Back to the Future

Did you know the future is often hidden in our past? Where can we look to find it?

Summary

Students analyze streamflow monitoring data to determine safe and beneficial locations for a growing community.

- Earth Science, Environmental Science, Mathematics, Government

- **Duration:**
  - Preparation time:
    - Part I: 30 minutes
    - Part II: 10 minutes
  - Activity time:
    - Part I: 30 minutes
    - Part II: 50 minutes

- **Setting:**
  Classroom

- **Skills:**
  Organizing (graphing); Interpreting

- **Vocabulary:**
  discharge, floodplain, hydrograph, inundate

Objectives

Students will:

- analyze and interpret streamflow data.
- identify the risks and benefits of development in a floodplain.

Materials

- *News reports of floods (in a local or international river basin) or of water shortages (optional)*
- *Copies of* ***Streamflow Discharge Data*** *(****Part I*** *and* ***Part II****)*
- *A cube 30 centimeters (12 inches) on a side*
- *Graph paper*
- *Copies of a* ***Community Planning Map****, or similar map, indicating existing and future land uses*

Making Connections

Floods and drought frequently make the news. While some events occur unexpectedly, people often prepare for events by looking to the past. Understanding and interpreting historical streamflow data helps students understand how water managers predict and prepare for water excess or shortage.

Background

Data collection is a critical component of most scientific investigations. Water experts calculate the amount of water flowing in a river and analyze streamflow data to assess water availability, allocate water supplies and document historic high water levels to predict flooding issues.

River Thames flood marks, United Kingdom

Streamflow data are collected by many government agencies worldwide, such as the National Hydrological Services, U.S. Geological Survey, navigation groups, irrigation organizations, hydropower operators, and many others. Streamflow (or discharge) data are a measure of water volume (in cubic meters per second or cubic feet per second) passing a given location over a period of time. To determine streamflow, water managers must know the streambed profile, the height (or stage) of a river, and its velocity. This information tells water managers how much water is flowing in a river at a given time and location.

Streamflow information is collected manually or with electronic gages. Electronic gages, typically located near dams or bridges, generally record flows 24 hours a day, 365 days a year. Manual sites are monitored daily, weekly, or monthly as needed, or after large rainfall events. To take a manual reading, a hydrographer wades into the stream or stands on a bridge or cable system, with a current meter and gaging stick, to record velocity and river depth.

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Streamflow data are used to develop hydrographs, which show the amount of water flowing or discharged over time at a given location. For example, the average monthly discharge may be plotted at a site over a one-year period (12 monthly readings or data entries) to create the historical hydrograph.

Hydrologists learn about stream fluctuation patterns by monitoring it over many years. For example, depending on the prevailing climate, rivers may have low flows in the fall and winter, increased levels in the spring, and peak flows in early summer. Hydrologists use this data to create computer models to help predict streamflow during and after rainfall, snowmelt, and drought.

Watershed precipitation amounts, and snowpack levels, also help forecast possible streamflow levels. The amount of snowpack in a local mountain range directly affects the amount of water discharged by a river in late spring or summer. Once hydrologists know streamflow patterns, they inform water resource management agencies, city planners, extension agencies, farmers and others of future estimated streamflow discharges.

Streamflow predictions, even when using scientific methods, might not be fully reliable. Significant changes in a river's watershed, like construction of dams, levees, or water diversions, can cause flows to vary from historical patterns. But, knowing historical patterns can help people predict streamflows and better prepare for possible flood disasters.

Knowledge of river slope (a river's change in elevation—for example, a high mountain stream with steep slope as opposed to a prairie stream that is relatively flat), as well as availability of water, land use, soil type, vegetation and flooding potential are essential for community planning. Water managers may recommend that people not live in a certain location because of frequent floods. Such an area is called a floodplain (any area that can be inundated when water levels exceed stream banks).

One option is to limit development in these areas or require that flood-prone areas remain in their natural state. However, such sites are often desirable for human settlement; they are fertile, level and scenic. In countries with largely agricultural economies, floodplains play a key role in the livelihood and food security of many people.

