 6.5 | 29.4 | 0.0 | 1953.0 | 1961.0 | <1954.5 | |
| 12S/03W-09BDC2 | LINN 10510 | 443232123034501 | 10/23/1996 | <0.1 | 250 | 6.0 | 127.6 | 0.0 | 1952.5 | 1972.5 | <1954.5 | 24 |
| 12S/03W-09BDC2 | LINN 10510 | 443232123034501 | 10/23/1996 | | 250 | 6.1 | 129.0 | 0.0 | 1953.0 | 1972.5 | <1954.5 | |
| 12S/03W-09BDC2 | LINN 10510 | 443232123034501 | 10/23/1996 | | 250 | 5.9 | 133.0 | 0.0 | 1952.5 | 1973.0 | <1954.5 | |
| 12S/03W-12BAA | LINN 10391 | 443252122595301 | 10/17/1996 | 2.7 | 271 | 169.2 | 124.6 | 115.6 | 1969.0 | 1972.5 | 1993.5 | 25 |
| 12S/03W-12BAA | LINN 10391 | 443252122595301 | 10/17/1996 | | 271 | 177.4 | 131.9 | 126.7 | 1969.5 | 1973.0 | * | |
| 12S/03W-12BAA | LINN 10391 | 443252122595301 | 10/17/1996 | | 271 | 173.3 | 119.8 | 121.3 | 1969.0 | 1972.0 | * | |
| 12S/04W-01ABB | LINN 50097 | 443343123070501 | 10/23/1996 | 2.8 | 223 | 5616.5 | 870.6 | 14.7 | * | * | 1974.0 | 0–57[2] |
| 12S/04W-01ABB | LINN 50097 | 443343123070501 | 10/23/1996 | | 223 | 5546.9 | 842.4 | 9.3 | * | * | 1971.0 | |

[1]Recharge elevation, assumed equal to elevation of static water level above NGVD29 in feet.

[2]Range of age for water given because sample contaminated with CFC by process other than air-water equilibrium.

[3]Mixture of water, one part < 57 yrs old and one part > 57 yrs old.

apparently old water lead to more recent $CCl_3F$-model recharge dates than $CCl_2F_2$-model recharge dates. Synthetic components in water pumps have been shown to be a source of $CCl_3F$ contamination to water samples (Plummer and Busenberg, 2000), and may have been the source of the observed small amounts of $CCl_3F$ in these two water samples.) In the case of site 06S/04W-03ABD, mixing of water from different contributing zones in the aquifer is the most likely explanation for the differences between $CCl_3F$ and $CCl_2F_2$-model recharge dates. The atmospheric ratio of $CCl_3F$ to $CCl_2F_2$ increased steadily between the late 1940s and late 1970s (Plummer and Busenberg, 2000). A mixture of CFC-free (pre-1940) water with CFC-containing (post-1940) water frequently results in different $CCl_3F$- and $CCl_2F_2$-model recharge dates, with $CCl_3F$-model recharge dates being more recent than $CCl_2F_2$-model recharge dates (Plummer and Busenberg, 2000). This was observed with site 06S/04W- 03ABD ($CCl_3F$-model recharge date of 1951 and $CCl_2F_2$-model recharge date of 1948). If no processes other than air-water equilibrium and mixing have affected CFC concentrations in the water at this site, the ratios of $CCl_3F$ to $CCl_2F_2$ could be interpreted as being a mixture of 22 percent water recharge in 1955 with 78 percent water recharged prior to 1940. These calculations would not be valid for conditions where both mixing of water and significant biodegradation of $CCl_3F$ occurred. In the presence of significant biodegradation, it would be safest to simply state that the water from this site contains a mixture of pre- and post-1940 water. It is worth noting that the contributing interval of this site (77 feet) was longer than at any of the other 20 sites, and, unlike any of the other sites, this site contained three distinct contributing zones. These well-construction data are consistent with the interpretation of a mixture of water at this site.

