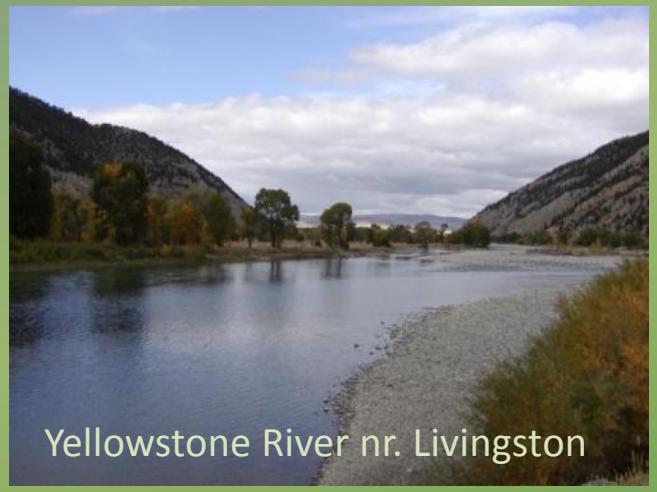
Water Quality in the Yellowstone River Basin

Yellowstone River Basin Advisory Council
November 15th, 2013


Yellowstone River nr. Livingston

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Water Science Center

Clarks Fork Yellowstone River

U.S. Department of the Interior
U.S. Geological Survey

Presentation objectives

- Summary of water-quality results from the National Water-Quality Assessment (NAWQA) Program
- SPARROW modeling activities relevant to the Yellowstone River Basin
- Describe tools to apply the SPARROW results in the Yellowstone River Basin

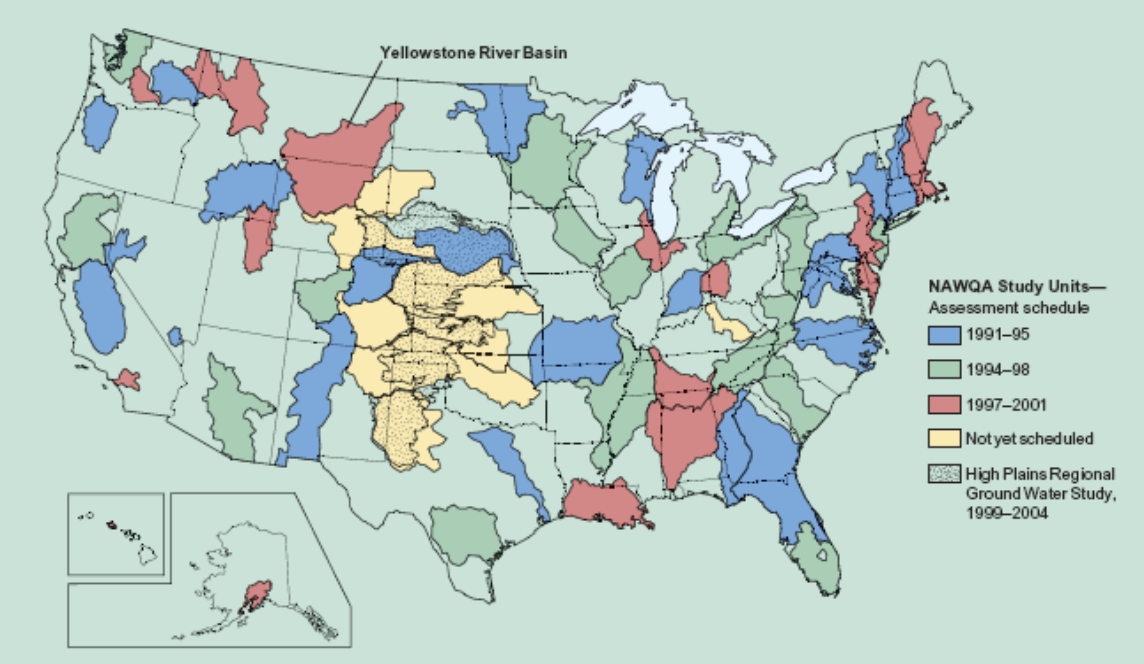
NAWQA program goals

- Describe current water-quality conditions for a large part of the Nation's freshwater streams and aquifers
- Describe how water quality is changing over time
- Improve our understanding of the primary natural and human factors affecting water quality

NAWQA monitoring in the Yellowstone River Basin

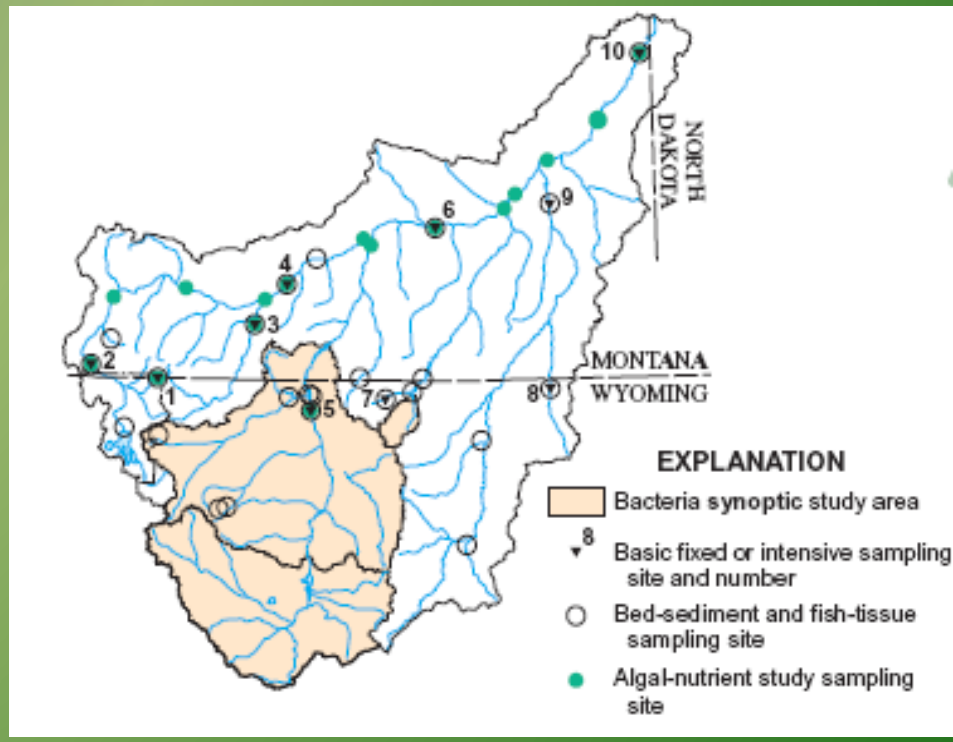
Initial sampling conducted from FY1998-FY2001

- Stream chemistry
- Groundwater chemistry
- Stream ecology



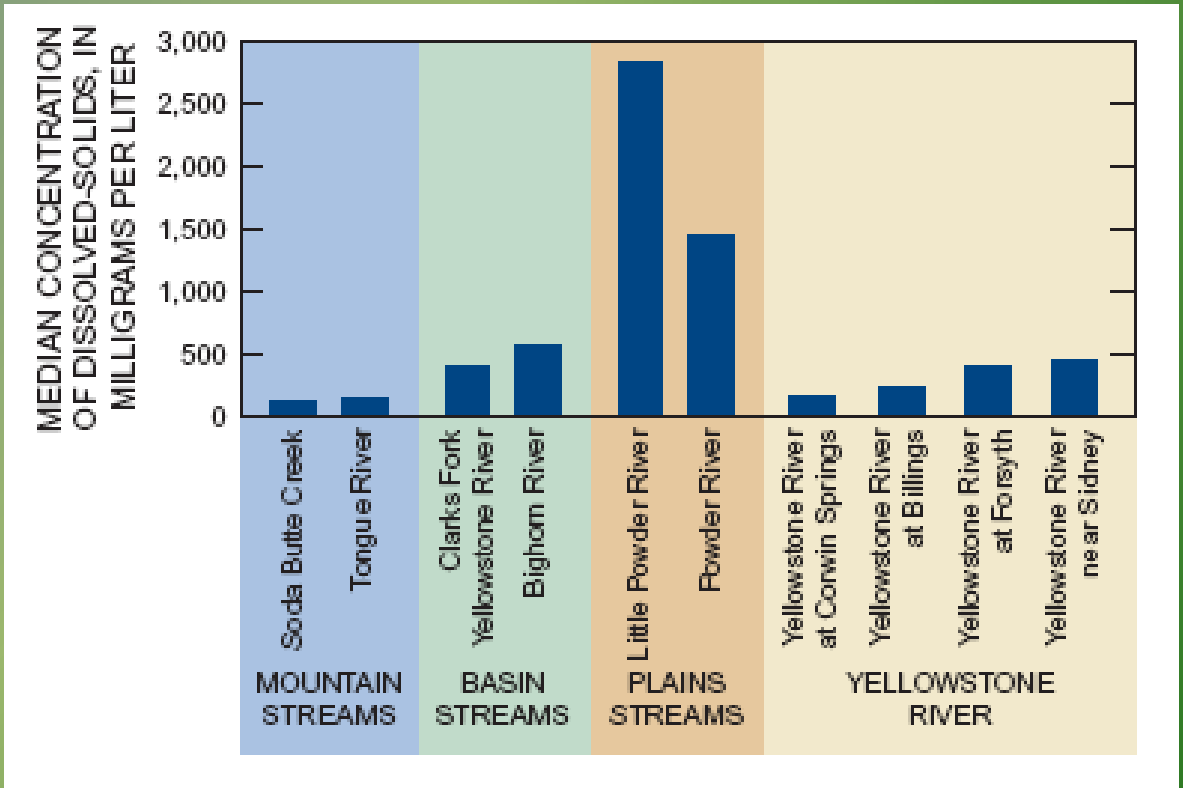
NAWQA monitoring : Stream chemistry

- Ten basic fixed sites
  - Monthly sampling
  - High flow sampling
- Intensive sampling sites
  - Biweekly to monthly sampling
  - Additional high flow samples
- Bacteria synoptic



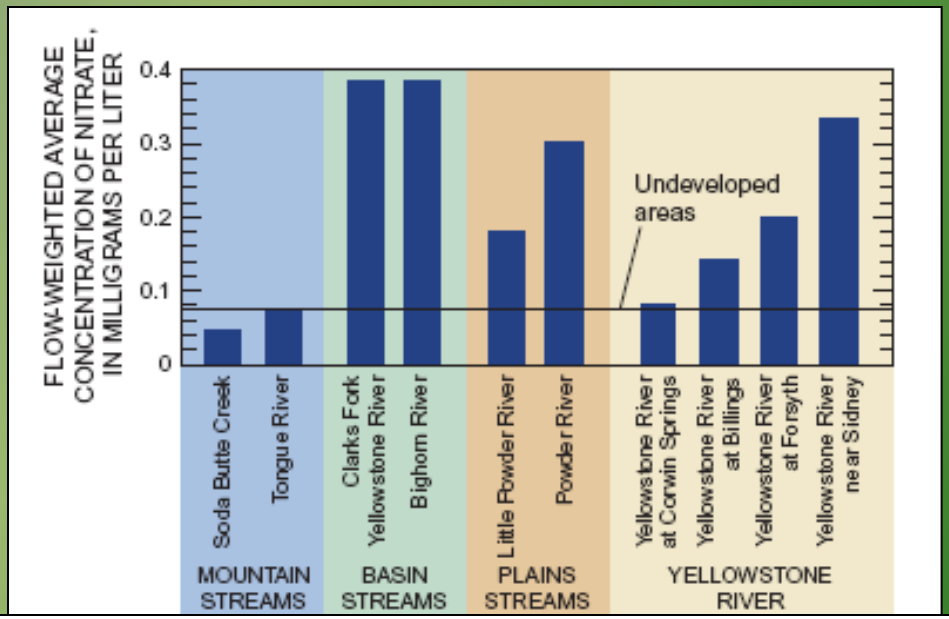
NAWQA: Stream chemistry results -total dissolved solids

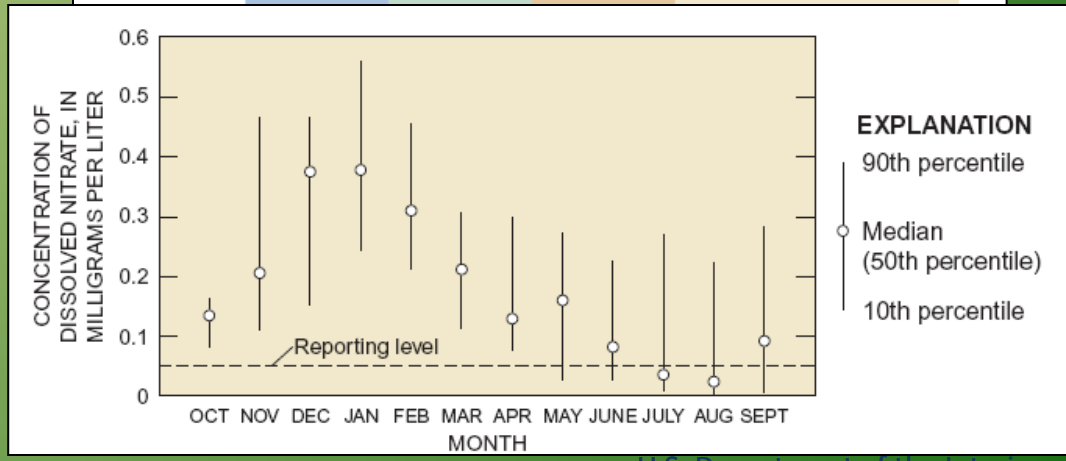
- Mountain streams dominated by calcium and bicarbonate
- Plains streams dominated by sodium and sulfate