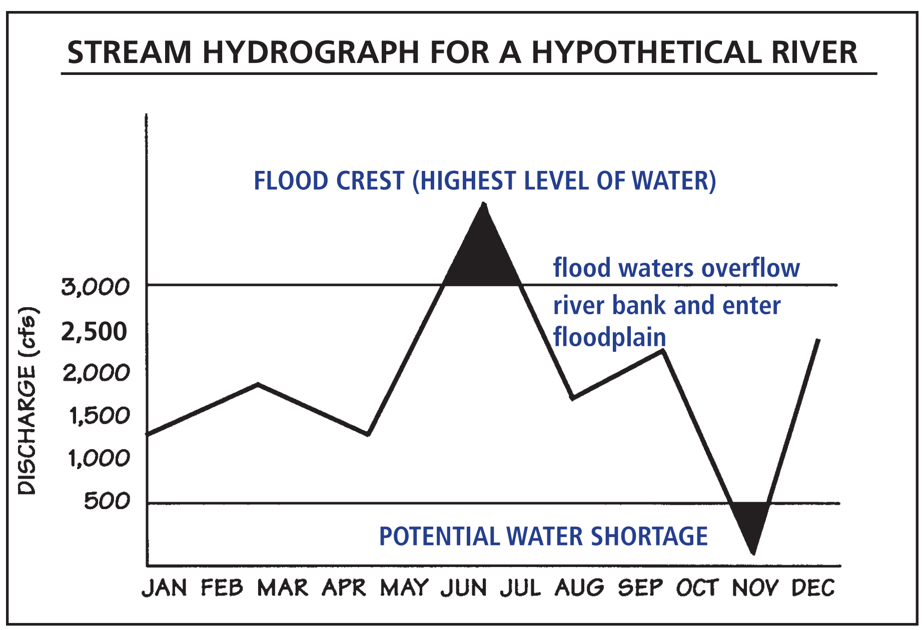
Dams, levees, detention basins and bypass channels are built to protect areas from inundation, up to a certain elevation. In other locations, flood waters are diverted to areas where less harm is caused, or where it can be stored for later use. These flood control projects are relatively costly, but even costlier measures are usually necessary to deal with large floods. Flood forecasting and warning systems, flood insurance programs, land use regulations, emergency preparedness and response plans, in addition to public awareness programs, comprise methods that can minimize the costs and impact of urban-area floods.

Throughout the world, floodplain areas can extend dozens of kilometers (miles) on each side of the river. This can force residents of entire communities to relocate on a regular basis—to temporary housing on higher ground—during the flood season.

Despite how devastating floods can be for human communities, they play a vital role in natural systems. River corridor ecosystems are accustomed to, and in many cases dependent on, variations in streamflow. For example, many fish species depend on floodplains temporarily covered by floodwaters. Wetlands may depend on water circulation and nutrient recycling during floods.

Floods are designated by their probability of occurrence—such as 500-, 100-, or 10-year floods. Past flood records must be studied to make this analysis. A 10-year flood means that in any particular year, there is a 1 in 10 chance of a flood of that magnitude or discharge occurring in a given location (based on historical data). A 100-year flood has a 1 in 100 chance of occurring at a given location in any given year. It's important to note that a 100-year flood can occur two consecutive years at a given location. Hydrologists can only say that, according to historical flood records and other statistical analysis, a flood of a particular magnitude has a given probability of occurring in any particular year.

The concept of a 10-, 100- or 500-year flood is often misunderstood. Many people think that if they have experienced a 500-year flood, it will



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not occur again for another 499 years. That is not true. A 500-year flood is the discharge of water in a river that has a 1 in 500 chance of happening in any one year. This is based on the laws of probability. For example, the U.S. Geological Survey (USGS) takes annual peak flow discharge values from USGS stream gages and uses a probability model to determine discharge values for a 10-, a 100-, or a 500-year flood. Designations of 10-, 100-, or 500-year floods can be thought of as big, bigger, and biggest floods. Scientists create maps to show the water levels and potential inundated areas of 10-, 100-, and 500-year floods. These are extremely useful for public safety and flood insurance purposes.

Of course, the more data hydrologists have available the more reliable their calculations. That is why the USGS and other organizations strive to keep their gaging stations active as long as possible. If a probability model uses data from a gaging station with a 25-year record, that mathematical model will not be as reliable as a gaging station that has 100 years of data.

Lack of streamflow data, incomplete or inconsistent data makes flood analysis in many countries very difficult. Lack of information can have major implications for planning new flood protection works or drainage infrastructure, as well as the location of settlements, roads and bridges.