# References Cited

Busenberg, Eurybiades, and Plummer, L.N., 1992, Use of chlorofluorocarbons ($CCl_3F$ and $CCl_2F_2$) as hydrologic tracers and age-dating tools—The alluvium and terrace system of central Oklahoma: Water Resources Research, v. 28, p. 2257–2283.

Busenberg, Eurybiades, Plummer, L.N., Bartholomay, R.C., and Wayland, J.E., 1998, Chlorofluorocarbons, sulfur hexafluoride, and dissolved permanent gases in ground water from selected sites in and near the Idaho National Engineering and Environmental Laboratory, Idaho, 1994-97: U.S. Geological Survey Open-File Report 98–274, 72 p.

Hinkle, S.R., and Snyder, D.T., 1997, Comparison of chlorofluorocarbon-age dating with particle-tracking results of a regional ground-water flow model of the Portland Basin, Oregon and Washington: U.S. Geological Survey Water-Supply Paper 2483, 47 p.

Plummer, L.N., and Busenberg, Eurybiades, 2000, Chlorofluorocarbons, in Cook, P.G., and Herczeg, A.L., eds., Environmental Tracers in Subsurface Hydrology: Boston, Kluwer Academic Publishers, p. 441–478.

# Appendix C. Seepage Estimates of Selected Streams using Streamflow Measurements, Willamette Basin, Oregon

[Data source refers to source of seepage measurements; ft³/s, cubic feet per second; RM, river mile; MF, Middle Fork; bold numbers indicate seepage exceeds measurement uncertainty]

| Stream name | Reach | Date | Estimated gain (+) or loss (-) (ft³/s) | Gain/loss as % of streamflow | Cumulative gain/loss (ft³/s) | Cumulative gain/loss as % of streamflow | Data source |
|---|---|---|---|---|---|---|---|
| Butte Creek | RM 10.3-5.9 | 6/30/99 | **-9.1** | -19% | | | |
| | RM 5.9-1.0 | 6/30/99 | **8.2** | 15% | -0.9 | -2% | This study |
| | RM 10.3-5.9 | 9/16/99 | **-2** | -52% | | | |
| | RM 5.9-1.0 | 9/16/99 | **-2.2** | -132% | **4.2** | -253% | This study |
| | RM 10.3-5.9 | 5/30/00 | 0 | 0% | | | |
| | RM 5.9-1.0 | 5/30/00 | 2 | 2% | 2 | 2% | This study |
| | RM 10.3-5.9 | 9/12/00 | **-1.8** | -17% | | | |
| | RM 5.9-1.0 | 9/12/00 | **2.2** | 17% | 0.4 | 3% | This study |
| Drift Creek | RM 6.5-3.2 | 6/23/99 | **2.09** | 22% | | | |
| | RM 3.2-0.6 | 6/23/99 | -0.17 | -2% | **1.9** | 20% | This study |
| | RM 6.5-3.2 | 9/15/99 | **0.07** | 11% | | | |
| | RM 3.2-0.6 | 9/15/99 | -0.05 | -8% | 0.02 | 3% | This study |
| | RM 6.5-3.2 | 6/2/00 | **2.34** | 13% | | | |
| | RM 3.2-0.6 | 6/2/00 | **1.97** | 10% | **4.31** | 21% | This study |
| | RM 6.5-3.2 | 9/11/00 | **-0.18** | -11% | | | |
| | RM 3.2-0.6 | 9/11/00 | 0.01 | 1% | **-0.17** | -10% | This study |
| Abiqua Creek | RM 5.8-2.4 | 6/1/00 | 9 | 6% | | | |
| | RM 2.4-0.4 | 6/1/00 | -1 | -1% | 8 | 6% | This study |
| | RM 5.8-2.4 | 9/13/00 | **-3.8** | -37% | | | |
| | RM 2.4-0.4 | 9/13/00 | **1.2** | 10% | **-2.6** | -23% | This study |