NAWQA: Stream chemistry results -nitrogen

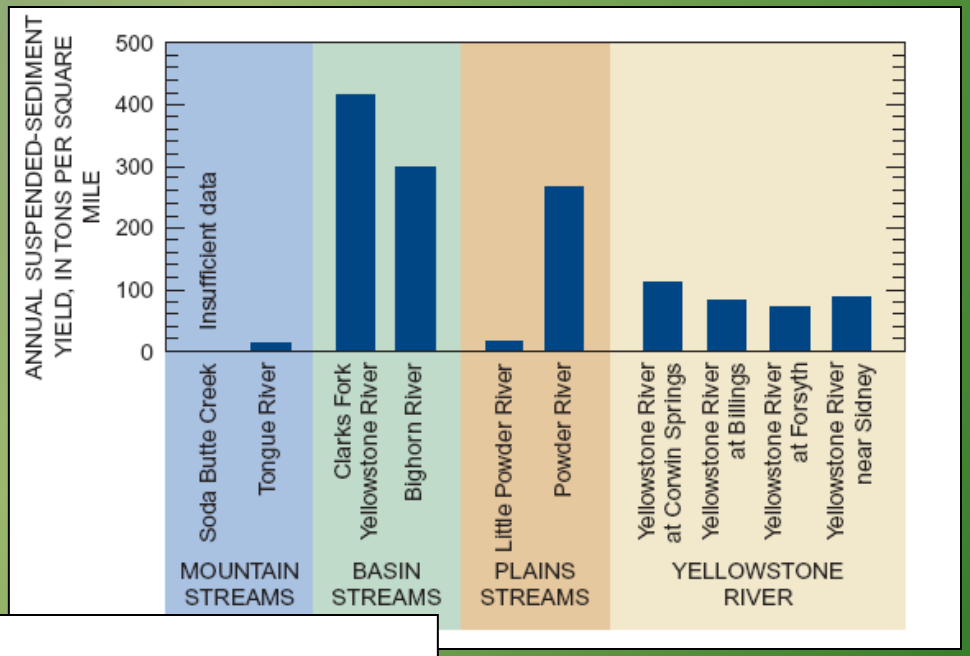
- Vary seasonally and related to land use
- Total nitrogen concentrations highest in the Little Powder and Powder
- Nitrate concentrations highest in Clarks Fork Yellowstone and Bighorn Rivers

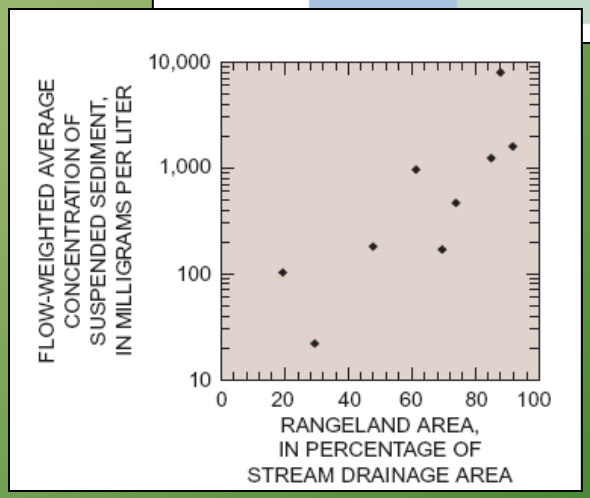




NAWQA: Stream chemistry results -phosphorus and suspended sediment

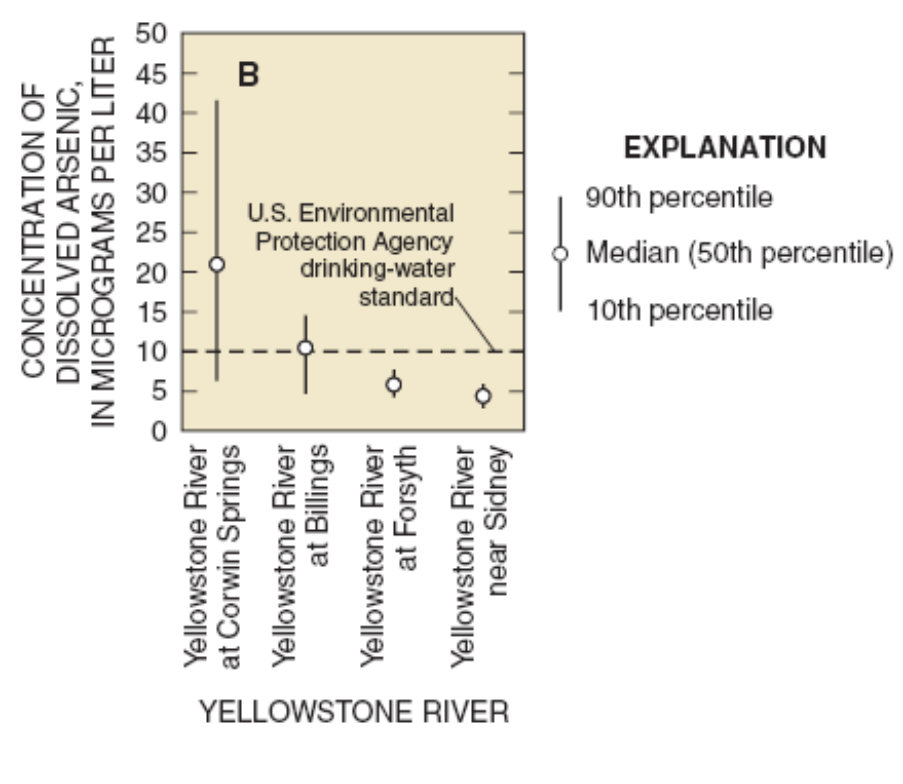
- Naturally occurring in soils
- Associated with suspended sediment concentrations
- Highest in rangeland areas with erodible soils and less vegetation





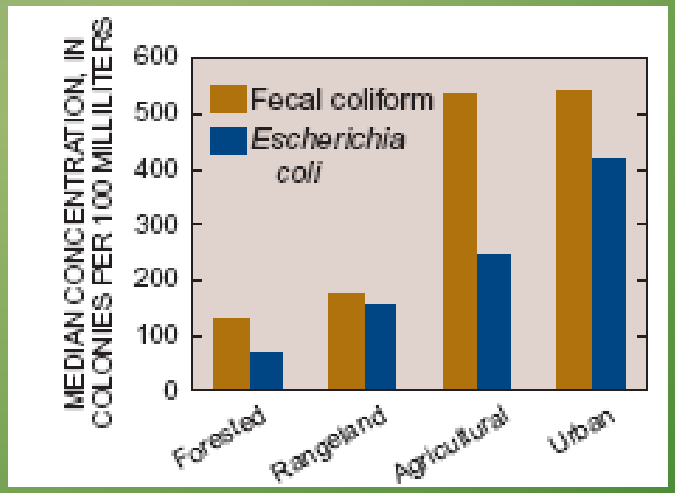
NAWQA: Stream chemistry results -trace elements

- High arsenic concentrations in upper reaches from naturally occurring sources
- Lower arsenic concentrations downstream due to dilution
- Other trace elements with elevated concentrations include selenium, mercury



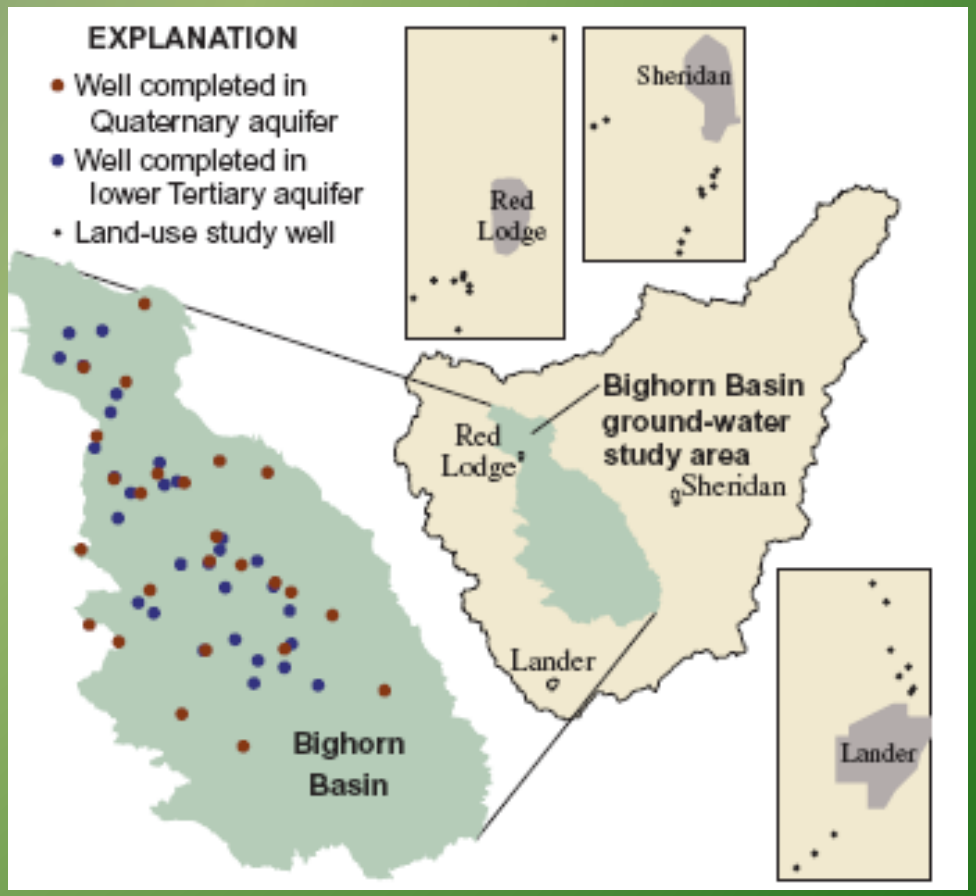
NAWQA: Stream chemistry results -bacteria synoptic

- Exceedance of the USEPA recommended limits for:
  - Fecal coliform primary contact recreation (>400 col/100mL in 37 samples)
  - E. coli recommended limit for moderate use, full-body contact (>298 col/100 mL in 38 samples)
  - E. coli recommended limit for infrequent use, full-body contact recreation (>576 col/100 mL in 25 samples)
- Potential sources in agricultural and urban area are sewage treatment plants; agricultural, domestic, and wildlife waste; and septic systems



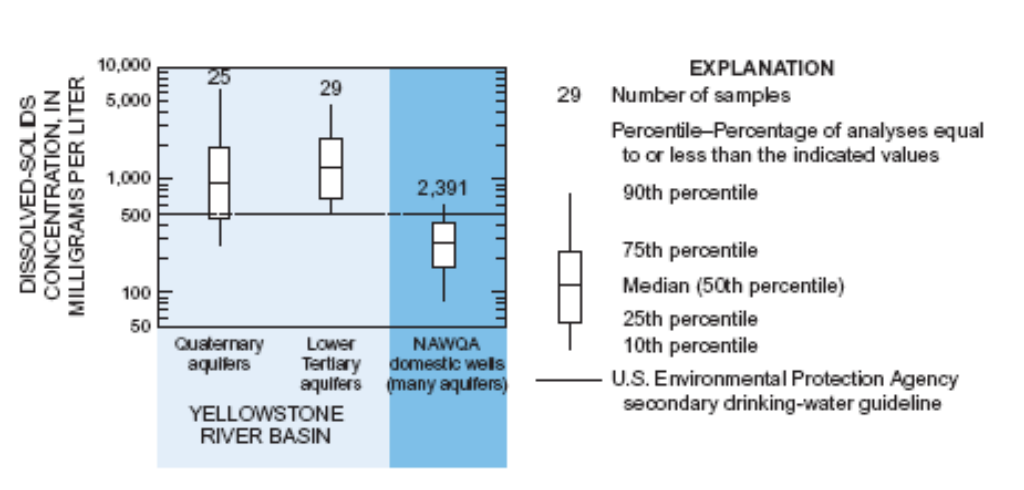
NAWQA monitoring in the Yellowstone River Basin: groundwater chemistry

- Aquifer surveys
  - Quaternary unconsolidated aquifers
  - Lower Tertiary aquifers
- Land use monitoring survey



NAWQA: Groundwater chemistry results -total dissolved solids

- Concentrations higher than most shallow wells in the nation
- Samples with high TDS dominated by sodium and bicarbonate
- Frequently exceeded USEPA secondary drinking-water standard of 500 mg/L



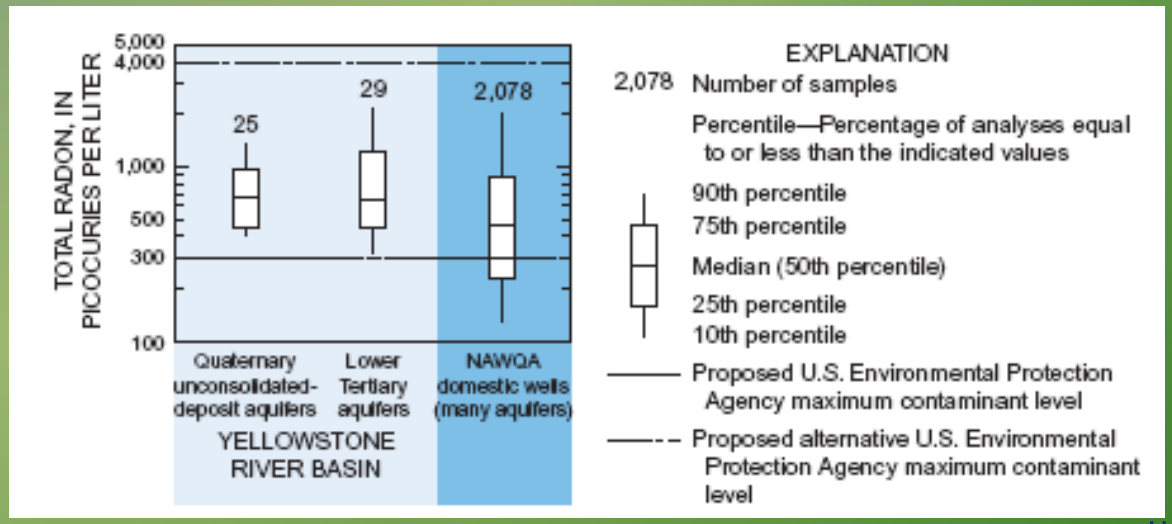
NAWQA: Groundwater chemistry results -nitrogen

- Concentrations of nitrate in 8 percent of samples collected from Quaternary aquifers and 3 percent from the lower Tertiary aquifers exceeded the USEPA drinking-water standard of 10 mg/L

- Concentration related to surrounding land uses:
  - In Quaternary aquifers increased with the percentage of cropland and other agricultural land; decreased as the percentage of rangeland and riparian land increased
  - In the lower Tertiary aquifer samples, nitrate concentrations increased with the percentage of cropland overlying the aquifer.

