Available Groundwater Determination
Technical Memorandum

Platte River Basin Water Plan Update
Groundwater Study
Level I (2009 – 2013)

by

Paul Taucher, Timothy T. Bartos, Karl G. Taboga, Laura L. Hallberg, Melanie L. Clark, James Stafford, Tomas Gracias, Bern Hinckley, Brett Worman, Keith Clarey, Lisa Lindemann, Scott A. Quillinan, Dave Copeland, Richard Hays, Melissa Thompson

Karl G. Taboga, Editor

Prepared for Wyoming Water Development Commission

Laramie, Wyoming

2013
Platte River Basin Water Plan Update
Groundwater Study
Level I (2009-2013)

Available Groundwater Determination
Technical Memorandum

Prepared for the Wyoming Water Development Commission

This publication is also available online at:
http://waterplan.state.wy.us/plan/platte/platte-plan.html

Wyoming State Geological Survey

Copyright © 2013 by the Wyoming State Geological Survey. All rights reserved.

The WSGS encourages fair use of its material. We request that credit be expressly given to the “Wyoming State Geological Survey” when citing information from this publication. Please contact the WSGS at (307) 766-2286, ext. 224, or by email at wsgs.sales@wyo.gov, if you have any questions about citing materials, preparing acknowledgments, or extensive use of this material. We appreciate your cooperation.

Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement or approval by the State of Wyoming or the WSGS. Individuals with disabilities who require an alternate form of this publication should contact the WSGS. TTY relay operator 800-877-9975.

For additional information about the WSGS or to order publications and maps, log on to www.wsgs.uwyo.edu, call (307) 766-2286, ext. 224, or email wsgs.sales@wyo.gov.

Suggested citation:

Cover photo: North Platte River below Seminoe Dam, Wyoming. Precambrian granitic outcrops of Seminoe Mountains shown in the background. Photo by James Stafford (2010).
Available Groundwater Determination

Technical Memorandum

WWDC Platte River Basin Water Plan Update

Groundwater Study
Level 1 (2009 – 2013)
December 2013

Paul Taucher3, Timothy T. Bartos2, Karl G. Taboga1, Laura L. Hallberg2, Melanie L. Clark2, James Stafford1, Tomas Gracias1, Bern Hinckley4, Brett Worman1, Keith Clarey2, Lisa Lindemann6; Scott A. Quillinan7, Dave Copeland1, Richard Hays1, Melissa Thompson1

Karl G. Taboga1, Editor

This report was prepared under contract for the Wyoming Water Development Commission (WWDC)5 by the Wyoming State Geological Survey (WSGS)1, the United States Geological Survey (USGS)2, and the Water Resources Data System (WRDS) in cooperation with the Wyoming State Engineer’s Office (WSEO) and the Wyoming Oil and Gas Commission (WOGCC).