# Appendix C. Seepage Estimates of Selected Streams using Streamflow Measurements, Willamette Basin, Oregon—Continued

[Data source refers to source of seepage measurements; ft³/s, cubic feet per second; RM, river mile; MF, Middle Fork; bold numbers indicate seepage exceeds measurement uncertainty]

| Stream name | Reach | Date | Estimated gain (+) or loss (-) (ft³/s) | Gain/loss as % of streamflow | Cumulative gain/loss (ft³/s) | Cumulative gain/loss as % of streamflow | Data source |
|---|---|---|---|---|---|---|---|
| Pudding River | RM 49.7-45.5 | 5/2/96 | 5 | 1% | | | |
| | RM 45.5-40.7 | 5/2/96 | 26 | 3% | 31 | 4% | Lee and Risley, 2002 |
| | RM 26.8-22.3 | 5/3/96 | 38 | 4% | 38 | 4% | Lee and Risley, 2002 |
| | RM 22.3-17.5 | 5/3/96 | 44 | 4% | 82 | 7% | Lee and Risley, 2002 |
| | RM 17.5-8.1 | 5/3/96 | 75 | 5% | **157** | 11% | Lee and Risley, 2002 |
| | RM 49.7-45.5 | 9/24/96 | -2.6 | -5% | | | Lee and Risley, 2002 |
| | RM 45.5-40.7 | 9/24/96 | **-5.8** | -12% | **-8.4** | -18% | Lee and Risley, 2002 |
| | RM 26.8-22.3 | 9/25/96 | **32.6** | 29% | **32.6** | 29% | Lee and Risley, 2002 |
| | RM 22.3-17.5 | 9/25/96 | **-23.2** | -22% | 9.4 | 9% | Lee and Risley, 2002 |
| | RM 17.5-8.1 | 9/25/96 | 11.8 | 9% | **21.2** | 16% | Lee and Risley, 2002 |
| | RM 49.7-45.5 | 9/16-17/1999 | 0.83 | 3% | 0.83 | 3% | This study |
| | RM 45.5-40.7 | 9/20/99 | | | | | |
| | RM 40.7-26.8 | 9/20/99 | **4.7** | 17% | **4.7** | 17% | This study |
| | RM 26.8-23.4 | 9/20-21/1999 | 0 | 0% | **4.7** | 17% | This study |
| | RM 23.4-17.5 | 9/21/99 | **3.87** | 11% | **8.57** | 25% | This study |
| | RM 17.5-8.1 | 9/21-22/1999 | **5.03** | 12% | **13.6** | 33% | This study |
| | RM 8.1-5.1 | 9/22/99 | 1.22 | 3% | **14.82** | 31% | This study |
| | RM 49.7-45.5 | 9/16-17/2000 | -0.7 | -3% | | | This study |
| | RM 45.5-40.7 | 9/20/00 | 0.1 | 0% | -0.6 | -3% | This study |
| | RM 40.7-23.4 | 9/20/00 | 0.8 | 2% | 0.2 | 1% | This study |
| | RM 23.4-17.5 | 9/21/00 | -1.3 | -3% | -1.1 | -3% | This study |
| | RM 17.5-8.1 | 9/21-22/2000 | **8.3** | 16% | 7.2 | 14% | This study |
| | RM 8.1-5.1 | 9/22/00 | 1.1 | 2% | 8.3 | 14% | This study |