NAWQA: Groundwater chemistry results -radon

- Naturally-occurring concentrations higher than in most shallow wells in the nation
- 52 of 54 samples exceeded the USEPA proposed drinking-water standard of 300pCI/L

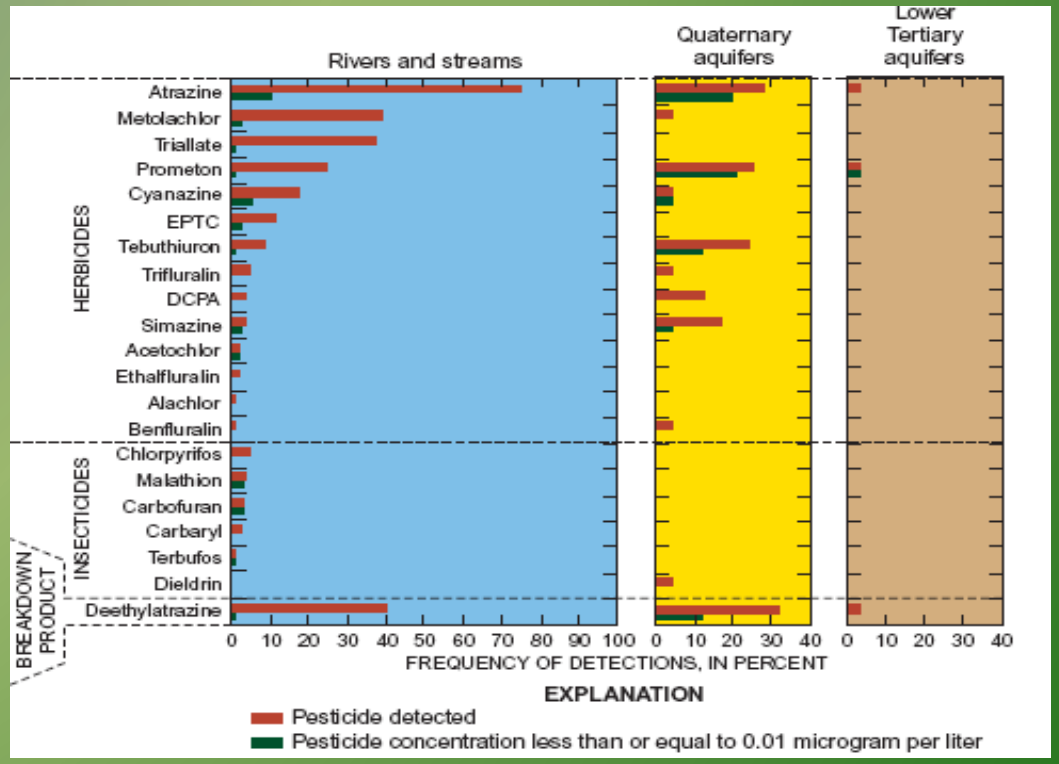


NAWQA: Groundwater chemistry results -trace elements

- Trace element concentrations found in samples from Quaternary wells didn't exceed federal standards and guidelines
- In samples from the Lower Tertiary wells, drinking-water standards for antimony, boron, cadmium, and selenium were exceeded once, and twice for molybdenum.

NAWQA: Stream and groundwater chemistry -pesticides

- Frequently detected but at low concentrations
- Atrazine was the most frequently detected
- Breakdown products present in surface- and groundwater

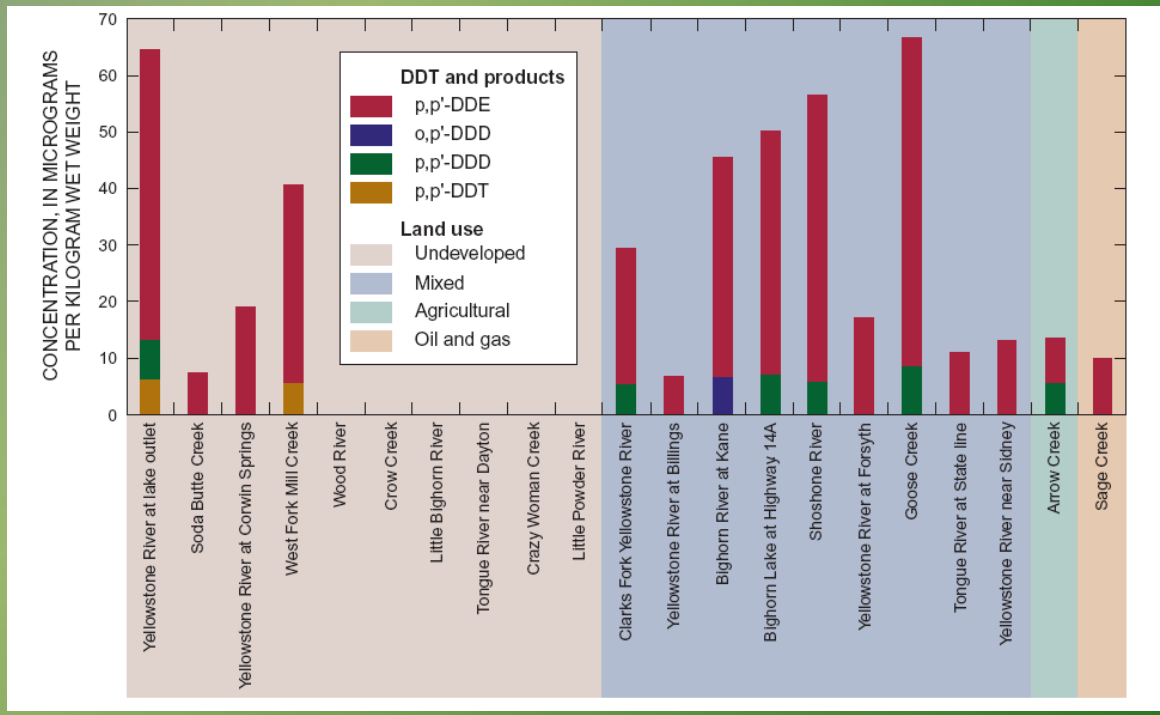


NAWQA monitoring in the Yellowstone River Basin: ecology sites

- Basic fixed or intensive sampling sites
- Bed sediment and fish tissue sites
- Algal-nutrient study

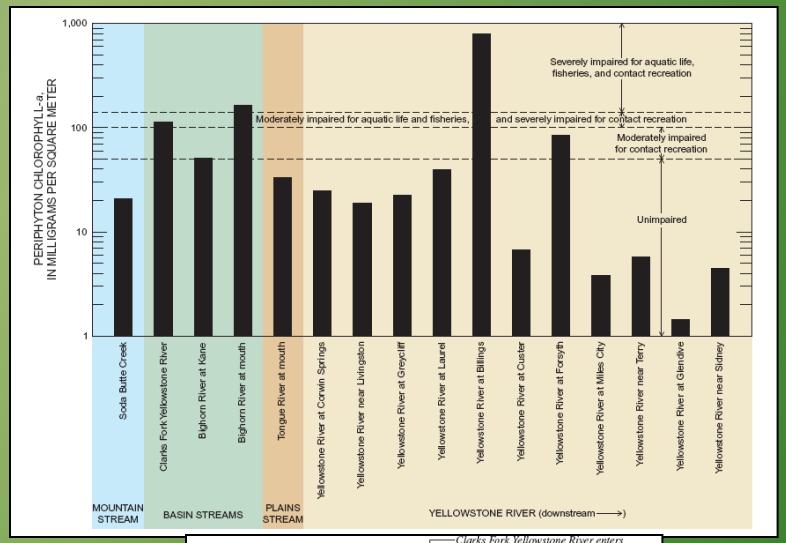
NAWQA: Tissue and bed sediment sample results -pesticides and organic compounds

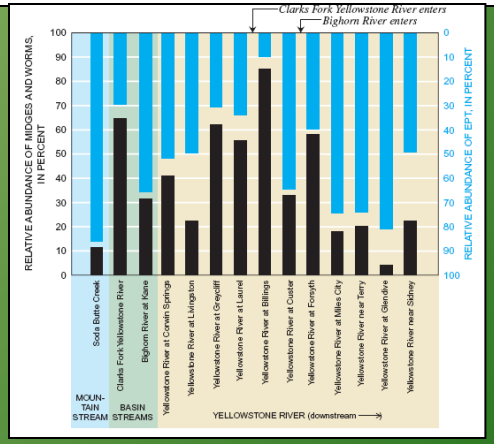
- DDT, dieldrin, and chlordane present in several fish samples
- Just one bed sediment sample contained DDT
- PCBs in 3 of 33 fish samples



NAWQA: Ecology
-periphyton chlorophyll and invertebrates

- Chlorophyll concentrations in Yellowstone at Billings and Bighorn River in range of severely impaired
- Pollution tolerant taxa (midges and worms) dominant in middle section of Yellowstone at sites downstream of major tributaries
- Mayfly, stonefly, and caddisfly species dominate in upper and lower segments of the Yellowstone and most tributaries





NAWQA monitoring in the Yellowstone River Basin, FY2002-FY2012

- Surface Water
  - Yellowstone River at Forsyth, MT (dropped in FY2010)
  - Yellowstone River near Sidney, MT
  - Bighorn River at Kane, WY (dropped in FY2010)
  - Little Powder above Dry Creek nr Weston, WY
- Groundwater
  - Alluvial aquifers study 2011-2012
- Ecology
  - Little Powder River above Dry Creek near Weston, WY

Current NAWQA monitoring in the Yellowstone River Basin (FY2013)

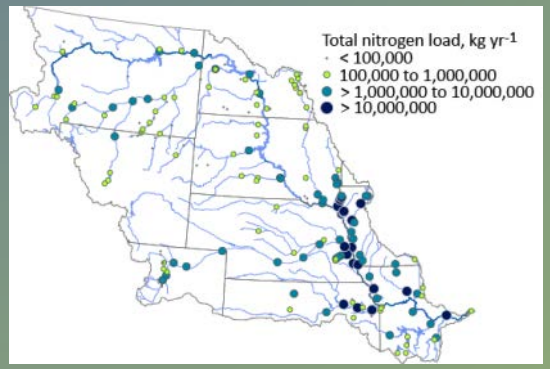
- Surface water
  - Yellowstone nr Sidney, MT
  - Little Powder above Dry Creek nr Weston, WY
- Groundwater
  - None
- Ecology
  - Little Powder above Dry Creek nr Weston, WY

SPARROW modeling
(SPAtially Referenced Regressions On Watershed attributes)

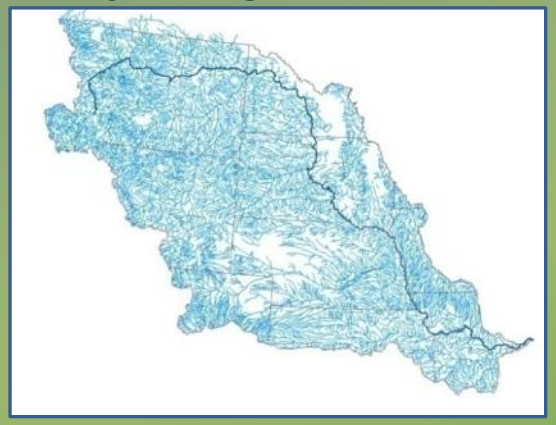
- Determine P and N loading to various receiving waters over large spatial scales
- Determine where are the main contributing basins (rank contributing basins based on loads and yields)
- Determine what are the main causes of the high loads (describe the relative importance of nutrient sources)
- Provide information to various states and regional organizations to support regional interpretation and guide local, more in-depth studies