1Wyoming State Geologic Survey, P.O. Box 1347, Laramie, Wyoming, 82073-1347
2U.S. Geological Survey, Wyoming Water Science Center, 21 Progress Circle, Suite 6, Cheyenne, Wyoming, 82007
3Energy Compliance LLC, 2302 Nighthawk Drive, Laramie, Wyoming, 82070
4Hinckley Consulting, 419 S. 5th Street, Laramie, Wyoming, 82070
5Wyoming Water Development Commission, 6920 Yellowtail Road, Cheyenne, Wyoming, 82002
6Wyoming State Engineer’s Office, Herschler Building, Cheyenne, Wyoming, 82002
7University of Wyoming, Carbon Management Institute, 2020 Grand Avenue, Suite 500, Laramie Wyoming, 82070
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>TABLE OF CONTENTS</td>
<td>ii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>x</td>
</tr>
<tr>
<td>CHAPTER 1: INTRODUCTION</td>
<td>1-1</td>
</tr>
<tr>
<td>1.1 Interagency Agreement and Scope</td>
<td>1-2</td>
</tr>
<tr>
<td>1.2 Agency participation</td>
<td>1-6</td>
</tr>
<tr>
<td>1.3 Legal and institutional framework</td>
<td>1-6</td>
</tr>
<tr>
<td>1.3.1 Wyoming water law – ground water appropriation, development and use</td>
<td>1-7</td>
</tr>
<tr>
<td>1.3.2 Interstate agreements</td>
<td>1-7</td>
</tr>
<tr>
<td>1.3.3 Wyoming water law – ground water quality</td>
<td>1-8</td>
</tr>
<tr>
<td>1.3.4 Other agencies</td>
<td>1-9</td>
</tr>
<tr>
<td>1.3.5 Authorship</td>
<td>1-9</td>
</tr>
<tr>
<td>1.3.6 Acknowledgements</td>
<td>1-9</td>
</tr>
<tr>
<td>CHAPTER 2: BACKGROUND</td>
<td>2-11</td>
</tr>
<tr>
<td>2.1 Sources of data</td>
<td>2-12</td>
</tr>
<tr>
<td>2.2 Previous regional scale investigations</td>
<td>2-12</td>
</tr>
<tr>
<td>2.3 Current USGS regional scale investigations</td>
<td>2-15</td>
</tr>
<tr>
<td>2.4 Current available groundwater determination</td>
<td>2-15</td>
</tr>
<tr>
<td>2.5 Maps</td>
<td>2-17</td>
</tr>
<tr>
<td>CHAPTER 3: DESCRIPTION OF THE STUDY AREA</td>
<td>3-19</td>
</tr>
<tr>
<td>3.1 Physiography, landforms, topography and surface drainage</td>
<td>3-20</td>
</tr>
<tr>
<td>3.2 Climate, precipitation and vegetation</td>
<td>3-23</td>
</tr>
<tr>
<td>3.3 Population distribution, land use, and land ownership</td>
<td>3-23</td>
</tr>
<tr>
<td>CHAPTER 4: GEOLOGIC SETTING</td>
<td>4-27</td>
</tr>
<tr>
<td>4.1 General/historical geology</td>
<td>4-28</td>
</tr>
<tr>
<td>4.2 Structural geology</td>
<td>4-29</td>
</tr>
<tr>
<td>4.3 Basin stratigraphy</td>
<td>4-30</td>
</tr>
<tr>
<td>4.4 Granite Mountains, Green Mountain, Ferris Mountains, Seminoe Mountains and Freezeout Mountains</td>
<td>4-30</td>
</tr>
<tr>
<td>4.4.1 Granite Mountains</td>
<td>4-30</td>
</tr>
<tr>
<td>4.4.2 Crooks Mountain, Green Mountain, Ferris Mountains, Seminoe Mountains, Shirley Mountains</td>
<td>4-33</td>
</tr>
<tr>
<td>4.5 Hanna-Carbon Basin and surrounding mountain ranges</td>
<td>4-35</td>
</tr>
<tr>
<td>4.6 Casper Arch</td>
<td>4-35</td>
</tr>
<tr>
<td>4.7 Shirley Basin</td>
<td>4-35</td>
</tr>
<tr>
<td>4.8 Laramie Basin</td>
<td>4-39</td>
</tr>
<tr>
<td>4.9 Laramie, Medicine Bow and Sierra Madre Mountain Ranges</td>
<td>4-39</td>
</tr>
<tr>
<td>4.10 Rawlins Uplift</td>
<td>4-50</td>
</tr>
<tr>
<td>4.11 Saratoga Valley</td>
<td>4-51</td>
</tr>
<tr>
<td>4.12 Great Divide Basin, Wind River Basin, Powder River Basin</td>
<td>4-51</td>
</tr>
<tr>
<td>4.12.1 Great Divide Basin</td>
<td>4-51</td>
</tr>
<tr>
<td>4.12.2 Wind River Basin</td>
<td>4-51</td>
</tr>
<tr>
<td>4.12.3 Powder River Basin</td>
<td>4-52</td>
</tr>
<tr>
<td>4.12.4 Green River Basin</td>
<td>4-54</td>
</tr>
<tr>
<td>4.13 Wind River Range</td>
<td>4-54</td>
</tr>
<tr>
<td>4.14 Hartville Uplift</td>
<td>4-55</td>
</tr>
<tr>
<td>4.15 Denver Basin</td>
<td>4-55</td>
</tr>
<tr>
<td>4.16 Geothermal resources</td>
<td>4-55</td>
</tr>
<tr>
<td>4.17 Mineral resources</td>
<td>4-60</td>
</tr>
<tr>
<td>CHAPTER 5: TECHNICAL CONCEPTS: HYDROGEOLOGY AND GROUNDWATER QUALITY</td>
<td>5-61</td>
</tr>
<tr>
<td>5.1 Definitions and concepts</td>
<td>5-62</td>
</tr>
</tbody>
</table>
CHAPTER 7: PHYSICAL AND CHEMICAL CHARACTERISTICS OF HYDROGEOLOGIC UNITS