Although living on a floodplain may expose its occupants to flooding, it also offers enormous advantages. The deep, fertile alluvial soil of floodplains—resulting from eons of flooding—is ideal for crop production. In addition, floodplains typically support very high density human settlements. It is not coincidental that population densities are high in the Netherlands and Bangladesh since they are comprised mostly of floodplains.

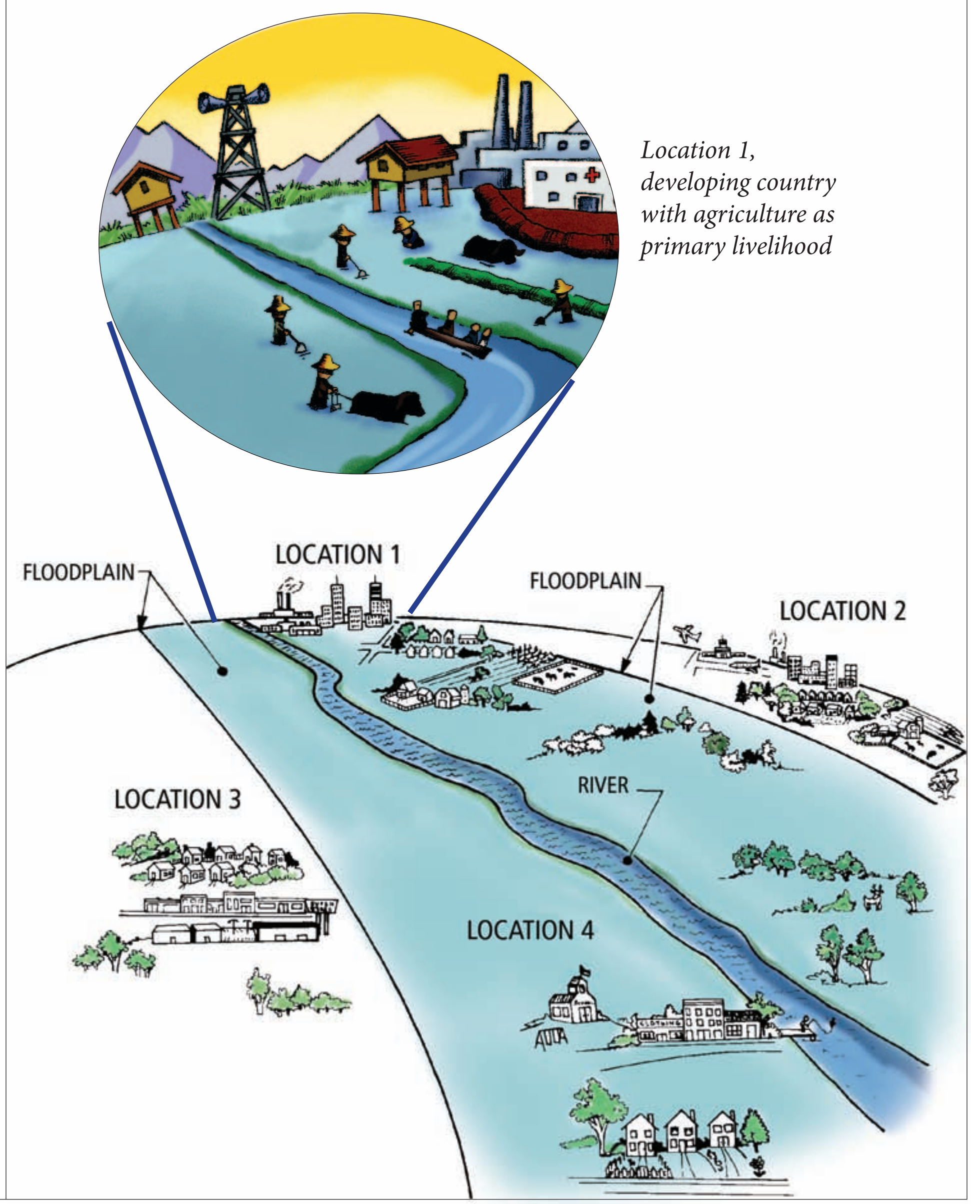
Floodplain managers depend on accurate, long-term streamflow records to make decisions about water management. One of the most important aspects is the "net-benefits" of a proposed plan. Net-benefits can be determined by calculating the overall benefits of a particular proposal and then deducting the expected losses from flooding. Maximizing these net-benefits is a primary goal of flood managers and community planners.