SPARROW model elements

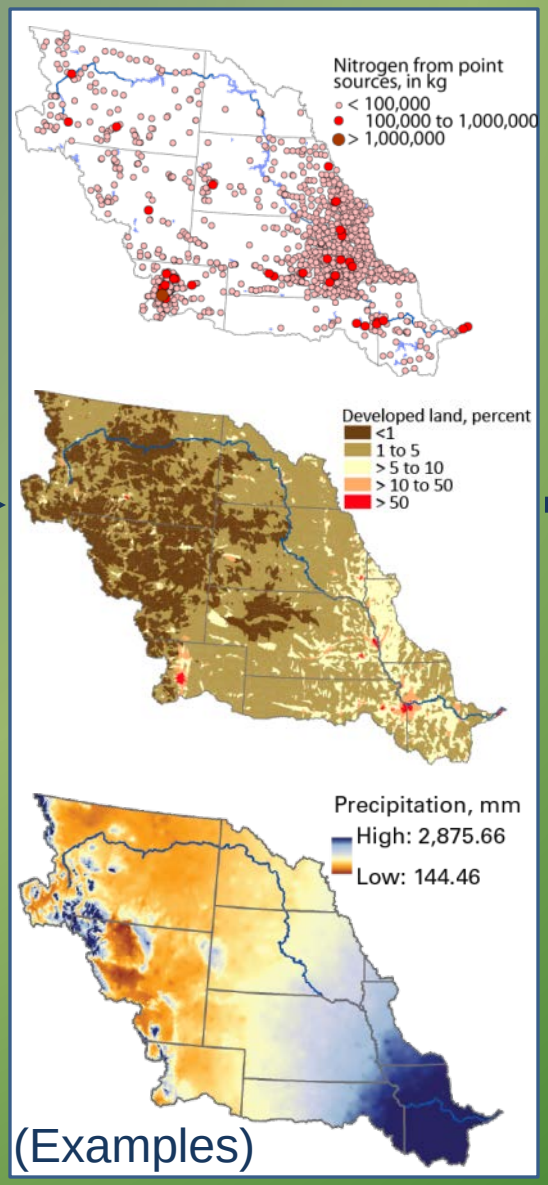
Monitoring data



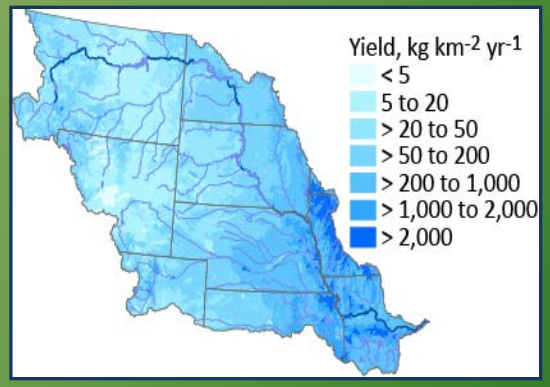
Hydrologic network



Geographical data



Predicted loads & concentrations



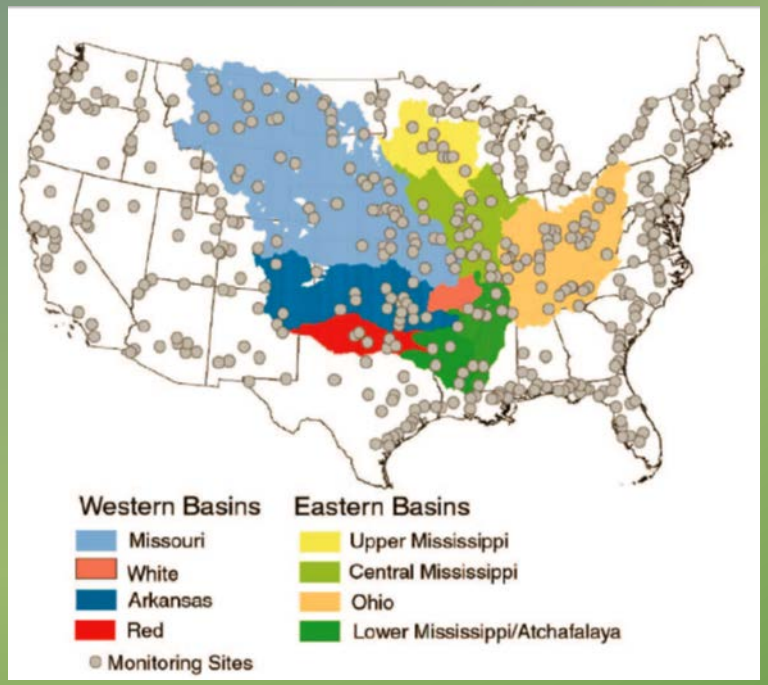
History/Status of SPARROW modeling

- National model (1992)
  - Suspended sediment
  - Total nitrogen
  - Total phosphorus
  - Total organic carbon
- Regional models:
  - Missouri River Basin and Pacific Northwest (2002)
    - Total nitrogen
    - Total phosphorus
  - Mississippi River Basin Model (release pending)
  - NHDPlus Nutrient Models (under development)

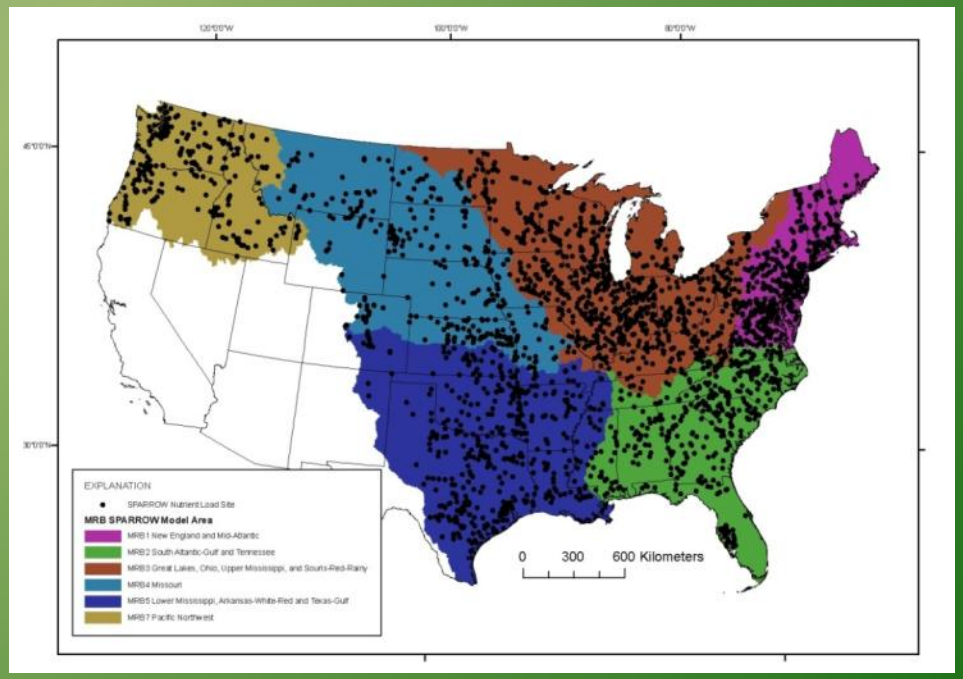
Regional SPARROW models-Missouri River Basin

- Developed total nitrogen and total phosphorus models for mean annual conditions in 2002.
- Local and regional nutrient sources and factors affecting nutrient transport
- Take advantage of updated GIS data
- Additional water-quality data from other USGS and outside agency programs

Sites used in National Models



Sites being used in Regional Models



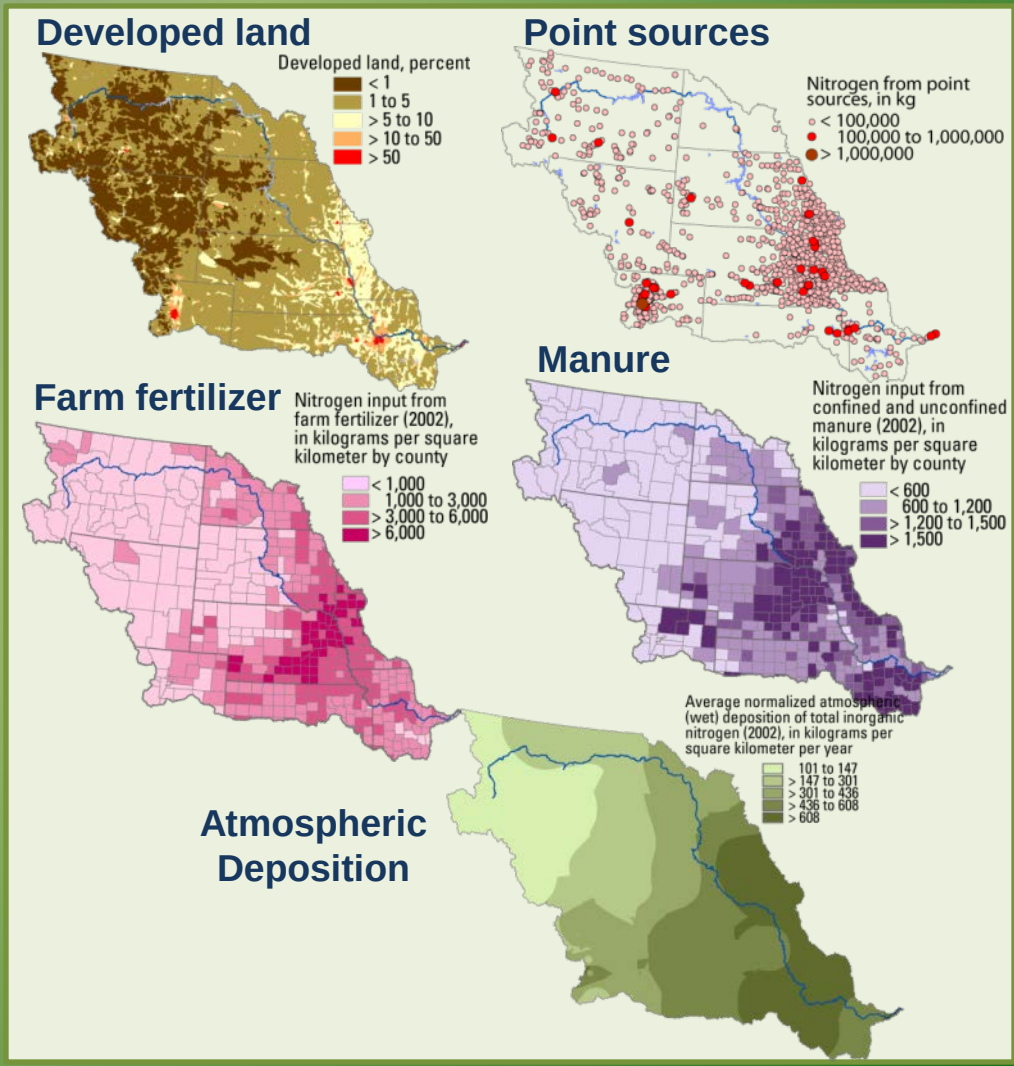
SPARROW model for total nitrogen

<u>Total nitrogen</u>

Sources
- Developed land
- Point sources
- Farm fertilizer
- Manure
- Atmospheric deposition

Land-to-water delivery
- Precipitation
- Loess surficial geology (%)
- Air temperature
- Irrigated agricultural area (%)

Aquatic loss
- In-stream attenuation
- Reservoir and lake attenuation



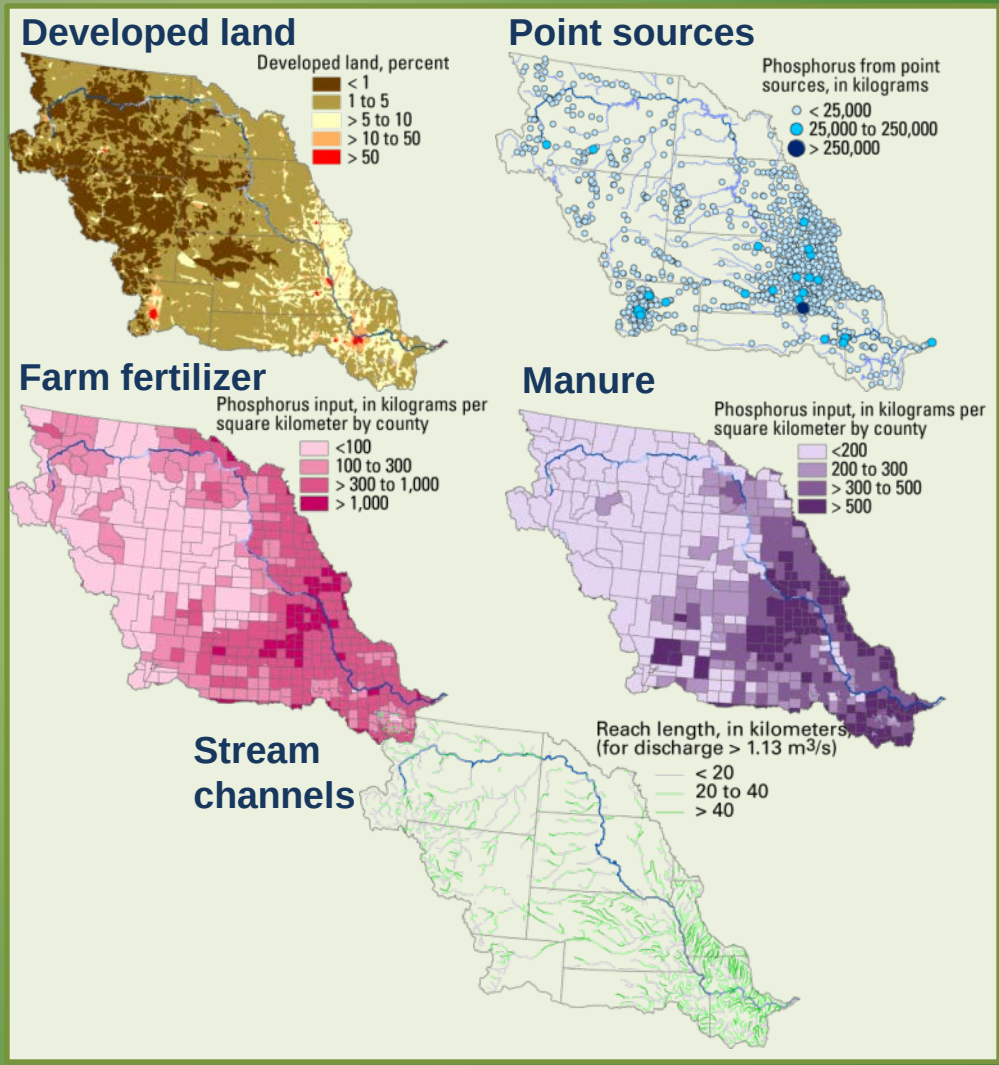
SPARROW model for total phosphorus

<u>Total phosphorus</u>

Sources
- Developed land
- Point sources
- Farm fertilizer
- Manure
- Stream channels (large streams)