7.1 Platte River Basin

7.2 Cenozoic hydrogeologic units

7.2.1 Quaternary unconsolidated-deposit aquifers

7.2.1.1 Quaternary alluvial aquifers

7.2.1.2 Quaternary terrace-deposit aquifers

7.2.1.3 Aquifers in Quaternary dune sand (eolian) deposits

7.2.1.4 Aquifers in Quaternary glacial deposits

7.2.2 Tertiary hydrogeologic units

7.2.2.1 High Plains aquifer system

7.2.2.1.1 Ogallala aquifer

7.2.2.1.2 Arikaree aquifer

7.2.2.1.3 White River aquifer/confining unit

7.2.2.2 Chadron aquifer/confining unit

7.2.2.3 Bug Formation

7.2.2.4 Kortes and Moonstone aquifers

7.2.2.5 Aquifers in undifferentiated Miocene rocks and Split Rock aquifer

7.2.2.6 Browns Park aquifer

CHAPTER 6: PLATTE RIVER BASIN HYDROGEOLOGY AND GROUNDWATER RESOURCES

6.1 Hydrostratigraphy and recharge to aquifer outcrop areas

6.2 Average annual recharge

6.3 Summary

CHAPTER 5: HYDROGEOLOGIC UNITS
7.2.2.7 White River aquifer and confining unit (not associated with the High Plains aquifer system) ... 7-167
7.2.2.8 Bishop Conglomerate ................................................................. 7-170
7.2.2.9 Bridger confining unit ............................................................... 7-170
7.2.2.10 Laney confining unit ............................................................... 7-170
7.2.2.11 Wagon Bed aquifer and confining unit ................................... 7-171
7.2.2.12 Ice Point Conglomerate .......................................................... 7-172
7.2.2.13 Crooks Gap Conglomerate ...................................................... 7-172
7.2.2.14 Battle Spring aquifer ............................................................... 7-173
7.2.2.15 Wind River aquifer ................................................................. 7-174
7.2.2.16 Wasatch aquifer ................................................................... 7-176
7.2.2.17 Coalmont Formation .............................................................. 7-178
7.2.2.18 Hanna aquifer ....................................................................... 7-180
7.2.2.19 Ferris aquifer ........................................................................ 7-182
7.2.2.20 Fort Union aquifer ................................................................. 7-184
7.3 Mesozoic Hydrogeologic Units ........................................................ 7-187
7.3.1 Lance aquifer .............................................................................. 7-187
7.3.2 Medicine Bow aquifer ................................................................. 7-190
7.3.3 Fox Hills aquifer ......................................................................... 7-191
7.3.4 Lewis confining unit .................................................................... 7-194
7.3.5 Pierre confining unit ..................................................................... 7-195
7.3.6 Mesaverde aquifer ..................................................................... 7-196
7.3.6.1 Teapot Sandstone Member of Mesaverde Formation ............. 7-201
7.3.6.2 Parkman Sandstone Member of Mesaverde Formation .......... 7-202
7.3.7 Cody confining unit ..................................................................... 7-203
7.3.7.1 Shannon Sandstone Member of the Cody Shale ..................... 7-205
7.3.8 Steele confining unit .................................................................... 7-206
7.3.9 Niobrara confining unit ............................................................... 7-208
7.3.10 Frontier aquifer ......................................................................... 7-211
7.3.10.1 Wall Creek Sandstone Member of Frontier Formation ......... 7-217
7.3.11 Carlile, Greenhorn, and Belle Fourche confining units ............ 7-218
7.3.12 Mowry-Thermopolis confining unit and Muddy Sandstone aquifer .......................................................... 7-220
7.3.13 Cloverly aquifer ......................................................................... 7-224
7.3.14 Inyan Kara aquifer ................................................................. 7-230
7.3.15 Morrison confining unit or Morrison aquifer and confining unit ................................................................................ 7-230
7.3.16 Sundance aquifer ....................................................................... 7-233
7.3.17 Gypsum Spring confining unit ................................................... 7-237
7.3.18 Nugget aquifer .......................................................................... 7-237
7.3.19 Jelm aquifer, Chugwater confining unit, and Chugwater aquifer and confining unit ........................................................... 7-241
7.3.19.1 Jelm aquifer ........................................................................... 7-243
7.3.19.2 Chugwater confining unit and Chugwater aquifer and confining unit ........................................................ 7-244
7.3.19.2.1 Alcova confining unit within Chugwater aquifer and confining unit ............................................................ 7-246
7.3.20 Goose Egg confining unit and Goose Egg aquifer and confining unit ........................................................................ 7-246
7.3.21 Dinwoody confining unit ............................................................ 7-248
7.4 Paleozoic hydrogeologic units ......................................................... 7-249
7.4.1 Minnekahta Limestone ................................................................. 7-250
7.4.2 Opeche confining unit ................................................................. 7-250
7.4.3 Phosphoria aquifer and confining unit ....................................... 7-250
7.4.4 Forelle Limestone ...................................................................... 7-253
7.4.5 Satanka confining unit ............................................................... 7-254
7.4.6 Casper aquifer ............................................................................ 7-256
7.4.6.1 Casper aquifer (samples from the Casper Formation) ............ 7-262
CHAPTER 9: LOOKING TO THE FUTURE