# Appendix C. Seepage Estimates of Selected Streams using Streamflow Measurements, Willamette Basin, Oregon—Continued

[Data source refers to source of seepage measurements; ft³/s, cubic feet per second; RM, river mile; MF, Middle Fork; bold numbers indicate seepage exceeds measurement uncertainty]]

| Stream name | Reach | Date | Estimated gain (+) or loss (-) (ft³/s) | Gain/loss as % of streamflow | Cumulative gain/loss (ft³/s) | Cumulative gain/loss as % of streamflow | Data source |
|---|---|---|---|---|---|---|---|
| South Yamhill | RM 37.7-26.9 | 06/12-13/96 | 10.3 | 0% | 10.3 | 0% | Lee and Risley, 2002 |
| | RM 26.9-16.7 | 06/12-13/96 | 38.7 | 4% | 49 | 4% | Lee and Risley, 2002 |
| | RM 16.8-5.6 | 06/12-13/96 | **95.1** | 10% | **144.1** | 13% | Lee and Risley, 2002 |
| | RM 37.7-26.9 | 9/18/96 | 8 | 5% | 8 | 5% | Lee and Risley, 2002 |
| South Santiam | RM 37.0-33.4 | 4/30/96 | 374.2 | 9% | | | Lee and Risley, 2002 |
| | RM 33.5-27.7 | 5/1/96 | -160.7 | -4% | 213.5 | 5% | Lee and Risley, 2002 |
| | RM 27.7-23.3 | 5/2/96 | -150.7 | -4% | 62.8 | 1% | Lee and Risley, 2002 |
| | RM 23.3-18.2 | 5/3/96 | -427.6 | -11% | -364.8 | -10% | Lee and Risley, 2002 |
| | RM 37.0-33.4 | 9/17/96 | 29 | 4% | 29 | | Lee and Risley, 2002 |
| | RM 33.5-27.7 | 9/18/96 | -77.8 | -11% | -48.8 | -7% | Lee and Risley, 2002 |
| | RM 27.7-23.3 | 9/19/96 | 62.7 | 8% | 13.9 | 2% | Lee and Risley, 2002 |
| | RM 23.3-18.2 | 9/20/96 | -47.7 | -7% | -33.8 | -5% | Lee and Risley, 2002 |
| MF Willamette River | RM 195-192.8 | 4/15/96 | -4.7 | -0% | -4.7 | -0% | Lee and Risley, 2002 |
| | RM 192.8-190.2 | 4/15/96 | -103.4 | -5% | -108.1 | -6% | Lee and Risley, 2002 |
| Willamette River | RM 169.6-163.7 | 5/7/96 | 117 | 2% | 117 | 2% | Lee and Risley, 2002 |
| | RM 163.7-161.0 | 5/8/96 | 190 | 3% | 307 | 4% | Lee and Risley, 2002 |
| | RM 161.0-156.3 | 5/9/96 | -70 | -1% | 237 | 3% | Lee and Risley, 2002 |
| | RM 156.3-149.6 | 5/10/96 | -50 | -1% | 187 | 3% | Lee and Risley, 2002 |
| | RM 134.4-127.5 | 5/8/96 | -307.4 | -4% | -307.4 | -4% | Lee and Risley, 2002 |
| | RM 127.5-124.4 | 5/8/96 | 60 | 1% | -247.4 | -3% | Lee and Risley, 2002 |
| | RM 124.4-119.9 | 5/8/96 | 110 | 1% | -137.4 | -2% | Lee and Risley, 2002 |

# Appendix C. Seepage Estimates of Selected Streams using Streamflow Measurements, Willamette Basin, Oregon—Continued

[Data source refers to source of seepage measurements; ft³/s, cubic feet per second; RM, river mile; MF, Middle Fork; bold numbers indicate seepage exceeds measurement uncertainty]