Land-to-water delivery
- Precipitation
- Mean basin slope
- Permeability

Aquatic loss
- Reservoir and lake attenuation



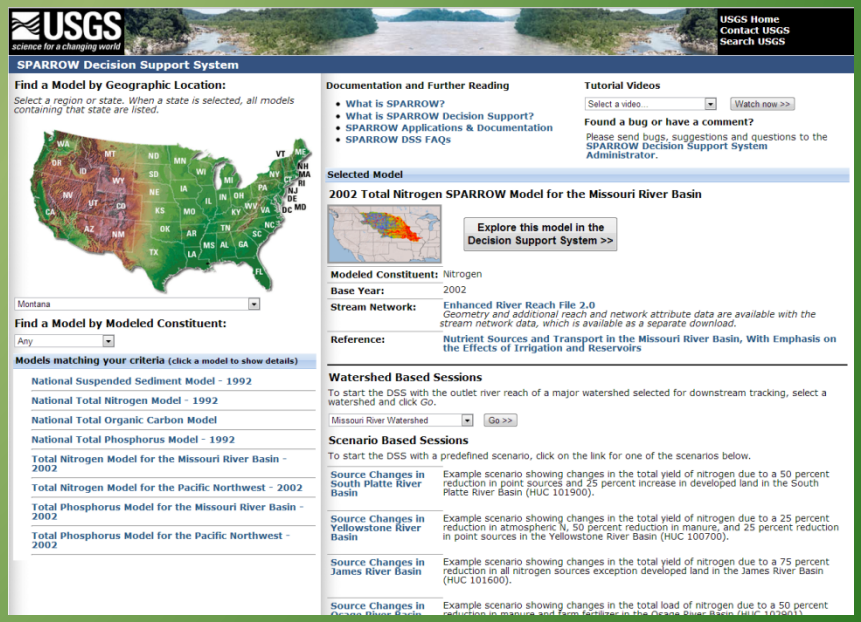
SPARROW Conclusions for Yellowstone Basin

- Yields of Total Phosphorus (TP) from stream channel
- Yields of Total Nitrogen (TN) from manure
- Yellowstone basin had smallest loads and yields of TP and TN within the Missouri River Basin
- Lowest percent load of TN (22%) and TP (2%) delivered to the Mississippi
- Low load delivery to the Mississippi due to low input, large reservoirs, and longer travel time

Brown, Juliane B., Lori A. Sprague, and Jean A. Dupree, 2011. Nutrient Sources and Transport in the Missouri River Basin, With Emphasis on the Effects of Irrigation and Reservoirs. Journal of the American Water Resources Association (JAWRA) 47(5):1034-1060. DOI: 10.1111/j.1752-1688.2011.00584.x

Tools to demonstrate results and help guide decisions: SPARROW Decision Support System (DSS)

- Allows scientists/managers to visualize SPARROW output
- Run various scenarios- predicted load or yield changes with changing nitrogen or phosphorus inputs



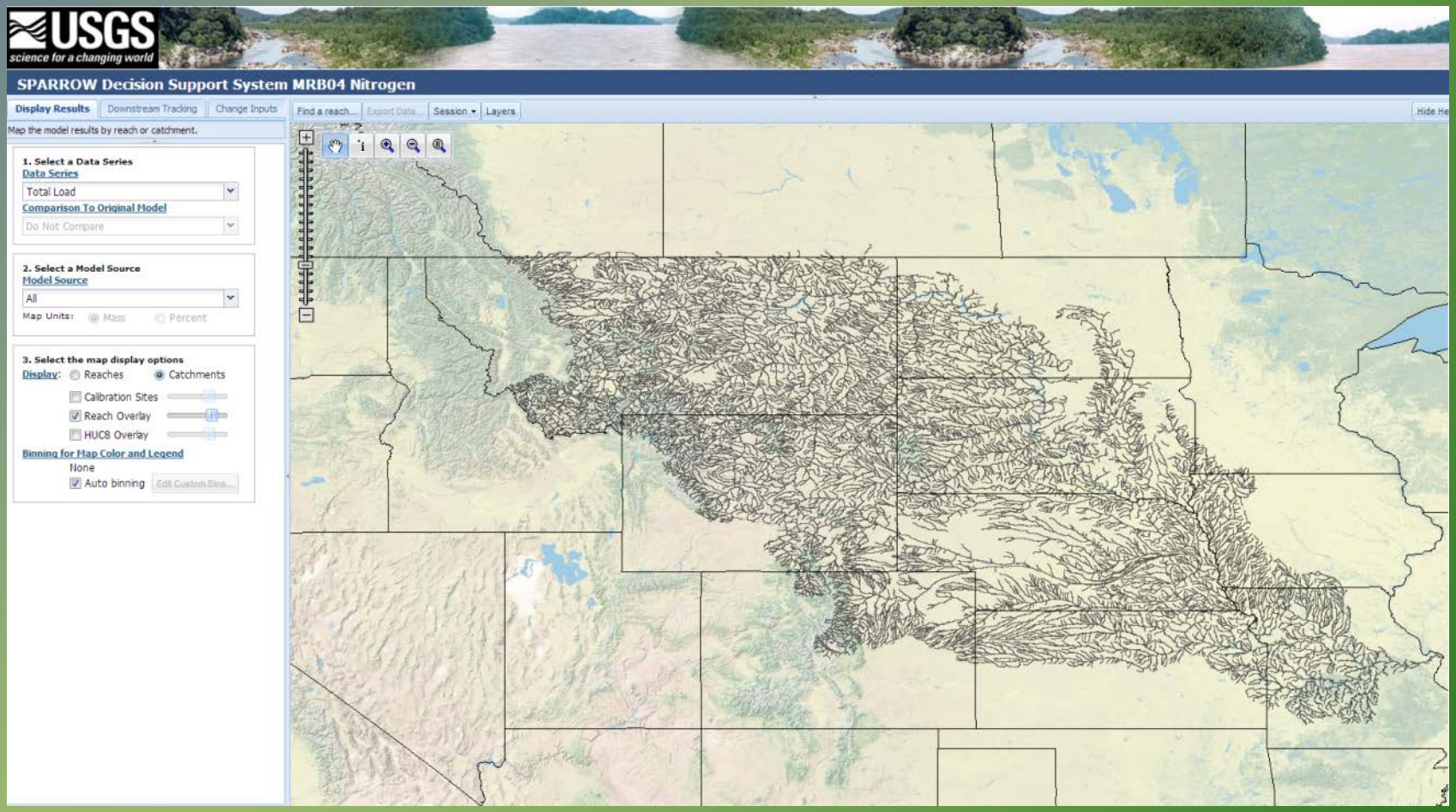
http://cida.usgs.gov/sparrow/

DSS: Data that can be mapped

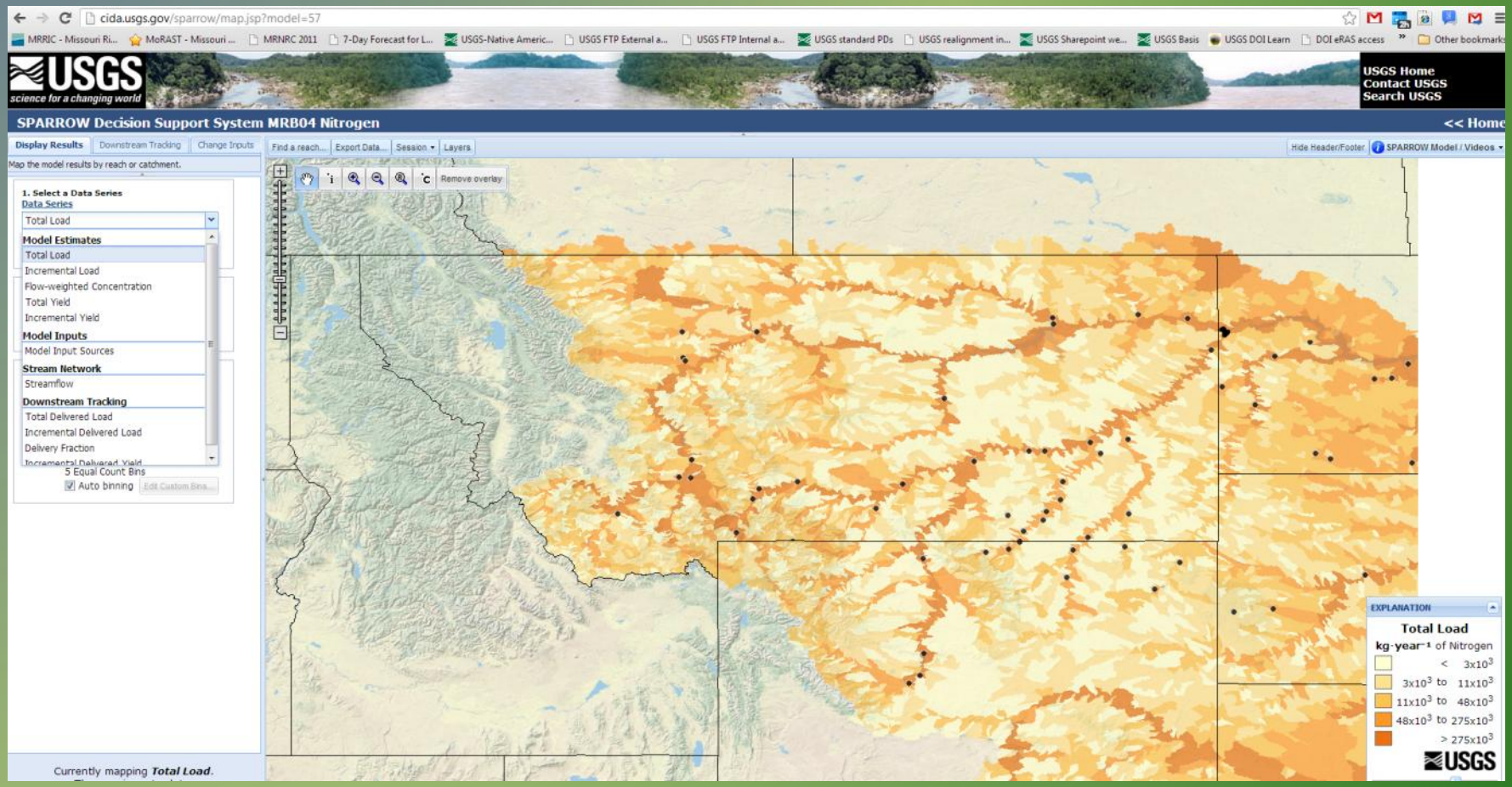
- Model estimates
  - Load
  - Concentrations
  - Yield (load/area)
  - Incremental yield (incremental yield=load/area for contributing drainage to that reach)
- Streamflow

- Model input sources
  - Fertilizer
  - Manure
  - Atmospheric
- Downstream tracking
  - Total delivered load
  - Incremental delivered load
  - Delivery fraction
  - Incremental delivery yield