7.4.6.2 Casper aquifer (samples from the Fountain Formation) ........................................... 7-266
7.4.7 Hartville aquifer ........................................................................................................ 7-267
7.4.8 Tensleep aquifer ....................................................................................................... 7-269
7.4.9 Amsden aquifer ...................................................................................................... 7-274
7.4.10 Madison aquifer .................................................................................................. 7-276
7.4.11 Guernsey aquifer ................................................................................................. 7-282
7.4.12 Englewood Formation/Limestone ........................................................................ 7-283
7.4.13 Fremont Canyon aquifer ..................................................................................... 7-283
7.4.14 Gallatin and Gros Ventre confining units .............................................................. 7-283
7.4.15 Aquifers in undifferentiated Cambrian rocks ....................................................... 7-285
7.4.16 Flathead aquifer ................................................................................................... 7-286
7.5 Precambrian basal confining unit ............................................................................. 7-288

CHAPTER 8: GROUNDWATER DEVELOPMENT AND USE AND BASIN-WIDE WATER BALANCE ... 8-291
8.1 Information from previous Water Plans ....................................................................... 8-293
8.2 Groundwater withdrawal and consumptive use estimations in this memorandum .......... 8-293
8.2.1 Irrigation .................................................................................................................. 8-300
8.2.2 Livestock watering ................................................................................................. 8-301
8.2.3 Municipal/community public water systems ............................................................ 8-301
8.2.4 Non-community public water systems .................................................................. 8-302
8.2.5 Rural domestic ...................................................................................................... 8-302
8.2.6 Combined municipal and domestic withdrawals and consumptive use .................... 8-303
8.2.7 Recreation and environmental .............................................................................. 8-303
8.2.8 Industrial and mining ............................................................................................ 8-303
8.3 Information from hydrogeologic unit studies .............................................................. 8-305
8.4 Groundwater permit information .............................................................................. 8-305
8.4.1 Groundwater permits by permit status ................................................................ 8-306
8.4.2 Groundwater permits by depth and yield ................................................................ 8-306
8.4.3 Groundwater permits by use ................................................................................ 8-308
8.4.4 Groundwater permits location maps by use ............................................................. 8-308
8.4.4.1 Irrigation-use permits ......................................................................................... 8-310
8.4.4.2 Livestock use permits ......................................................................................... 8-310
8.4.4.3 SEO municipal-use permits ............................................................................ 8-324
8.4.4.4 Domestic-use permits ....................................................................................... 8-324
8.4.4.5 Source Water Assessment Program (SWAP) wells and springs ......................... 8-324
8.4.4.6 Industrial and mineral use and CBNG permits .................................................... 8-327
8.4.4.6.1 Groundwater use for oil and gas production .................................................. 8-331
8.4.4.6.2 Groundwater use for coal and uranium mining ............................................. 8-348
8.4.4.6.3 Groundwater use for non-energy minerals development ................................ 8-348
8.4.4.7 Monitoring wells .............................................................................................. 8-348
8.4.4.8 Miscellaneous-use permits .............................................................................. 8-357
8.4.4.9 Hydrothermal use ............................................................................................. 8-357
8.5 Groundwater interference/interconnection with surface water .................................. 8-357
8.5.1 Interference between wells .................................................................................... 8-360
8.5.2 Interconnection between groundwater and surface water ...................................... 8-360

