GAM run 05-26

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Texas Water Development Board
Groundwater Availability Modeling Section
(512) 936-0877
September 1, 2005

REQUESTOR:

Ms. Janet Guthrie, on behalf of the Hemphill County Underground Water Conservation District

DESCRIPTION OF REQUEST:

Ms. Guthrie requested that we run the Groundwater Availability Model (GAM) of the northern part of the Ogallala aquifer (Dutton and others, 2001; Dutton, 2004), based on present conditions and modeling parameters, to determine the following information:

1. The annual volume of water that discharges from the aquifer to springs and any surface water bodies, including lakes, streams and rivers.
2. The annual flow out of the District (i.e., Hemphill County) into Oklahoma.
3. The average aquifer thickness for the District north of the Canadian River and south of the Canadian River and the number of acres encompassed by each area.
4. The average specific yield for the area north and south of the Canadian River in addition to a contour map of the specific yield for those areas.
5. The recharge for those areas north and south of the Canadian River.
6. The recharge and the lateral inflows to those areas of the District north and south of the Canadian River.
7. Determine the decline in feet of the water table which corresponds to the volume determined in part 6 above and the percentage decline in the overall volume that corresponds to part 6 above.
8. Provide a GIS compatible map file showing the center line of the Canadian River.

METHODS:

After running the model, we extracted from the water budget of Hemphill County the annual volume of water that discharges from the aquifer to springs and other surface water bodies. We estimated flow volumes leaving the county to the east into Oklahoma by zoning the eastern cells of Hemphill County and extracting the horizontal flow from the water budget. We calculated the average aquifer thickness using the saturated thickness at the beginning of the predictive period. We then subtracted the base of the aquifer from the hydraulic heads in each cell to obtain the thickness and then averaged the results for the areas north and south of the Canadian River. The number of acres encompassed in each area was determined using ArcGIS. The specific yield was obtained from the model on a cell-by-cell basis and then contoured in PMWIN to form a map.

Recharge and lateral inflows were extracted from the water budget at the beginning of the predictive period for each zoned area. The total volume of groundwater north and south of the Canadian River was calculated by zoning each of those areas within Hemphill County in ArcGIS. We obtained the cell-by-cell specific yield values and multiplied those by the corresponding cell-by-cell saturated thickness and by the aerial extent of the zoned area in acres to arrive at the total volume for each area in acre-feet. The decline in head which corresponds to the combined volume of recharge and lateral inflows was calculated using a proportional analysis; that is, the total volume is proportional to the average thickness which is equal to the reduced total volume's proportionality to the reduced thickness. Percentage decline was calculated by dividing the change in head by the total average head.

A GIS file of the major rivers of Texas in decimal degrees was reprojected for the northern part of the Ogallala aquifer GAM. The metadata file is included in Appendix A.

PARAMETERS AND ASSUMPTIONS:

- See Dutton and others (2001) and Dutton (2004) for assumptions and limitations of the GAM. The overall root mean squared error was up to 53 feet at the end of the transient calibration in 1998. This error will have more of an effect on model results where the aquifer is thin.
- The recharge in the model represents average climatic conditions for the entire model run of 2001 to 2060.
- We assumed conditions in 1998 (the last year of the calibration period) represented present conditions.
- To represent the demand numbers that the Panhandle Regional Water Planning Group plans to include in their 2006 regional water plan, we proportionally adjusted the pumping distribution in the predictive run from Dutton and others (2001). To extend this run from 2050 to 2060, we assumed the same distribution applied through 2060.

RESULTS:

.The volume of water that discharges from the aquifer in Hemphill County to springs and any surface water body, including lakes, streams, and rivers is about 45,000 acre-feet per year. The annual flow out of Hemphill County into Oklahoma via horizontal flow is about 3,000 acre-feet per year. The average aquifer thickness for Hemphill County north of the Canadian River is 148.6 feet at the beginning of the predictive period in 2000. The average aquifer thickness south of the Canadian River in Hemphill County is 159.7 feet at the beginning of the predictive period in 2000. The total number of acres north of the river is approximately 211,200 and the total number south of the river is approximately 364,800. The average specific yield north of the Canadian River in Hemphill County is 0.1809 and south of the Canadian River is 0.1672. A contour map of the specific yields used in the model for Hemphill County is shown in Figure 1. The average recharge for the area north of the Canadian River in Hemphill County is 9,400 acre-feet per year and 22,200 acre-feet per year south of the river. The combined total of lateral inflows and recharge north of the river is 14,900 acre-feet per year and 31,600 acre-feet per year south of the river. The decline in the water table north of the river corresponding to the 9,400 acre-foot volume is 0.4 feet. The decline in the water table south of the river corresponding to the 31,600 acre-foot volume is 0.5 feet. The percent of decline in the volume north of the Canadian River is 0.26 percent and 0.32 percent south of the Canadian River. A GIS compatible map file accompanies this report. The projection is:

1. Albers Equal-Area Conic
2. Spheriod: GRS 80
3. Central Meridian: -101.5
4. Reference Latitude: 36
5. Standard Parallel 1: 35
6. Standard Parallel 2: 37
7. False Easting: 820210
8. False Northing: 820210

REFERENCES:

Dutton, A., 2004, Adjustments of parameters to improve the calibration of the Og-N model of the Ogallala aquifer, Panhandle Water Planning Area: prepared for Freese and Nichols, Inc. and the Panhandle Regional Water Planning Group by the Bureau of Economic Geology, The University of Texas at Austin, 9 p.

Dutton, A., Reedy, R., and Mace, R., 2001, Saturated thickness of the Ogallala aquifer in the Panhandle Water Planning Area–Simulation of 2000 through 2050 withdrawal projections: prepared for the Panhandle Water Planning Group by the Bureau of Economic Geology, The University of Texas at Austin, 54 p.

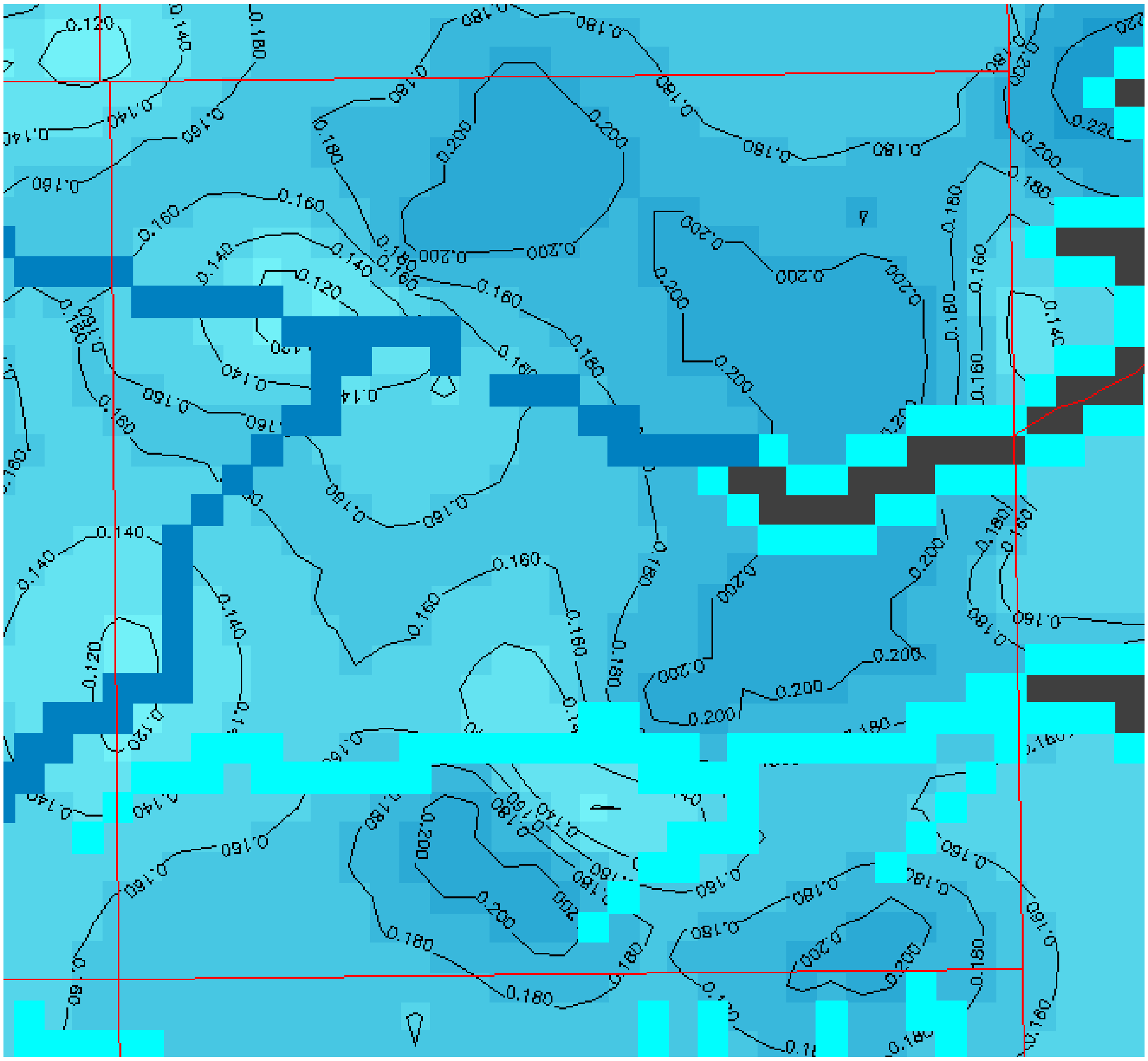

Figure 1: Specific yield map of Hemphill County. North is at the top of the map and the contour interval is 0.02. Streams and rivers are in dark blue, while drains are in cyan. The black cells are inactive.

Appendix A – Metadata for the GIS Texas Rivers Shapefile

U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency ESRI 20040301 2004 vector digital data ESRI® Data & Maps 2004 Redlands, California, USA ESRI Location: \usa\hydro U.S. Rivers and Streams represents detailed rivers and streams in the United States. U.S. Rivers and Streams provides a database of linear water features that interconnects and identifies the stream segments or reaches that comprise the surface water drainage system of United States. Largest scale when displaying the data: 1:24,000. 1999 publication date Complete Matches software update releases -160.186636 -66.988391 49.358327 18.922745 None line rivers streams hydrography inlandWaters None United States None 1999 Access granted to Licensee only. The data are provided by multiple, third party data vendors under license to ESRI for inclusion on ESRI Data & Maps for use with ESRI® software. Each data vendor has its own data licensing policies and may grant varying redistribution rights to end users. Please consult the redistribution rights below for this data set provided on ESRI Data & Maps. As used herein, "Geodata" shall mean any