DSS: Missouri River Basin base map

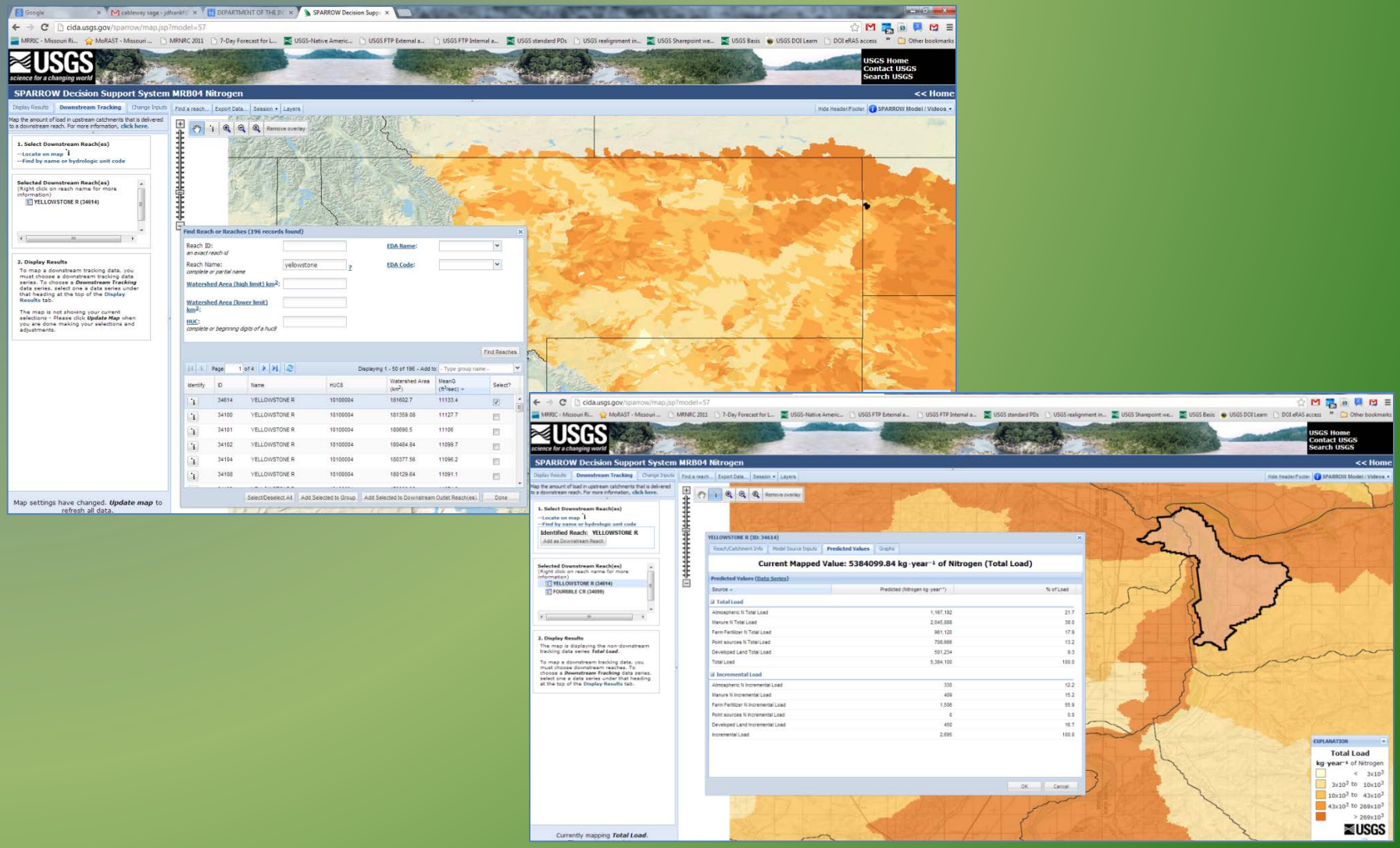


DSS: Zoom into selected areas

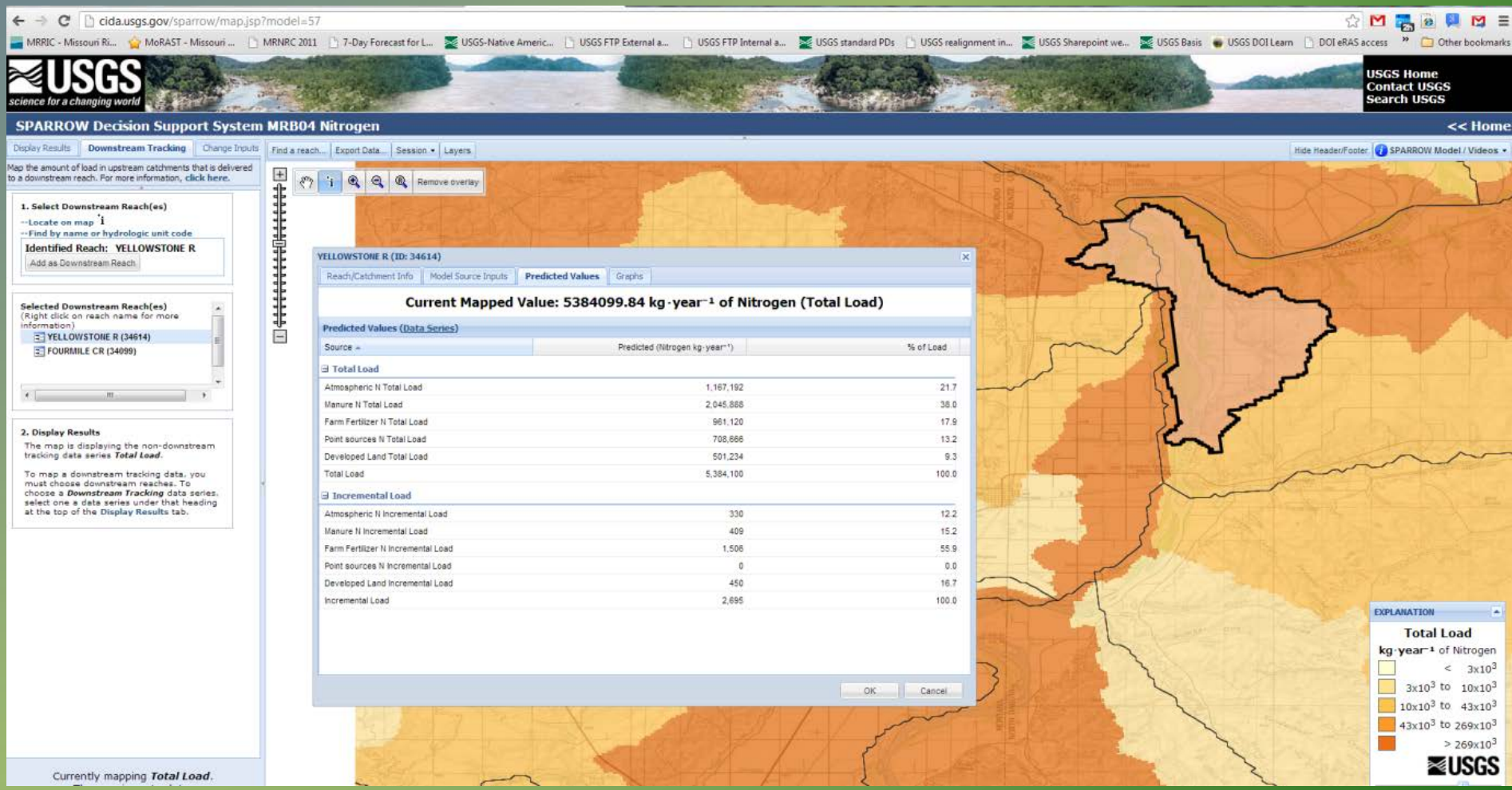


- Total nitrogen loads from all sources (model input)
- Location of calibration sites
- Pick list of possible data series

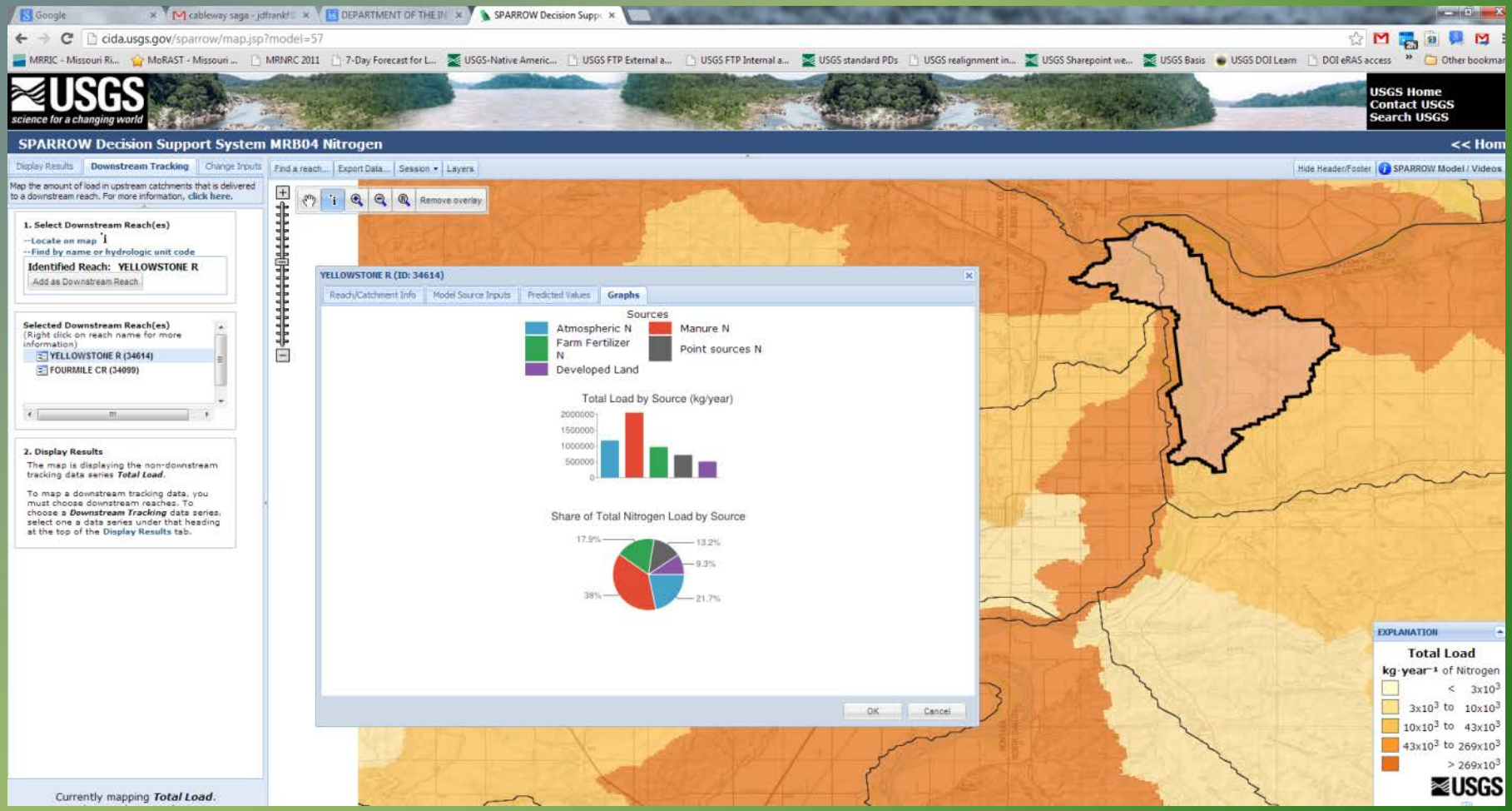
DSS: Identify reach by stream name or location



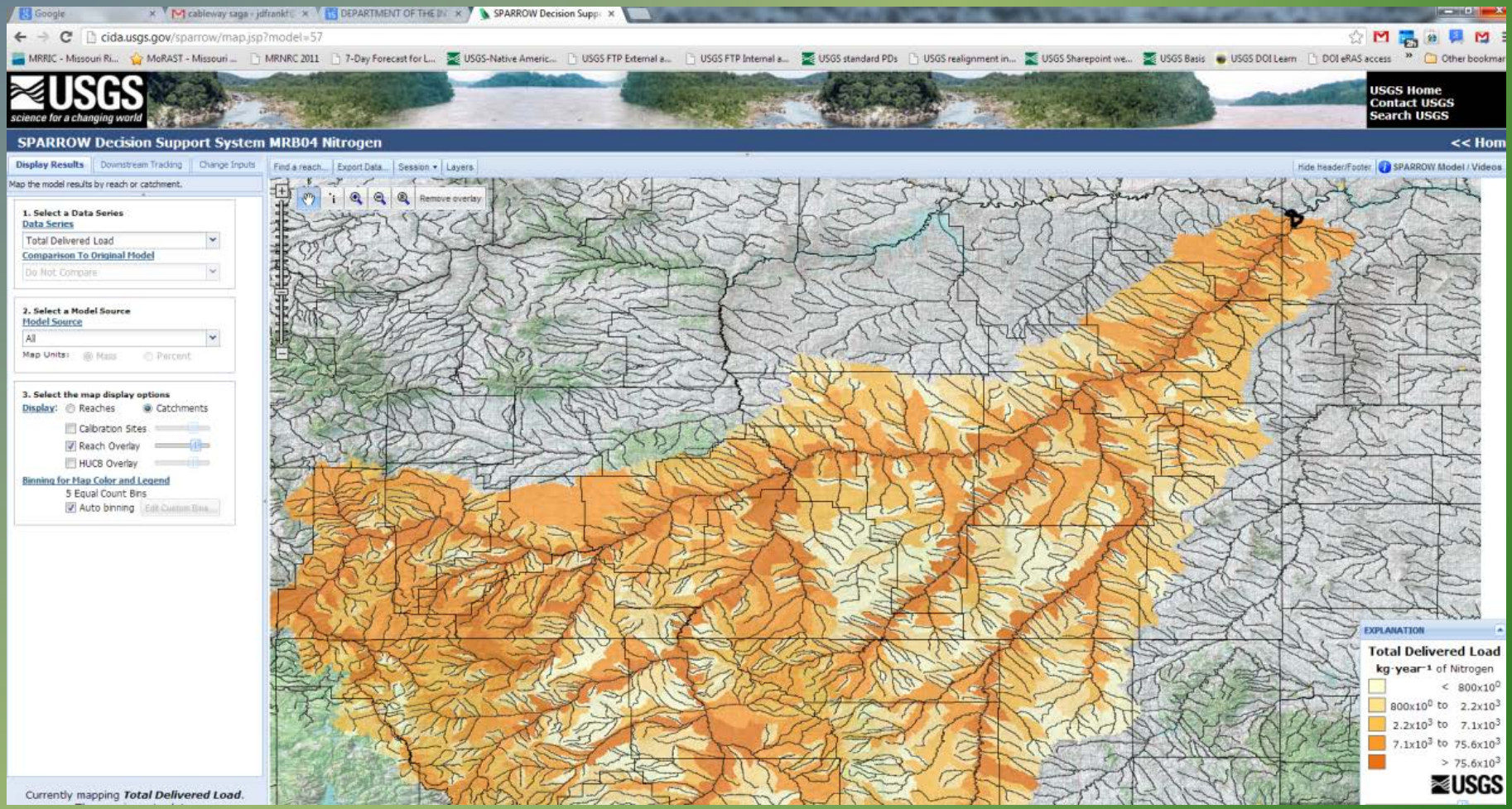
DSS: Display detailed information for the reach