Procedure

▼ *Warm Up*

Ask students to describe the effects streamflow variations can have on people, property, and ecosystems. Have them describe events they have heard or read about regarding floods. Share news articles about these events. Have students scan the reports to discover what conditions might have led to severe flooding (for example, large amounts of rainfall in a brief period, or inadequate flood control structures).

COMMUNITY PLANNING MAP



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The Activity

Part I

1. **Show students the Streamflow Discharge Data (Part I). Explain that these measure the quantity of river water flowing past a certain point within a certain timeframe.**

2. **Explain that streamflow measurements are typically in cubic meters per second (cms) or cubic feet per second (cfs). Show students a one cubic meter or cubic foot box.** If a river discharges 300 cubic meters or cubic feet per second, that means that 300 "boxes of water" pass by a certain point of the river within one second!

3. **Have students work in groups to plot the monthly averages from *Streamflow Discharge Data* (*Part I*). There are 39 years of data. Divide the number of years by the number of groups, and assign each group a set of data to graph. All data can be plotted on one graph, or, for clarity, each group can plot their data on a separate graph.** Hydrologists refer to this as a hydrograph.

4. **Discuss the following questions: During which month(s) does the greatest amount of water flow in the river? In which month(s) is the streamflow lowest?**

5. **Have students locate months when the streamflow exceeds 3,000 units.** Tell them this is when river discharge is at flood stage. How many years are there between floods? Indicate time periods when discharge is less than 600 units in June or July; these may be times of critical water shortage.

VIEWS

LOCATION 1:

I think we should build at Location 1. The property values are low and we won't have to pay high prices to get water into our homes. The soil is great for farming and the views of the river are wonderful! I also think we should allow industries to build their factories here. There is plenty of water for their production needs, and they will provide jobs for community members. There hasn't been a flood here in over 10 years, so it's nothing to fret about. In addition, floodplain management program funds or subsidies are available for structural and non-structural flood management measures.

LOCATION 2:

Well, just because a flood hasn't happened in 10 years doesn't mean it won't. I say let's build above the floodplain. We'll have to pay more in property taxes and for water, but homes will be less expensive because we won't have to floodproof them. If we invite industries to locate here, people will have secure jobs and the city will prosper.

LOCATION 3:

Even though we'll have to pay more, I think we should build above the floodplain. Location 3 is a good distance from the floodplain, and the land is not too steep. I don't think we should allow industry to settle here; it will use too much water and could create pollution problems. Instead, we should promote small businesses.

LOCATION 4:

I agree that we should plan for a small community and promote small businesses instead of industry. More people will place more demands on our water supply . . . and what happens during times of drought? However, if we build in the floodplain, at Location 4, we'll have flat, fertile land, which is easier to farm and better for constructing houses. I don't think a flood will happen in our lifetime, so that shouldn't stop us from building.

BUILDING IN THE FLOODPLAIN

PRO	CON
flat building surface	chance of flooding
scenic views	economic and emotional impacts
easy access to river	temporary or permanent:
fertile soil	- loss of home and contents
ease of transporting water	- business closure with loss of income
livelihood opportunities in fisheries and agriculture	- sense of property violation
	- fear
	- injury or death

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Part II

1. Show groups the *Community Planning Map*. Normally, river discharge is low enough that no inundation occurs. But, when a river floods, surface water flows into the floodplain area. Explain to students that a community plans to expand into a new area along this river. Four sites—Locations 1, 2, 3, and 4—have been proposed.

2. Provide students with the following information. The land in the floodplain is flat and fertile, and provides attractive views of the river. In addition, the land on the floodplain provides great opportunities for farming. Because the area is known to become inundated, land values in the floodplain are lower than land away from it. In addition, certain industries want to build factories in the area so they can have access to river water for manufacturing. Towns that support industry are more likely to have larger populations because factories provide job opportunities. At Location 1, floodplain management program funds or subsidies are available for structural and non-structural flood management measures. At Location 4, no such program is available (Note: This information pertains to this activity's scenario and may differ in actual situations.)

3. Have students listen to the views of four people—proponents of Locations 1, 2, 3, and 4—on where to expand the community. Students may wish to role-play the different views. In addition to discussing where to build, consider the issue of allowing certain industries to locate their factories in the community.