digital data set consisting of geographic data coordinates and associated attributes. The redistribution rights for this data set: Redistribution rights are granted by the data vendor for hard-copy renditions or static, electronic map images (e.g. .gif, .jpeg, etc.) that are plotted, printed, or publicly displayed with proper metadata and source/copyright attribution to the respective data vendor(s). Geodata is redistributable with a Value-Added Software Application developed by ESRI Business Partners on a royalty-free basis with proper metadata and source/copyright attribution to the respective data vendor(s). Geodata is redistributable without a Value-Added Software Application (i.e., adding the sample data to an existing, [non]commercial data set for redistribution) with proper metadata and source/copyright attribution to the respective data vendor(s). The terms and conditions below apply to all the data sets provided on ESRI Data & Maps. Proprietary Rights and Copyright: Licensee acknowledges that the Data and Related Materials contain proprietary and confidential property of ESRI and its licensor(s). The Data and Related Materials are owned by ESRI and its licensor(s) and are protected by United States copyright laws and applicable international copyright treaties and/or conventions. Limited Warranty and Disclaimer: ESRI warrants that the media upon which the Data and Related Materials are provided will be free from defects in materials and workmanship under normal use and service for a period of ninety (90) days from the date of receipt. THE DATA AND RELATED MATERIALS ARE EXCLUDED FROM THE LIMITED WARRANTY, AND THE LICENSEE EXPRESSLY ACKNOWLEDGES THAT THE DATA CONTAINS SOME NONCONFORMITIES, DEFECTS, OR ERRORS. ESRI DOES NOT WARRANT THAT THE DATA WILL MEET LICENSEE'S NEEDS OR EXPECTATIONS; THAT THE USE OF THE DATA WILL BE UNINTERRUPTED; OR THAT ALL NONCONFORMITIES, DEFECTS, OR ERRORS CAN OR WILL BE CORRECTED. ESRI IS NOT INVITING RELIANCE ON THIS DATA, AND THE LICENSEE SHOULD ALWAYS VERIFY ACTUAL DATA. EXCEPT FOR THE LIMITED WARRANTY SET FORTH ABOVE, THE DATA AND RELATED MATERIALS CONTAINED THEREIN ARE PROVIDED "AS-IS," WITHOUT WARRANTY OF ANY KIND, EITHER EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR

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Redlands California 92373-8100 USA 909-793-2853 909-793-5953 info@esri.com 8:00 a.m.–5:30 p.m. Pacific time, Monday–Friday In the United States– Please direct all inquiries regarding software/data pricing and consulting services to your local ESRI Regional Office. For support, you may contact Technical Support by telephone (voice) between 6:00 a.m. and 6:00 p.m. Pacific time, Monday through Friday, by dialing 909-793-3774; facsimile (fax) available at 909-792-0960; electronic mail (e-mail) support@esri.com; or visit http://support.esri.com; ESRI holidays excluded. Outside the United States– Please direct all inquiries regarding software/data pricing, sales, support, and consulting services to your local ESRI International Distributor. This information can be found at http://gis.esri.com/intldist/contactint.cfm. For other questions or comments, you may contact ESRI headquarters by e-mail, telephone, or fax or write to us. Microsoft Windows 2000 Version 5.0 (Build 2195) Service Pack 3; ESRI ArcCatalog 8.3.0.800 No duplicate features are present. The shapefile is converted to SDC (Smart Data Compression) format in ArcSDE®. This verifies and validates the geometry. After processing, the data set is checked for drawing display and number of records and file sizes compared with source materials. Some of the cartographic disparities with this data, inherent in the original 1:100,000 source data, remain in that the density of features can change abruptly. [From National Hydrography Dataset (NHD) documentation - The completeness of the data reflects the content of the sources, which, in the initial release of the National Hydrography Dataset, most often are U.S. Geological Survey topographic maps. Features found on the ground may have been eliminated or generalized on the source graphic because of scale and legibility constraints. In general, streams longer than one mile (approximately 1.6 kilometers) were collected. Most streams that flow from a lake were collected regardless of length. Only definite channels were collected so not all swamp/marsh features have stream/rivers delineated through them. Lake/ponds having an area greater than 6 acres (approximately 2.4 hectares) were collected. Note, however, that these general rules were applied unevenly among maps during compilation. Some map quadrangles have a much sparser pattern of hydrography than do adjoining maps and these differences continue in the digital rendition of these features. Transport reaches are defined on nearly all features of type stream/river, canal/ditch, artificial path, pipeline, and connector. Waterbody reaches are defined on the subset of lake/pond features that were identified as waterbodies during the development of Reach File Version 3. Most attention in applying geographic names was given to transport reaches that follow stream/rivers and waterbody reaches. Near the international boundaries with Canada and Mexico, only the parts of features within the United States are delineated. Detailed capture conditions are provided for every feature type in the Standards for National Hydrography Dataset (USGS, 1999), available online through http://mapping.usgs.gov/standards/.] The data set originally comes from several sources. Most of the data is from U.S. Geological Survey topographic quadrangle maps or sources that exceed its horizontal accuracy. These maps were compiled to meet National Map Accuracy Standards. For horizontal accuracy, this standard is met if at least 90 percent of points tested are within 0.02 inch (at map scale) of their true position. At 1:100,000 scale, 0.02 inch is approximately 167 feet (50.8 meters). U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency 1999 vector digital data Reston, Virginia, USA U.S. Geological Survey National Hydrography Dataset is an ongoing project with Alaska being worked on currently. http://nhd.usgs.gov/ 100000 CD–ROM 1999 publication date NHD Attribute and geospatial data Convert DLG [Digital Line Graph] data to features: This process converted DLG data to features and associated characteristics and converted the coordinate system to geographic (longitude-latitude) coordinates in NAD83 in five steps: 1. The USGS's [U.S. Geological Survey] "Batch DLG-3 to DLG-F Conversion System" converted DLG-3 nodes, lines, areas, and associated attribute codes to temporary features and associated characteristics. Known conditions for which conversions could not be reliably made were flagged for later inspection. Only known conversion problems were flagged, and no additional steps were taken to detect or repair discrepancies in the original DLG-3 or the converted NHD [National Hydrography Dataset]. 2. A default value of a characteristic was added in cases where the description was incomplete. 3. All instances in which data were flagged were inspected and resolved interactively. 4. Feature delineation rules were applied to the temporary features in a batch process to create the final version of features. 5. Coordinate values were converted to geographic coordinates and to the NAD83 using the NADCON software version 2.1 (National Geodetic Survey, n.d.). This process generated the "features" data. Build reaches: The basic steps for building reaches are as follows: 1. Convert RF3 [Reach File Version 3] to RF3" (RF3 double prime). This batch operation processed Reach File Version 3 to delete duplicate reaches, reassign reaches to the correct cataloging unit, validate geographic names assigned to reaches against data from the Geographic Names Information System (December 1996 extract), apply updates supplied by the States of California and Arizona, redelineate reaches on the basis of standards used for the NHD, and identify inflow/outflow points where transport reaches entered and exited waterbodies. 2. Create artificial paths. Using waterbodies from the feature data and inflow/outflow points extracted from RF3", this process automatically generated the centerlines used to delineate artificial paths within waterbodies by using subroutines within the ARC/INFO® GRID module. 3. Blind pass. This batch step conflated features and RF3" reaches and transferred reach information (reach code, reach date, name, stream level, and flow relationships) to the features. It also integrated the artificial paths generated in the previous step with the other features, built reaches on the artificial paths, and assigned geographic names (February 1995 extract) to waterbodies. 