DSS: Display detailed information

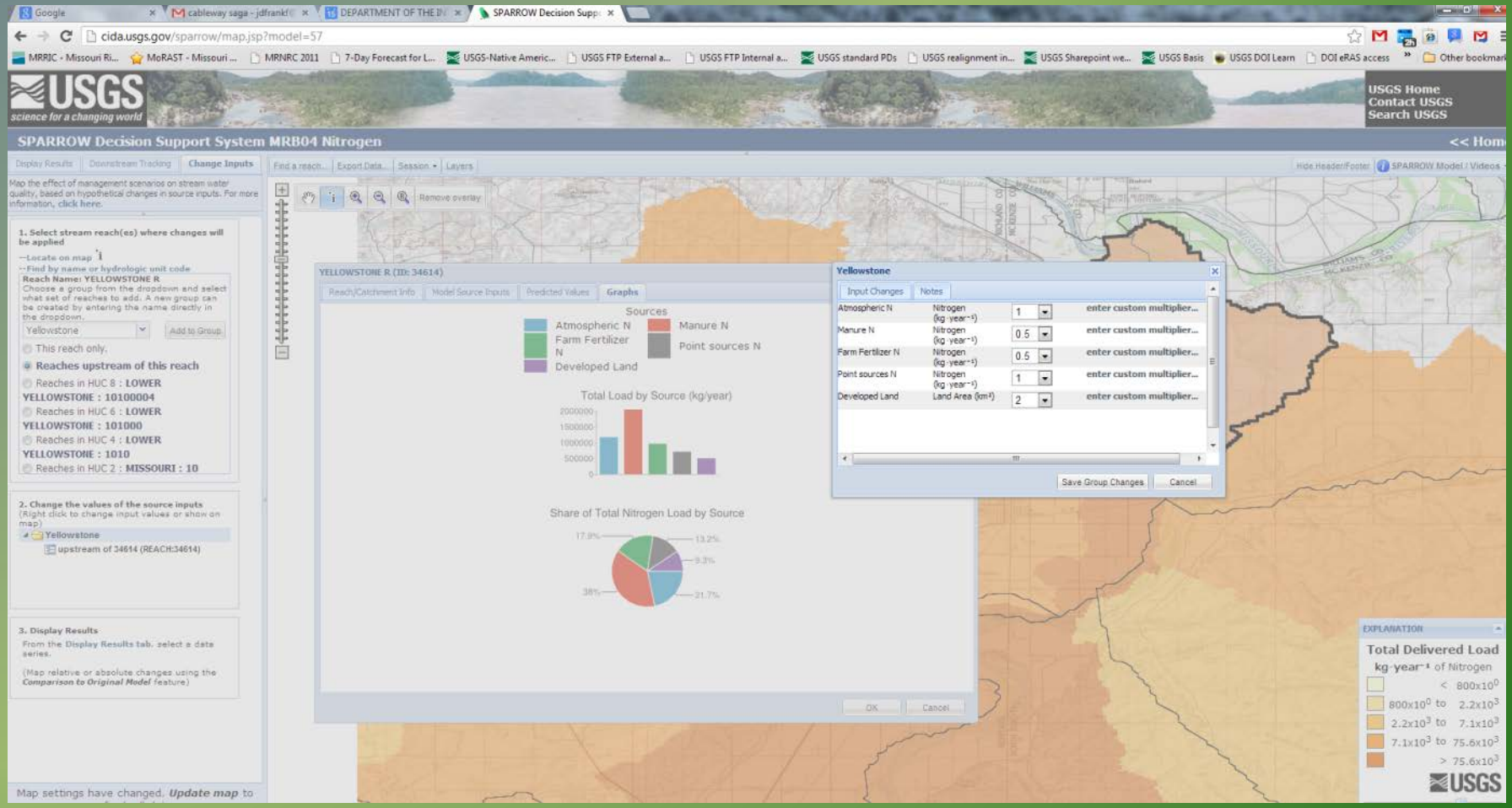


DSS: Downstream tracking

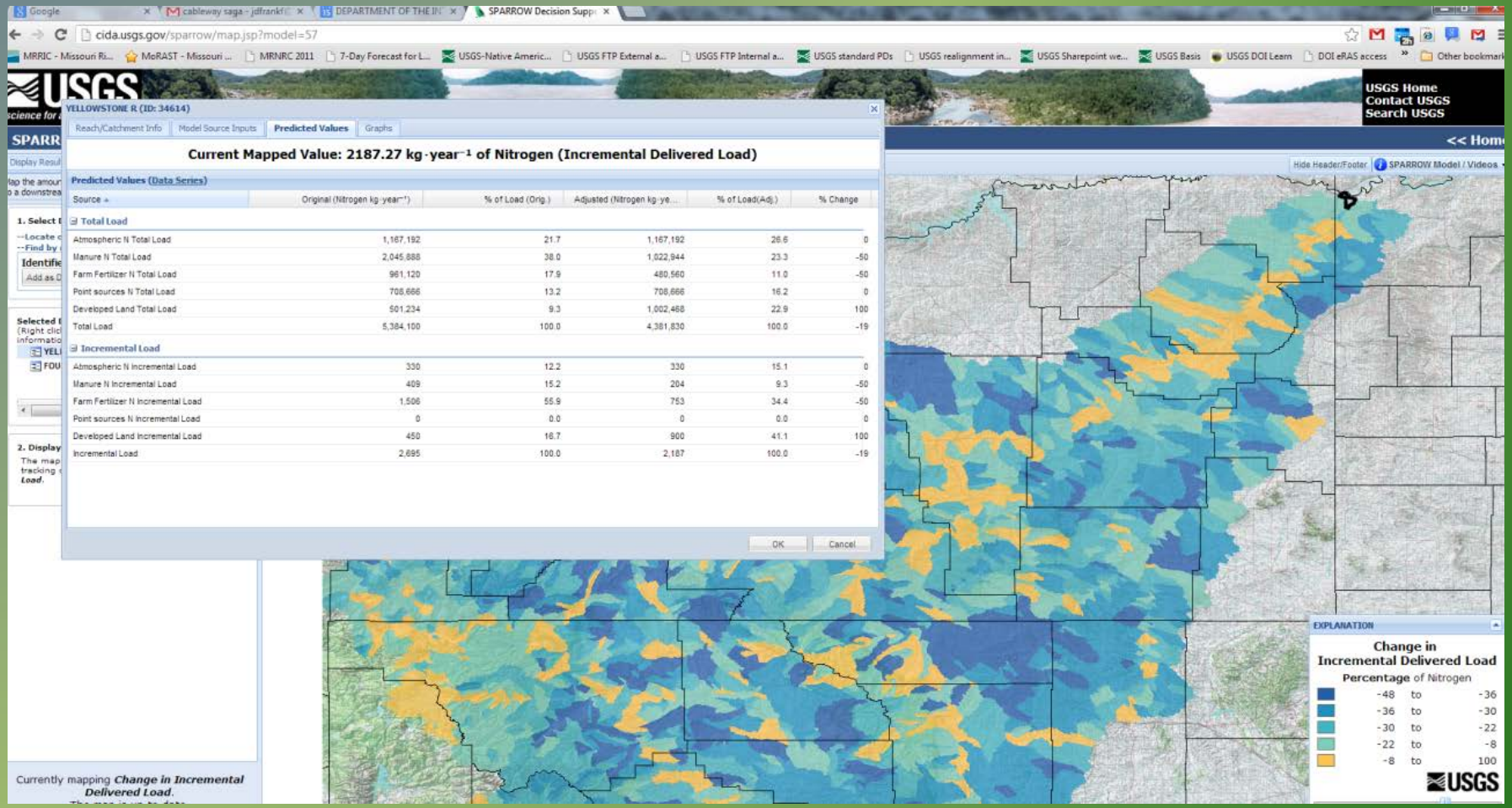


- Total delivered load
- Incremental delivered load
- Delivery fraction
- Incremental delivered yield