4. Ask students to list the pros and cons for building on a floodplain. Discuss the benefits and drawbacks of establishing industries in a community. The chart *Building in the Floodplain*—presenting pros and cons—is an example of a decision-making strategy.

OUTCOMES

The outcome for Locations 1 and 2 is the same, except that 1 is in the floodplain and 2 is not. If you choose 1 or 2, the end result is a large community including three factories and several farms. The farms in Location 1 need less fertilizer and have easy access to irrigation water. During winter, the community needs about 60 million gallons (228 million liters) per day. In summer, because of agriculture and additional water requirements in energy production, water needs increase to nearly 500 million gallons (1.9 billion liters) per day.

Based on the argument that floodplains can provide opportunities, but also potential flood losses, Location 1 is the best selection for a rapidly growing population (e.g., developing countries with agriculture as the main source of livelihood). In addition, it may be the only viable option for placing settlements even though it's in a floodplain. Many small farms prosper on the floodplain, but small agricultural levees are required to protect crops from frequent/smaller floods. Houses are built on stilts to avoid flood waters or they are elevated. An effective flood warning system is also necessary. Industries, key infrastructure and other vulnerable buildings (power stations, hospitals, etc.) are located at the outer end of the floodplain, and are protected by small ring levees. Emergency shelters are made available in nearby towns outside the floodplain in case of a major flood.

The outcomes for Locations 3 and 4 are the same, except that 4 is in the floodplain and 3 is not. It is likely that Location 4 has no funding from a floodplain management program, and cannot develop adequate safeguards to protect human life and property from flooding. If you choose Locations 3 or 4, the end result is a medium-sized community, including one small factory, a number of small businesses, and several farms. During winter, the community needs approximately 50 million gallons (190 million liters) of water per day. In summer, water needs increase to nearly 350 million gallons (1.33 billion liters) per day because of agriculture and additional water requirements in energy production.

5. Ask students to predict outcomes for each location (1, 2, 3, or 4). Have each group select one site for expansion and discuss the reasons for their choice.

6. After groups have made their selections, read the Outcomes in the sidebar.

7. Provide students with the *Streamflow Discharge Data* (*Part II*). This table represents the six-year period following the community's expansion. Have students look for times when the river flooded (> 3,000 units). Have them identify times when the community might have experienced times of water shortage (<600 units in June or July). To confirm whether or not there is enough water for community needs, have students use the conversion of 1 unit per second = 0.646 million gallons (2.4 million liters) per day. They can then calculate how many gallons (or liters) of water the river supplies (i.e., 922 units per second x 0.646 = 595.61 million gallons (2.3 trillion liters) per day.

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8. Instruct students choosing Location 3, that they should find that their community avoided inundation. Students may be interested in checking how other sites fared. Locations 1 and 4 would have flooded. Location 2 would not have flooded.

9. Ask students if they think their choices of locations would have been different if the annual probability of flooding was 1 in 50 (2%) in any given year. What about a 1 in 100 chance? Or 1 in 500? Provide students with information about an extreme flood in their area. Ask students if they think homes destroyed by a flood should be rebuilt on a floodplain. If they answer yes, what conditions would they require to allow for rebuilding in a floodplain? The answers could include: mandatory flood insurance, flood proofing houses, flood forecasting and warning systems, flood defenses, mandatory flood emergency response plans for the community, etc.

Wrap Up and ActionEducation

Have students summarize how past records can help plan for the future. They could contact community planners and state government agencies to study their local floodplain laws and flood management plans.

Ask students to survey friends and family to determine if they would build their homes in a location that had reasonable property rates, attractive views, or a friendly community, even if the site was located in a 100-year floodplain. Have students tally the responses and draw conclusions from the results.

Assessment

Have students:

- graph streamflow data (***Part I***, step 3).
- interpret streamflow data to identify fluctuations in discharge (***Part I***, step 5).
- analyze the risks and benefits of living in a floodplain (***Part II***, step 9, and ***WrapUp***).

Extensions

Students may be interested in entering data into a spreadsheet software program that will plot the data.

Have an insurance representative visit the class to discuss floodplain insurance. Ask students how flood insurance premiums would affect the outcomes of their decisions.

Contact city planners to learn if local rivers flood or if water shortages occur. Take a field trip to a stream and observe development of the surrounding area.

Resources

Leopold, Luna B. 1974. *Water: A Primer*. San Francisco, Calif.: W. H. Freeman & Co.