4. Quadrangle-based visual pass. During this interactive step, analysts ensured that the data developed in the previous batch processes conformed to reach delineation rules and that reaches were assigned to the appropriate cataloging unit. Batch procedures identified and developed a list of possible errors. (Errors not detected by the software may continue in the data.) Using the list, software presented each case to analysts to make appropriate edits to the data. Analysts recorded notes about repairs that could not be made and about other errors in the data. (These notes are encoded in the cataloging unit digital update units.) 5. Build superquads. After the quadrangle-based visual pass was complete, all quadrangles that cover all or part of each cataloging unit were paneled into a superquad. In this batch process, reaches that cross quad boundaries were corrected to conform to reach delineation rules. 6. Cataloging unit-based visual pass. As they did with the quadrangle-based visual pass, analysts ensured that reaches conformed to reach delineation rules. Batch procedures identified and developed a list of possible errors. (Errors not detected by the software may continue in the data.) Analysts examined each error and corrected the data. Analysts recorded notes about repairs that could not be made and about other errors in the data. (These notes are encoded in the cataloging unit digital update units.) 7. Central quality assurance/quality control. This step (1) confirmed that integrity checks were performed successfully during the visual pass activity, and (2) assessed statistics gathered during the earlier processes to determine if additional review of data was needed. A check of data from the cataloging unit-based visual pass was run in batch; any data that did not pass the procedure were reviewed interactively. If substantive changes were required, the data were reprocessed using procedures (as required) described in previous steps. The edited data then were rechecked using the central quality assurance/quality control process. 8. Data preparation and database load. This batch procedure performed final processing to the data emerging from the quality assurance/quality control step. Some of the activities included assigning the final reach codes, building waterbody reaches, adding final artificial paths in waterbodies, and implementing any recent changes in standards for the NHD. The spelling of geographic names was replaced using the March 1999 data extract from the Geographic Names Information System. After this, reaches, features, characteristics, geographic names, and relations were loaded into the database that holds the NHD. 9. Flow relation correction and validation. The flow relations were checked for consistency through a batch procedure, which generated a list of possible errors. Software presented possible errors to analysts, who corrected flow relations and, occasionally, the delineation of reaches. Changes were posted to the database. 10. Extract distribution copies of data. Data for a cataloging unit were extracted from the database and converted into an ARC/INFO® workspace containing coverages and other files. Data available in the Spatial Data Transfer Standard format were developed from the workspaces. The workspaces and the Spatial Data Transfer Standard-formatted files were made available to the public. 1999 NHD The following steps were performed by ESRI: Extracted NHD Route DRAIN from National Hydrography Dataset (NHD). Added STRM_LEVEL and NAME attributes from NHD Route RCH. Removed unneeded attributes. Split the data set by U.S. states (for easier processing). Unsplit features based on combining NAME, FTYPE, FCODE, and STRM_LEVEL attributes. Merged the data sets into one. Recalculated the lengths for the METERS attribute. Formatted the attributes. Created ArcGIS® layer file (.lyr), projection file (.prj), and spatial indices. Converted the data set to SDC. NHD 20021113 Vector String 1899923 0.000009 0.000009 Decimal degrees North American Datum of 1983 Geodetic Reference System 80 6378137.000000 298.257222 dtl_riv The lines represent the detailed rivers and streams in the United States. ESRI ObjectID Internal feature number. ESRI Sequential unique whole numbers that are automatically generated. NAME The name of the river or stream. ESRI Names for the features. FTYPE The feature type of river or stream. ESRI ARTIFICIAL PATH The linear water feature allows connectivity through areal features (for example, lake/ponds and stream/rivers). U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency CANAL/DITCH The linear water feature is a canal (1-dimensional) or ditch (1-dimensional). U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency CONNECTOR The linear water feature is a connector (fill gaps in the delineation of features through which water flows). U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency PIPELINE The linear water feature is a pipeline. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency STREAM/RIVER The linear water feature is a stream (1-dimensional) or river (1-dimensional). U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency FCODE The feature code (five-digit) for the river or stream. The first three digits encode the feature type; the last two digits encode values for a set of characteristics associated with the feature. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency 0 unknown ESRI 33400, 33600, 42800, 46000, 55800 Feature type only: no attributes. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency 33601 Canal/Ditch Type|aqueduct. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency 33602 Canal/Ditch Type|unspecified. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency 42801 Product|water; Pipeline Type|aqueduct; Relationship to Surface|at or near. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency 42802 Product|water; Pipeline Type|aqueduct; Relationship to Surface|elevated. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency 42803 Product|water; Pipeline Type|aqueduct; Relationship to Surface|underground. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency 42804 Product|water; Pipeline Type|aqueduct; Relationship to Surface|underwater. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency 42807 Product|water; Pipeline Type|general case; Relationship to Surface|underground. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency 42809 Product|water; Pipeline Type|penstock;