DSS: Change fertilizer, manure, or atmospheric input

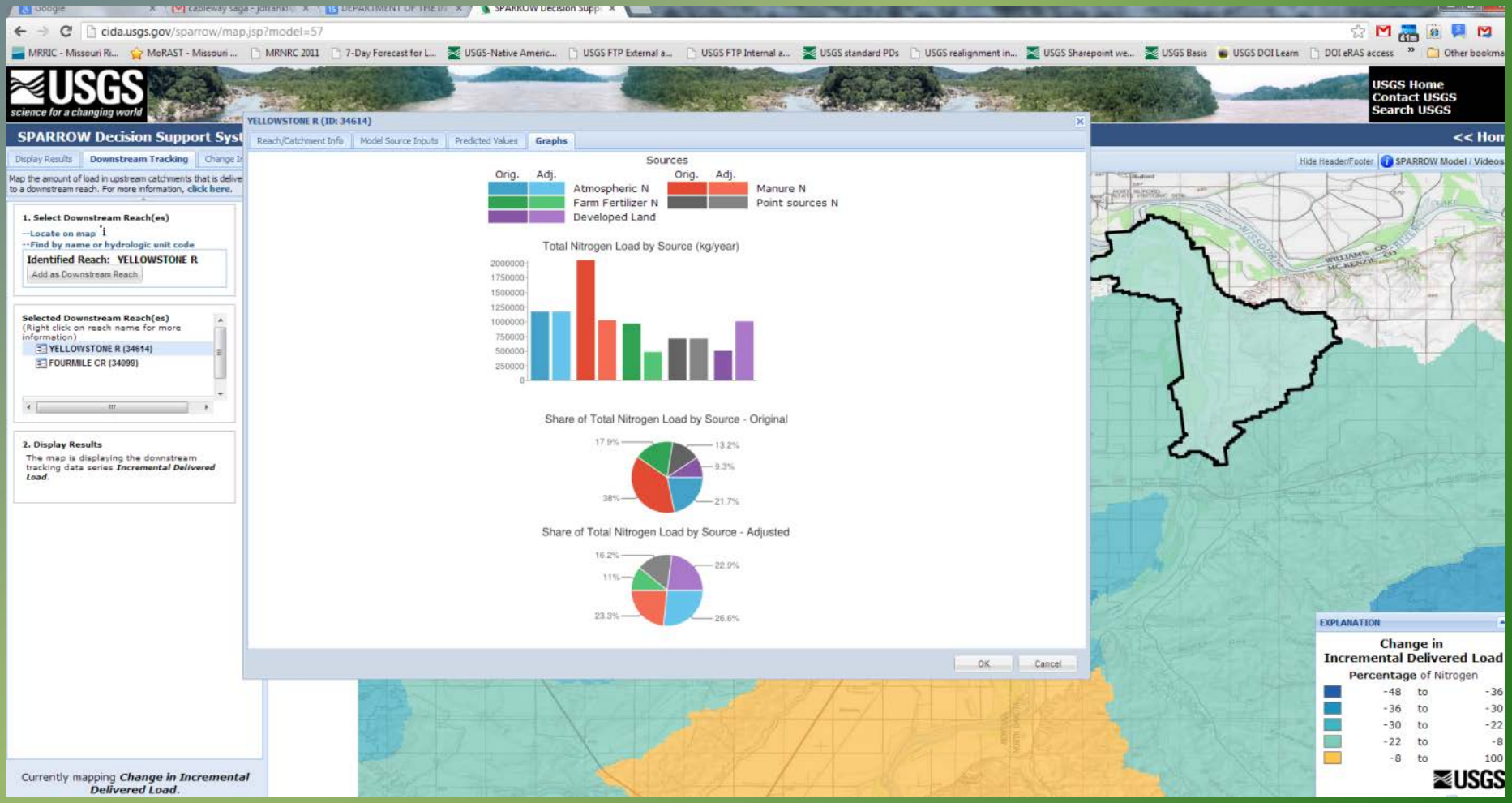


DSS: Estimate changes in predicted load

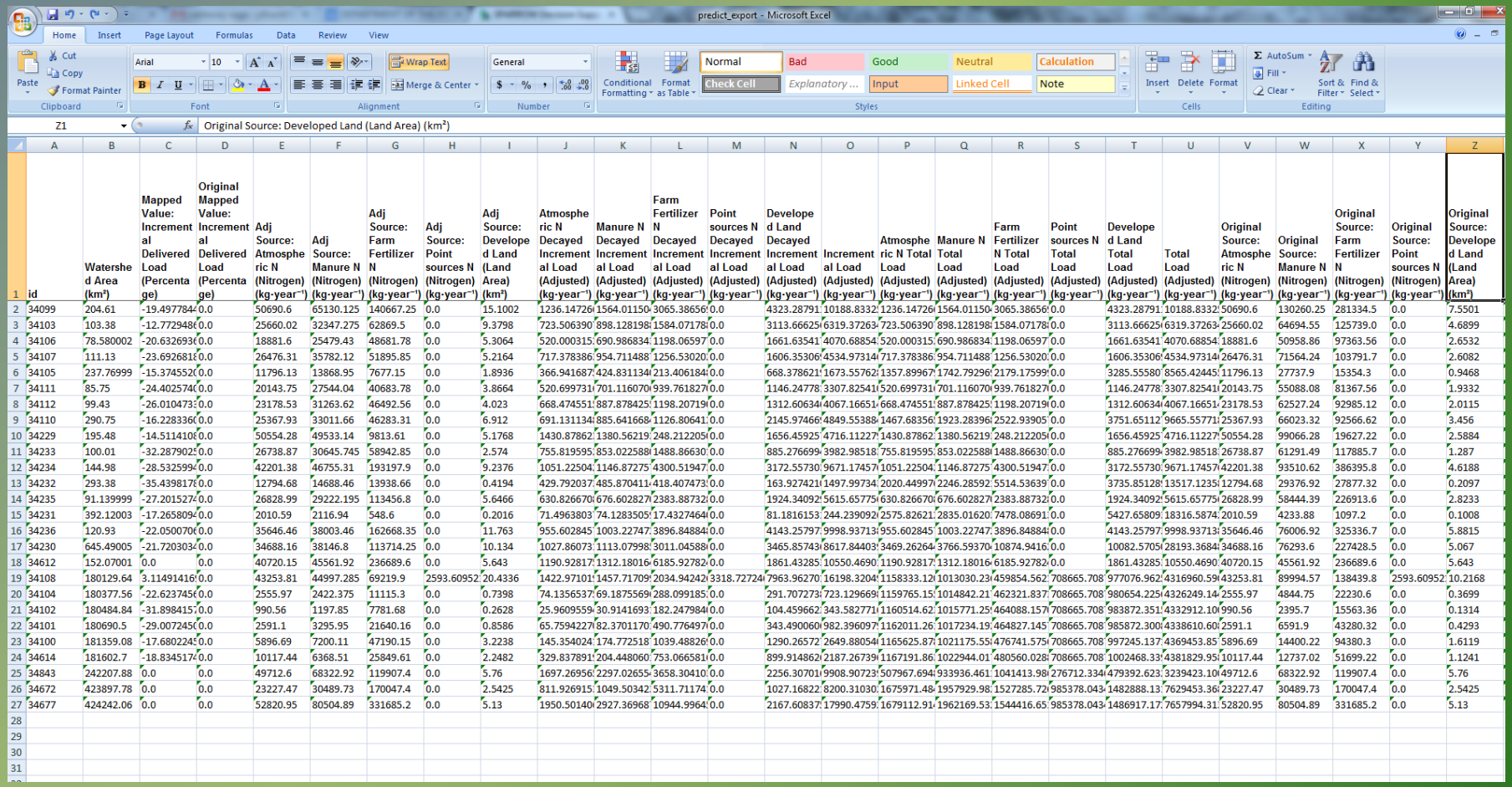


- Incremental delivered load (percent change from original)

DSS: Plots of predicted change in loads



DSS: Export data



predict_export - Microsoft Excel

Z1 | Original Source: Developed Land (Land Area) (km²)

id	Watershed Area (km²)	Mapped Value: Incremental Delivered Load (Percentage)	Original Mapped Value: Incremental Delivered Load (Percentage)	Adj Source: Atmospheric N (Nitrogen) (kg·year⁻¹)	Adj Source: Manure N (Nitrogen) (kg·year⁻¹)	Adj Source: Farm Fertilizer N (Nitrogen) (kg·year⁻¹)	Adj Source: Point sources N (Nitrogen) (kg·year⁻¹)	Adj Source: Developed Land (Land Area) (km²)	Atmospheric N Decayed Incremental Load (Adjusted) (kg·year⁻¹)	Manure N Decayed Incremental Load (Adjusted) (kg·year⁻¹)	Farm Fertilizer N Decayed Incremental Load (Adjusted) (kg·year⁻¹)	Point sources N Decayed Incremental Load (Adjusted) (kg·year⁻¹)	Developed Land Decayed Incremental Load (Adjusted) (kg·year⁻¹)	Incremental Load (Adjusted) (kg·year⁻¹)	Atmospheric N Total Load (Adjusted) (kg·year⁻¹)	Manure N Total Load (Adjusted) (kg·year⁻¹)	Farm Fertilizer N Total Load (Adjusted) (kg·year⁻¹)	Point sources N Total Load (Adjusted) (kg·year⁻¹)	Developed Land Total Load (Adjusted) (kg·year⁻¹)	Total Load (Adjusted) (kg·year⁻¹)	Original Source: Atmospheric N (Nitrogen) (kg·year⁻¹)	Original Source: Manure N (Nitrogen) (kg·year⁻¹)	Original Source: Farm Fertilizer N (Nitrogen) (kg·year⁻¹)	Original Source: Point sources N (Nitrogen) (kg·year⁻¹)	Original Source: Developed Land (Land Area) (km²)
34099	204.61	-19.497784	0.0	50690.6	65130.125	140667.25	0.0	15.1002	1236.14726	1564.01150	3065.38656	0.0	4323.28791	10188.8332	1236.14726	1564.01150	3065.38656	0.0	4323.28791	10188.8332	50690.6	130260.25	281334.5	0.0	7.5501
34103	103.38	-12.772948	0.0	25660.02	32347.275	62869.5	0.0	9.3798	723.506390	898.128198	1584.07178	0.0	3113.66625	6319.37263	723.506390	898.128198	1584.07178	0.0	3113.66625	6319.37263	25660.02	64694.55	125739.0	0.0	4.6899
34106	78.580002	-20.632693	0.0	18881.6	25479.43	48681.78	0.0	5.3064	520.000315	690.986834	1198.06597	0.0	1661.63541	4070.68854	520.000315	690.986834	1198.06597	0.0	1661.63541	4070.68854	18881.6	50958.86	97363.56	0.0	2.6532
34107	111.13	-23.692681	0.0	26476.31	35782.12	51895.85	0.0	5.2164	717.378386	954.711488	1256.53020	0.0	1606.35306	4534.97314	717.378386	954.711488	1256.53020	0.0	1606.35306	4534.97314	26476.31	71564.24	103791.7	0.0	2.6082
34105	237.76999	-15.374552	0.0	11796.13	13868.95	7677.15	0.0	1.8936	366.941687	424.831134	213.406184	0.0	668.378621	1673.55762	1357.89967	1742.79296	2179.17599	0.0	3285.55580	8565.42445	11796.13	27737.9	15354.3	0.0	0.9468
34111	85.75	-24.402574	0.0	20143.75	27544.04	40683.78	0.0	3.8664	520.699731	701.116070	939.761827	0.0	1146.24778	3307.82541	520.699731	701.116070	939.761827	0.0	1146.24778	3307.82541	20143.75	55088.08	81367.56	0.0	1.9332
34112	99.43	-26.010473	0.0	23178.53	31263.62	46492.56	0.0	4.023	668.474551	887.878425	1198.20719	0.0	1312.60634	4067.16651	668.474551	887.878425	1198.20719	0.0	1312.60634	4067.16651	23178.53	62527.24	92985.12	0.0	2.0115
34110	290.75	-16.228336	0.0	25367.93	33011.66	46283.31	0.0	6.912	691.131134	885.641668	1126.80641	0.0	2145.97466	4849.55388	1467.68356	1923.28396	2522.93905	0.0	3751.65112	9665.55771	25367.93	66023.32	92566.62	0.0	3.456
34229	195.48	-14.511410	0.0	50554.28	49533.14	9813.61	0.0	5.1768	1430.87862	1380.56219	248.212205	0.0	1656.45925	4716.11227	1430.87862	1380.56219	248.212205	0.0	1656.45925	4716.11227	50554.28	99066.28	19627.22	0.0	2.5884
34233	100.01	-32.287902	0.0	26738.87	30645.745	58942.85	0.0	2.574	755.819595	853.022588	1488.86630	0.0	885.276699	3982.98518	755.819595	853.022588	1488.86630	0.0	885.276699	3982.98518	26738.87	61291.49	117885.7	0.0	1.287
34234	144.98	-28.532599	0.0	42201.38	46755.31	193197.9	0.0	9.2376	1051.22504	1146.87275	4300.51947	0.0	3172.55730	9671.17457	1051.22504	1146.87275	4300.51947	0.0	3172.55730	9671.17457	42201.38	93510.62	386395.8	0.0	4.6188
34232	293.38	-35.439817	0.0	12794.68	14688.46	13938.66	0.0	0.4194	429.792037	485.870411	418.407473	0.0	163.927421	1497.99734	2020.44997	2246.28592	5514.53639	0.0	3735.85128	13517.1235	12794.68	29376.92	27877.32	0.0	0.2097
34235	91.139999	-27.201527	0.0	26828.99	29222.195	113456.8	0.0	5.6466	630.826670	676.602827	2383.88732	0.0	1924.34092	5615.65775	630.826670	676.602827	2383.88732	0.0	1924.34092	5615.65775	26828.99	58444.39	226913.6	0.0	2.8233
34231	392.12003	-17.265809	0.0	2010.59	2116.94	548.6	0.0	0.2016	71.4963803	74.1283505	17.4327464	0.0	81.1816153	244.239092	2575.82621	2835.01620	7478.08691	0.0	5427.65809	18316.5874	2010.59	4233.88	1097.2	0.0	0.1008
34236	120.93	-22.050070	0.0	35646.46	38003.46	162668.35	0.0	11.763	955.602845	1003.22747	3896.84884	0.0	4143.25797	9998.93713	955.602845	1003.22747	3896.84884	0.0	4143.25797	9998.93713	35646.46	76006.92	325336.7	0.0	5.8815
34230	645.49005	-21.720303	0.0	34688.16	38146.8	113714.25	0.0	10.134	1027.86073	1113.07998	3011.04588	0.0	3465.85743	8617.84403	3469.26264	3766.59370	10874.9416	0.0	10082.5705	28193.3684	34688.16	76293.6	227428.5	0.0	5.067
34612	152.07001	0.0	0.0	40720.15	45561.92	236689.6	0.0	5.643	1190.92817	1312.18016	6185.92782	0.0	1861.43285	10550.4690	1190.92817	1312.18016	6185.92782	0.0	1861.43285	10550.4690	40720.15	45561.92	236689.6	0.0	5.643
34108	180129.64	3.11491416	0.0	43253.81	44997.285	69219.9	2593.60952	20.4336	1422.97101	1457.71709	2034.94242	3318.72724	7963.96270	16198.3204	1158333.12	1013030.23	459854.562	708665.708	977076.962	4316960.59	43253.81	89994.57	138439.8	2593.60952	10.2168
34104	180377.56	-22.623745	0.0	2555.97	2422.375	11115.3	0.0	0.7398	74.1356537	69.1875569	288.099185	0.0	291.707273	723.129669	1159765.15	1014842.21	462321.837	708665.708	980654.225	4326249.14	2555.97	4844.75	22230.6	0.0	0.3699
34102	180484.84	-31.898415	0.0	990.56	1197.85	7781.68	0.0	0.2628	25.9609559	30.9141693	182.247984	0.0	104.459662	343.582771	1160514.62	1015771.25	464088.157	708665.708	983872.351	4332912.10	990.56	2395.7	15563.36	0.0	0.1314
34101	180690.5	-29.007245	0.0	2591.1	3295.95	21640.16	0.0	0.8586	65.7594227	82.3701170	490.776497	0.0	343.490060	982.396097	1162011.26	1017234.19	464827.145	708665.708	985872.300	4338610.60	2591.1	6591.9	43280.32	0.0	0.4293
34100	181359.08	-17.680224	0.0	5896.69	7200.11	47190.15	0.0	3.2238	145.354024	174.772518	1039.48826	0.0	1290.26572	2649.88054	1165625.87	1021175.55	476741.575	708665.708	997245.137	4369453.85	5896.69	14400.22	94380.3	0.0	1.6119
34614	181602.7	-18.834517	0.0	10117.44	6368.51	25849.61	0.0	2.2482	329.837891	204.448060	753.066581	0.0	899.914862	2187.26739	1167191.86	1022944.01	480560.028	708665.708	1002468.33	4381829.95	10117.44	12737.02	51699.22	0.0	1.1241
34843	242207.88	0.0	0.0	49712.6	68322.92	119907.4	0.0	5.76	1697.26956	2297.02655	3658.30410	0.0	2256.30701	9908.90723	507967.694	933936.461	1041413.98	276712.334	479392.623	3239423.10	49712.6	68322.92	119907.4	0.0	5.76
34672	423897.78	0.0	0.0	23227.47	30489.73	170047.4	0.0	2.5425	811.926915	1049.50342	5311.71174	0.0	1027.16822	8200.31030	1675971.48	1957929.98	1527285.72	985378.043	1482888.13	7629453.36	23227.47	30489.73	170047.4	0.0	2.5425
34677	424242.06	0.0	0.0	52820.95	80504.89	331685.2	0.0	5.13	1950.50140	2927.36968	10944.9964	0.0	2167.60837	17990.4759	1679112.91	1962169.53	1544416.65	985378.043	1486917.17	7657994.31	52820.95	80504.89	331685.2	0.0	5.13

Questions?