Patterson, Mark, and Ron Mahoney. 1993. *Environmental Education Software and Multimedia Source Book*. Moscow, Idaho: University of Idaho Agricultural Publications.

e-Links

World Meteorological Organization, 2004. *Integrated Flood Management Concept Paper*, http://www.apfm.info/pdf/concept_paper_e.pdf

United States Geological Survey Fact Sheet 229-96 http://pubs.usgs.gov/fs/FS-229-96/

United States Geological Survey CoreCast, June 2008 *Two 500-Year Floods Within 15 Years?* http://www.usgs.gov/corecast/details.asp?ID=81

United States Geological Survey The National Streamflow Statistics Program: A Computer Program for Estimating Streamflow Statistics for Ungaged Sites

http://pubs.usgs.gov/tm/2006/tm4a6/

Photo Resources

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Streamflow Discharge Data (Part I)

Monthly average discharge in units

Students should plot data until present date. After they decide on a location for the community, they should use Part II of this table to plot the rest of the data.

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
19—	147	144	150	306	802	1043	581	184	118	46	58	44
19—	43	47	61	861	1430	1158	437	159	145	207	112	85
19—	74	82	184	609	1411	937	462	150	82	113	108	75
19—	70	63	60	265	991	1648	502	168	108	144	142	157
19—	162	144	138	536	1194	863	235	54	85	86	97	81
19—	124	122	123	382	1055	1361	706	256	222	217	204	137
19—	152	172	172	910	1790	1453	820	374	203	207	169	154
19—	156	145	140	926	2708	3079	859	351	260	218	185	190
19—	199	164	200	585	755	1507	927	276	176	187	169	142
19—	149	149	157	549	1287	908	617	191	143	150	133	110
19—	108	105	99	137	694	1174	489	193	124	121	156	202
19—	178	138	180	941	2288	2132	747	291	215	227	190	163
19—	143	147	161	336	1600	1900	683	256	184	189	169	159
19—	144	146	145	386	2862	1950	692	326	240	191	183	163
19—	148	147	146	371	520	938	308	135	207	220	166	129
19—	125	115	169	545	659	751	213	101	101	107	105	92
19—	97	94	100	248	515	751	207	126	138	134	121	96
19—	99	119	117	703	952	2121	566	245	180	201	162	137
19—	120	159	146	214	1180	3608	670	257	215	206	209	158
19—	145	149	143	391	942	1437	707	259	173	169	158	197
19—	219	179	206	852	2057	2916	1759	666	438	312	247	184
19—	197	172	179	507	805	562	202	118	105	121	127	112
19—	113	113	141	269	1876	2778	1194	351	249	269	234	188
19—	172	166	216	347	516	974	355	276	229	212	185	151
19—	156	156	163	1312	2031	2010	741	314	250	243	189	168
19—	157	147	169	297	914	687	283	208	154	152	140	132
19—	146	142	154	642	1726	1662	1049	363	310	259	215	186
19—	177	170	216	568	1198	3353	449	205	152	201	194	158
19—	150	162	216	492	2393	2877	1426	500	326	304	256	220
19—	212	198	273	494	2189	2272	1550	683	426	427	430	324
19—	289	275	288	641	1755	1985	1112	469	329	283	259	224
19—	216	189	213	712	1003	749	330	219	383	265	214	196
19—	189	194	475	1178	1815	2410	694	344	290	278	226	167
19—	155	152	213	375	725	520	284	172	128	125	131	121
19—	119	119	153	343	621	715	217	133	116	120	125	115
19—	120	114	149	644	994	954	351	174	156	165	156	131
19—	126	121	157	439	464	831	359	185	152	150	146	122
19—	167	150	177	288	1107	1661	832	277	240	241	254	204
Present	212	208	334	439	1263	2550	660	315	257	266	226	161

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Streamflow Discharge Data (Part II)

Monthly average discharge in units

For six-year period following the community's expansion

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
First	159	159	155	324	861	743	632	380	160	169	210	166
Second	181	168	279	1089	2199	3161	953	378	246	244	223	171
Third	168	158	162	209	1083	2227	1517	392	253	256	233	202
Fourth	181	181	179	492	1486	1114	615	349	312	238	183	152
Fifth	143	132	134	151	201	574	550	153	141	148	134	136
Sixth	132	131	198	623	1319	1783	955	347	346	230	196	160

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