CHAPTER 9: LOOKING TO THE FUTURE ......................................... 9-363
9.1 Issues affecting future groundwater development ....................................................... 9-364
9.1.1 Groundwater development potential in areas of the North Platte River Basin that fall within the jurisdiction of the 2001 Modified North Platte River Decree .............................................. 9-366
9.1.2 Future water use opportunities .............................................................................. 9-366
9.1.3 Potential new groundwater development prospects .............................................. 9-367
9.1.4 Recent WWDC groundwater development prospects ........................................... 9-370
9.1.4.1 Cheyenne ....................................................................................................... 9-370
9.1.4.2 Douglas ......................................................................................................... 9-370
9.1.4.3 Elk Mountain .................................................................................................. 9-370
9.1.4.4 Lander Mill ..................................................................................................... 9-370
9.1.4.4 Encampment........................................................................................................................................ 9-371
9.1.4.5 Glendo ................................................................................................................................................. 9-371
9.1.4.6 Glenrock................................................................................................................................................. 9-371
9.1.4.7 Lance Creek ......................................................................................................................................... 9-371
9.1.4.8 Laramie County .................................................................................................................................... 9-371
9.1.4.9 Laramie ................................................................................................................................................. 9-371
9.1.4.10 Manville .............................................................................................................................................. 9-371
9.1.4.11 Split Rock aquifer ............................................................................................................................. 9-372
9.1.4.12 Riverside ............................................................................................................................................ 9-372
9.1.4.13 Yoder ................................................................................................................................................ 9-372
9.1.5 Current WWDC groundwater development prospects ........................................................................... 9-372
9.1.6 Current SEO project in the Laramie county groundwater control area .............................................. 9-373
9.1.6.1 State Engineer's Temporary Order ................................................................................................... 9-374
9.1.6.2 Hydrogeologic Study of the Laramie County Control Area ................................................................. 9-375
9.1.7 Groundwater interference and interconnection with surface water .................................................... 9-375
9.2 Recommendations for future updates ...................................................................................................... 9-376
9.2.1 Data challenges ....................................................................................................................................... 9-376
9.2.2 Current and future research efforts......................................................................................................... 9-377

REFERENCES ................................................................................................................................................ 379
APPENDIX A: DESCRIPTION OF GIS GEOLOGIC UNITS, PLATTE RIVER BASIN, WYOMING, COLORADO, AND NEBRASKA................................................................................................................................. 413
APPENDIX B: WWDC GROUNDWATER STUDIES .......................................................................................... 427
APPENDIX C: GIS DATASET SOURCES FOR PLATES AND FIGURES ............................................................ 445
APPENDIX D: TECHNICAL MEMORANDUM TO SEO REGARDING HYDROLOGICAL CONNECTION OF GROUNDWATER WELLS TO SURFACE FLOWS IN PLATTE RIVER BASIN ........................................................................ 449
APPENDIX E: SUMMARY STATISTICS FOR ENVIRONMENTAL GROUNDWATER SAMPLES, VARIOUS SITES IN PLATTE RIVER BASIN ........................................................................................................................................ 465
APPENDIX F: SUMMARY STATISTICS FOR PRODUCED GROUNDWATER SAMPLES, VARIOUS SITES IN PLATTE RIVER BASIN ........................................................................................................................................ 541
APPENDIX G: TRILINEAR DIAGRAMS FOR ENVIRONMENTAL GROUNDWATER SAMPLES, VARIOUS SITES IN PLATTE RIVER BASIN ........................................................................................................................................ 565
APPENDIX H: TRILINEAR DIAGRAMS FOR PRODUCED GROUNDWATER SAMPLES, VARIOUS SITES IN PLATTE RIVER BASIN ........................................................................................................................................ 575
LIST OF FIGURES