Relationship to Surface|at or near. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency 42811 Product|water; Pipeline Type|penstock; Relationship to Surface|underground. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency 42813 Product|water; Pipeline Type|siphon; Relationship to Surface|unspecified. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency 46001 Hydrographic Category|intermittent; Positional Accuracy|definite. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency 46002 Hydrographic Category|intermittent; Positional Accuracy|indefinite. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency 46004 Hydrographic Category|perennial; Positional Accuracy|definite. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency 46005 Hydrographic Category|perennial; Positional Accuracy|indefinite. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency FCODE_DESC The description of the feature code for the river or stream. ESRI Descriptions for the features. STRM_LEVEL The numeric code that identifies the path level of water flow through a drainage network for the river or stream. The lowest value ["1" for rivers or streams that terminate at the Atlantic, Pacific, or Arctic Oceans, the Gulf of Mexico, or the Caribbean Sea; "2" for rivers or streams that terminate at the Great Lakes or the Great Salt Lake; "3" for rivers or streams that terminate at the boundary of the United States with Canada or Mexico; "4" for rivers or streams that terminate at any other place (isolated drainage).] for stream level is assigned to a river or stream at the end of a flow and to upstream rivers and streams that trace the main path of flow back to the head. The stream level value is incremented by one and is assigned to all rivers and streams that terminate at this path (that is, all tributaries to the path) and to all rivers and streams that trace the main path of the flow along each tributary back to its head. The stream level value is incremented again and is assigned to rivers and streams that trace the main path of the tributaries to their heads. This process is continued until all rivers and streams for which flow is encoded are assigned a stream level. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency 1 99 -9998 The linear water feature is unspecified. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency METERS The length of the river or stream in meters. U.S. Geological Survey in cooperation with U.S. Environmental Protection Agency Calculated lengths for the features. shape Feature geometry. ESRI Coordinates defining the features. ESRI; ESRI International Distributors mailing and physical address

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Redlands California 92373-8100 USA 800-447-9778 In the United States, contact the ESRI Telesales staff at 800-447-9778 for more information about our software and data. Outside the United States, please direct all inquiries to your local ESRI International Distributor. This information can be found at http://gis.esri.com/intldist/contactint.cfm. Offline Data See use constraints. SDC The SDC file contains the geospatial and attribute data. The SDI file contains the spatial and attribute indexes. The PRJ file contains the coordinate system information (optional). The XML file (*.sdc.xml) contains the metadata describing the data set (optional). ArcGIS® software 98.377 DVD–ROM 4.38 GB (gigabytes) ISO 9660 CD–ROM 650 MB (megabytes) ISO 9660 Software purchase price ESRI Data & Maps is available only as part of ESRI® software. To use this data

requires software that supports SDC files. 20040115 ESRI Data Team mailing and physical address
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http://www.esri.com/metadata/esriprof80.html ESRI Metadata Profile