| Stream name | Reach | Date | Estimated gain (+) or loss (-) (ft³/s) | Gain/loss as % of streamflow | Cumulative gain/loss (ft³/s) | Cumulative gain/loss as % of streamflow | Data source |
|---|---|---|---|---|---|---|---|
| Willamette River | RM 94.2-89.1 | 5/9/96 | 0 | 0% | 0 | 0% | Lee and Risley, 2002 |
| | RM 89.1-84.1 | 5/9/96 | 321.3 | 2% | 321.3 | 2% | Lee and Risley, 2002 |
| | RM 84.1-77.8 | 5/9/96 | 136.6 | 1% | 457.9 | 3% | Lee and Risley, 2002 |
| | RM 52.4-46.5 | 5/10/96 | 64.1 | 0% | 64.1 | 0% | Lee and Risley, 2002 |
| | RM 46.5-43.0 | 5/10/96 | -224 | -1% | -159.9 | -1% | Lee and Risley, 2002 |
| | RM 43.0-39.0 | 5/10/96 | 593 | 4% | 433.1 | 3% | Lee and Risley, 2002 |
| MF Willamette River | RM 195-192.8 | 7/23/96 | **-350** | -14% | -350 | -14% | Lee and Risley, 2002 |
| | RM 192.8-190.5 | 7/23/96 | **381.4** | 14% | 31.4 | 1% | Lee and Risley, 2002 |
| | RM 190.5-187.8 | 7/23/96 | -95.9 | -4% | -64.5 | -2% | Lee and Risley, 2002 |
| Willamette River | RM 169.6-163.3 | 7/24/96 | 370.8 | 7% | 370.8 | 7% | Lee and Risley, 2002 |
| | RM 163.7-161.0 | 7/24/96 | -50 | -1% | 320.8 | 6% | Lee and Risley, 2002 |
| | RM 161.0-156.3 | 7/24/96 | 180 | 3% | 500.8 | 10% | Lee and Risley, 2002 |
| | RM 156.3-149.6 | 7/24/96 | -30 | -1% | **470.8** | 9% | Lee and Risley, 2002 |
| | RM 134.4-127.5 | 7/30/96 | -191.7 | -4% | -191.7 | -4% | Lee and Risley, 2002 |
| | RM 127.5-124.4 | 7/30/96 | -49.1 | -1% | -240.8 | -5% | Lee and Risley, 2002 |
| | RM 124.4-119.9 | 7/30/96 | 42.2 | 1% | -198.6 | -4% | Lee and Risley, 2002 |
| | RM 94.2-89.1 | 7/31/96 | 11.7 | 0% | 11.7 | 0% | Lee and Risley, 2002 |
| | RM 89.1-84.1 | 7/31/96 | -31.3 | -0% | -19.6 | -0% | Lee and Risley, 2002 |
| | RM 84.1-77.8 | 7/31/96 | -281.8 | -4% | -301.4 | -4% | Lee and Risley, 2002 |
| | RM 52.4-46.5 | 8/1/96 | -280.5 | -4% | -280.5 | -4% | Lee and Risley, 2002 |
| | RM 46.5-43.0 | 8/1/96 | -22.7 | -0% | -303.2 | -4% | Lee and Risley, 2002 |
| | RM 43.0-39.0 | 8/1/96 | 219.3 | 3% | -83.9 | -1% | Lee and Risley, 2002 |

# Appendix C. Seepage Estimates of Selected Streams using Streamflow Measurements, Willamette Basin, Oregon—Continued

[Data source refers to source of seepage measurements; ft$^3$/s, cubic feet per second; RM, river mile; MF, Middle Fork; bold numbers indicate seepage exceeds measurement uncertainty]

| Stream name | Reach | Date | Estimated gain (+) or loss (-) (ft$^3$/s) | Gain/loss as % of streamflow | Cumulative gain/loss (ft$^3$/s) | Cumulative gain/loss as % of streamflow | Data source |
|---|---|---|---|---|---|---|---|
| Tualatin River | RM 58.8-51.4 | low flow | **13.4** | 12% | 13.4 | 12% | Kelly and others, 1999 |
| | RM 51.5-38.4 | low flow | 7.2 | 5% | 20.6 | 14% | Kelly and others, 1999 |
| | RM 38.4-33.3 | low flow | 15.1 | 8% | 35.7 | 18% | Kelly and others, 1999 |
| | RM 33.3-1.8 | low flow | 9.5 | 5% | 45.2 | 24% | Kelly and others, 1999 |