1. Figure 1-1. Major drainage basins, Wyoming.
2. Figure 3-1. Subregion, township, and range index map, Platte River Basin.
3. Figure 3-2. Major structural and physiographic features, drainages, and bodies of water, Platte River Basin.
4. Figure 3-3. Average Annual Precipitation (1981 - 2010), Platte River Basin.
5. Figure 4-1. Major Laramide structural elements, Platte River Basin
6. Figure 4-2. Geologic cross section A-A’.
7. Figure 4-3. Geologic cross section B-B’-B”.
8. Figure 4-4. Geologic cross section C-C’.
9. Figure 4-5. Geologic cross section D-D’.
10. Figure 4-6. Geologic cross section E-E’.
11. Figure 4-7. Geologic cross section F-F’.
12. Figure 4-8. Geologic cross section G-G’.
13. Figure 4-9. Geologic cross section H-H’.
14. Figure 4-10. Geologic cross section I-I’.
15. Figure 4-11. Geologic cross section J-J’.
16. Figure 4-12. Geologic cross section K-K’.
17. Figure 4-13. Geologic cross section L-L’.
18. Figure 4-14. Geologic cross section M-M’.
19. Figure 4-15. Geologic cross section N-N’.
20. Figure 4-16. Geologic cross section O-O’.
21. Figure 4-17. Geologic cross section P-P’.
22. Figure 4-18. Geologic cross section Q-Q’.
23. Figure 4-19. Geologic cross section R-R’.
24. Figure 4-20. Geologic cross section S-S’.
25. Figure 4-21. Geothermal resources, Platte River Basin
26. Figure 5-1. Conceptual cross-section of groundwater features that occur in a typical Rocky Mountain Laramide structural basin. (Adapted from WWC Engineering and others, 2007)
27. Figure 5-2. Estimated net annual aquifer recharge, Platte River Basin, Wyoming.
28. Figure 5-3. Aquifer sensitivity, Platte River Basin, Wyoming.
29. Figure 5-4. Potential groundwater contaminant sources: oil and gas fields, pipelines, refineries, and Class II injection and disposal wells, Platte River Basin, Wyoming.
30. Figure 5-5. Potential groundwater contaminant sources: Class I, III, and V injection wells permitted through the Wyoming Department of Environmental Quality Underground Injection Control (UIC) program, and active and expired outfalls in the Wyoming Pollutant Discharge Elimination System (WYPDES) program, Platte River Basin, Wyoming.
31. Figure 5-6 - Potential groundwater contaminant sources: Wyoming Department of Environmental Quality permitted and inventoried solid and hazardous waste facilities, and concentrated animal feeding operations (CAFOs), Platte River Basin, Wyoming.
32. Figure 5-7 - Potential groundwater contaminant sources: Wyoming Department of Environmental Quality Abandoned Mine Land Division abandoned mine sites, Platte River Basin, Wyoming.
33. Figure 5-8 - Potential groundwater contaminant sources: Wyoming Department of Environmental Quality Land Quality Division permitted mines, [quarries, and pits], Platte River Basin, Wyoming.
34. Figure 5-9 - Potential groundwater contaminant sources: Wyoming State Geological Survey mapped mines, Platte River Basin, Wyoming, (locations from Harris, 2004).
35. Figure 5-10 - Potential groundwater contaminant sources: Wyoming Department of Environmental Quality (WDEQ) permitted storage tanks and commercial disposal pits; WDEQ Voluntary
Remediation Program (VRP), Brownfield, Independent cleanup process (ICP), and orphan sites; and known contaminated areas in WDEQ’s groundwater program, Platte River Basin, Wyoming.

36. Figure 5-11 - Surface Water Assessment and Protection, Platte River Basin, Wyoming.
37. Figure 6-1. Estimated net annual aquifer recharge – surface Quaternary Aquifer, Platte River Basin, Wyoming.
38. Figure 6-2. Estimated net annual aquifer recharge – surface Lower Tertiary Aquifer, Platte River Basin, Wyoming.
39. Figure 6-3. Estimated net annual aquifer recharge – surface Upper Tertiary Aquifer, Platte River Basin, Wyoming.
40. Figure 6-4. Estimated net annual aquifer recharge – surface Mesozoic Aquifer, Platte River Basin, Wyoming.
41. Figure 6-5. Estimated net annual aquifer recharge – surface Paleozoic Aquifer, Platte River Basin, Wyoming.
42. Figure 6-6. Estimated net annual aquifer recharge – surface Precambrian Aquifer, Platte River Basin, Wyoming.
43. Figure 6-7. Aquifer recharge as percentage of precipitation using 1981 - 2010 precipitation normals, Platte River Basin, Wyoming.
44. Figure 7-1. Environmental and produced groundwater quality sample locations, grouped by sub-regions, Platte River Basin, Wyoming.
45. Figure 7-2. Relation of Cenozoic lithostratigraphic units to hydrogeologic units, High Plains aquifer system, southeastern Wyoming. Modified from Bartos et al. (2013).
46. Figure 7-3. Water-table contours for Split Rock aquifer in Sweetwater River Basin, Wyoming (modified from Borchert, 1977, 1987).
47. Figure 7-4. Potentiometric surface of the Browns Park aquifer in the Saratoga Valley area, Carbon County, Wyoming (modified from Crist, 1990).
48. Figure 7-5. Pre-mining potentiometric surface of aquifers in Tertiary hydrogeologic units for a part of the Shirley Basin, Carbon County, Wyoming (modified from Harshman, 1972).
49. Figure 7-6. Generalized potentiometric surface for the Hanna and Ferris aquifers east of Seminoe Reservoir, Hanna Basin, south-central Wyoming (modified from Davis, 1977, Figure 1).
50. Figure 7-7. Generalized potentiometric surface for the Ferris aquifer east of Seminoe Reservoir, northwest Hanna Basin, south-central Wyoming (modified from Bureau of Land Management, 1975).
51. Figure 7-8. Generalized potentiometric surface map for the Muddy Sandstone aquifer, Laramie County, Wyoming (modified from Wiersma, 1989).
52. Figure 7-9. Generalized potentiometric surface for the Casper aquifer, southern Laramie Basin, Wyoming (modified from Chen, 1990, Figure 3.5).
53. Figure 7-10. Generalized potentiometric surface for the Paleozoic aquifer system in southeastern Wyoming (modified from Western Water Consultants, Inc., 1982, Plate 3).
54. Figure 8-1. Wyoming SEO, Colorado DWR, and Nebraska DNR permitted and drilled irrigation wells.
55. Figure 8-2. Wyoming SEO permitted and drilled irrigation wells in the Denver Basin and Hartville Uplift Subregion.
56. Figure 8-3. Wyoming SEO permitted and drilled irrigation wells in the Denver Basin and Hartville Uplift Subregion.
57. Figure 8-4. Wyoming SEO permitted and drilled irrigation wells in the Casper Arch, Wind River and Powder River Basins Subregion.
58. Figure 8-5. Wyoming SEO permitted and drilled irrigation wells in the Casper Arch, Wind River and Powder River Basins Subregion.
59. Figure 8-6. Wyoming SEO, Colorado DWR, and Nebraska DNR permitted and drilled livestock wells.
60. Figure 8-7. Wyoming SEO permitted and drilled livestock wells in the Denver Basin and Hartville Uplift Subregion.
61. Figure 8-8. Wyoming SEO permitted and drilled Livestock wells in the Laramie Mountains and Central Uplifts Subregion.
62. Figure 8-9. Wyoming SEO permitted and drilled livestock wells in the Laramie and Hanna Basins Subregion.
63. Figure 8-10. Wyoming SEO permitted and drilled livestock wells in the Medicine Bow Mountains and Sierra Madre Subregion.
64. Figure 8-11. Wyoming SEO permitted and drilled livestock wells in the Granite Mountains and Shirley Basin Subregion.
65. Figure 8-12. Wyoming SEO permitted and drilled livestock wells in the Casper Arch, Wind River and Powder River Basins Subregion.
66. Figure 8-13. Wyoming SEO permitted and drilled livestock wells in the Wind River Mountains and Great Divide Basin Subregion.
67. Figure 8-14. Wyoming SEO permitted and drilled municipal wells.
68. Figure 8-15. Wyoming SEO, Colorado DWR, and Nebraska DNR permitted and drilled domestic wells.
69. Figure 8-16. Wyoming SEO permitted and drilled domestic wells in the Denver Basin and Hartville Uplift Subregion.
70. Figure 8-17. Wyoming SEO permitted and drilled domestic wells in the Laramie Mountains and Central Uplifts Subregion.
71. Figure 8-18. Wyoming SEO permitted and drilled domestic wells in the Laramie and Hanna Basins Subregion.
72. Figure 8-19. Wyoming SEO permitted and drilled domestic wells in the Medicine Bow Mountains and Sierra Madre Subregion.
73. Figure 8-20. Wyoming SEO permitted and drilled domestic wells in the Granite Mountains and Shirley Basin Subregion.
74. Figure 8-21. Wyoming SEO permitted and drilled domestic wells in the Casper Arch, Wind River and Powder River Basins Subregion.
75. Figure 8-22. Wyoming SEO permitted and drilled domestic wells in the Wind River Mountains and Great Divide Basin Subregion.
76. Figure 8-23. Surface Water Assessment and Protection, Platte River Basin, Wyoming.
77. Figure 8-24. Wyoming SEO, Colorado DWR, and Nebraska DNR permitted and drilled industrial wells.
78. Figure 8-25. Wyoming SEO, Colorado DWR, and Nebraska DNR permitted and drilled monitoring wells.
79. Figure 8-26. Wyoming SEO permitted and drilled monitoring wells in the Denver Basin and Hartville Uplift Subregion.
80. Figure 8-27. Wyoming SEO permitted and drilled monitoring wells in the Laramie Mountains and Central Uplifts Subregion. Figure 8-28. Wyoming SEO permitted and drilled monitoring wells in the Laramie and Hanna Basins Subregion.
81. Figure 8-29. Wyoming SEO permitted and drilled monitoring wells in the Medicine Bow Mountains and Sierra Madre Subregion.
82. Figure 8-30. Wyoming SEO permitted and drilled monitoring wells in the Granite Mountains and Shirley Basin Subregion.
83. Figure 8-31. Wyoming SEO permitted and drilled monitoring wells in the Casper Arch, Wind River and Powder River Basins Subregion.
84. Figure 8-32. Wyoming SEO permitted and drilled monitoring wells in the Wind River Mountains and Great Divide Basin Subregion.
85. Figure 8-33. Wyoming SEO permitted and drilled miscellaneous and test wells.
86. Figure 8-34. Wyoming SEO permitted springs and USGS mapped springs.
87. Figure 9-1. Areas not “hydrologically connected” and Groundwater Control Areas.
LIST OF TABLES

1. Table 2-1. Platte River Basin sub-regions for data presentation
3. Table 5-2. Selected groundwater quality standards and advisories.
4. Table 6-1. Percent of aquifer recharge zones recharging at varying efficiencies
5. Table 6-2. Platte River Basin Average Annual Recharge Calculations
6. Table 6-3. Annual recharge statistics for Platte River Basin aquifer recharge zones
7. Table 8-1a. Total groundwater withdrawal and consumptive use estimates: Irrigation and Stock Watering
8. Table 8-1b. Total groundwater withdrawal and consumptive use estimate: Industrial
9. Table 8-1c. Total groundwater withdrawal and consumptive use estimates: Municipal and Domestic
10. Table 8-1d. Total groundwater withdrawal and consumptive use estimates: SEO miscellaneous, monitor, test, other, multi-use
11. Table 8-1e. Total groundwater withdrawal and consumptive use estimates: All uses
12. Table 8-2a. Platte River Basin water resources mass balance.
13. Table 8-2b. Range of estimated recharge & non-reservoir evapotranspiration total and sedimentary aquifers.
14. Table 8-2c. Summary of recharge as percentage of water balance statistics
15. Table 8-2d. Summary of groundwater use statistics as percentage of recharge
16. Table 8-2e. Summary of future groundwater requirements as percentages of recharge
17. Table 8-3. SEO groundwater permits in the Platte River Basin by permit status.
18. Table 8-4. SEO groundwater permits in the Platte River Basin by depth.
19. Table 8-5. SEO groundwater permits in the Platte River Basin by yield.
20. Table 8-6. SEO groundwater permits in the Platte River Basin by intended use.
21. Table 8-7. CDWR groundwater permits in the Platte River Basin by intended use.
22. Table 8-8. NDNR groundwater permits in the Platte River Basin by intended use.
23. Table 8-9. SEO fully adjudicated well permits in the Wyoming PrRB database by municipal use.
24. Table 8-10. SEO incomplete, cancelled, abandoned, and not listed well permits in the Wyoming PrRB database by municipal use.
25. Table 8-11. WDEQ Source Water Assessment Program (SWAP) wells and springs used for municipal and non-community public water supply

LIST OF PLATES

Plate 1. Bedrock geology of Platte River Basin, Wyoming, Colorado and Nebraska
Plate 2. Hydrogeology of Platte River Basin, Wyoming, Colorado and Nebraska
Plate 3. Spring discharge, well yield, and hydraulic properties, Platte River Basin, Wyoming.
Plate 5. Generalized potentiometric-surface, Paleozoic aquifer system, Denver-Julesburg Basin, southeastern Wyoming
Plate J. Relation of lithostratigraphic units to hydrogeologic units, Granite Mountains Uplift and Shirley Basin.
Plate K. Relation of lithostratigraphic units to hydrogeologic units, Hartville Uplift and Laramie Mountains
Plate M. Relation of lithostratigraphic units to hydrogeologic units, Denver-Julesberg Basin
Plate S. Relation of lithostratigraphic units to hydrogeologic units, Rawlins Uplift.
Plate T. Relation of lithostratigraphic units to hydrogeologic units, Sierra Madre, Medicine Bow Mountains, and Saratoga Valley.
Plate U. Relation of lithostratigraphic units to hydrogeologic units, Hanna and Laramie Basins.