Appendix C: Linear Extrapolation of Flow Duration Curves and Linear Interpolation of Load Duration Curves

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C-1 Introduction

The Illinois Streamflow Assessment Model (ILSAM) equations were used to estimate percentile flows (in cubic feet per second, cfs) at each of 19 stations; for a full discussion of ILSAM, see Appendix A, Section A-4. Two difficulties were encountered with the ILSAM method. First, if the drainage area of a stream was too small, ILSAM could not estimate flows at all the necessary percentiles. Second, most water quality sample events occurred at percentiles that were not estimated by ILSAM. The first dilemma was rectified by performing a linear extrapolation of a flow duration curve that was generated from the ILSAM estimations. The second dilemma was rectified by performing a linear interpolation between ILSAM-estimated percentile flows.

C-2 Linear Extrapolation of the Flow Duration Curve

This section discusses why it was necessary to perform linear extrapolations of certain flow duration curves and provides figures that display the linear extrapolations.

C-2.1. Methodology

ILSAM was used to estimate percentile flows that were then used to generate a flow duration curve. If an ungaged station had sufficient drainage area, ILSAM could estimate the following percentile flows: 1, 2, 5, 15, 25, 40, 50, 60, 75, 85, 90, 95, 98, and 99. Table C-1 displays the flow percentiles per station that ILSAM could calculate given the stations' drainage area.

Table C-1. Flow percentiles calculated at each station

Station	1	2	5	10	15	25	40	50	60	75	85	90	95	98	99
X02K04	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
X02K11	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
X02K14	x	x	x	x	x	x	x	x	x	x	x	x	x		
X02K15	x	x	x	x	x	x	x	x	x	x	x				
X01K17	x	x	x	x	x	x	x	x	x	x	x				
X02K20	x	x	x	x	x	x	x	x	x	x	x	x			
X02K23	x	x	x	x	x	x	x	x	x	x	x	x	x		
X02K25	x	x	x	x	x	x	x	x	x	x					
X02K26	x	x	x	x	x	x	x	x	x	x	x	x			
X02K28	x	x	x	x	x	x	x	x	x	x					
K02K32	x	x	x	x	x	x	x	x	x	x					
X02K40	x	x	x	x	x	x	x	x	x	x					
X02K41	x	x	x	x	x	x	x	x	x	x	x	x	x		
X02W04	x	x	x	x	x	x	x	x	x						
X02W05	x	x	x	x	x	x	x	x	x	x	x	x			
X02W06	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
X02W12	x	x	x	x	x	x	x	x	x	x	x	x			
MO-901	x	x	x	x	x	x	x	x	x						
S-901	x	x	x	x	x	x	x	x	x	x	x	x			

x = ILSAM-generated flow.

The ILSAM-estimated percentile flows were used to generate flow duration curves that were then used to generate load duration curves. To calculate a total maximum daily load (TMDL) for the low–flow zone (90^{th}–100^{th} percentiles), either the 95^{th} percentile flow or the percentile flow corresponding to a water quality sample event was necessary. In the second scenario, the corresponding percentile flow would need to be estimated using linear interpolation of the flow duration curve with the 95^{th} percentile as the terminus. Therefore, a 95^{th} percentile flow is needed for every station.

At 13 stations, the 95^{th} percentile could not be calculated (Table C-1) using ILSAM. Linear extrapolation was used to estimate a 95^{th} percentile flow for nine of these stations. Four stations are on streams with WWTPs. The design flow for the WWTPs was added to the ILSAM-estimated flows. Thus, when ILSAM could not estimate a streamflow for a certain percentile, the flow assigned to that percentile was the WWTP design flow.

A flow duration curve was generated at each of the nine stations and the value of the 95th percentile flow was visually estimated (see figures in Section C-2.2). The y-axis (streamflow in cfs) was always plotted on a log-scale. The point was chosen by manually adjusting a visually displayed line such that the slope of the line was consistent with the slope of the line or curve geometry at the last ILSAM-generated flow percentile. Table C-2 displays the visually estimated 95th percentile flow.

Table C-2. Visually estimated 95th percentile using flow duration curves

Station	95th percentileflow (cfs)
X02K15	0.0015
X02K17	0.0005
X02K20	0.015
X02K25	0.002
X02K26	0.015
X02K28	0.003
X02K32	0.002
X02K40	0.005
X02W05	0.015

The 95th percentile flow (in cfs) at these stations was used to calculate the load (in kilograms per day). These flows were visually estimated and could be of limited accuracy. Because ILSAM could not estimate natural streamflow at these stations for the 95th percentile and because the flows are very small (possibly not even field-measurable), it could be assumed that the stream is dry.

The estimated flow duration line connecting the visually estimated 95th percentile flow to the last ILSAM-generated flow is always represented as a dashed line and labeled as *Linear Extrapolation* in the legend on all figures in this appendix. In the figures in the main report, the portion of the load duration curve that is based on the visually estimated 95th percentile is also always represented by a dashed line and labeled as *Linear Extrapolation*.

C-2.2. Figures

Flow duration curves for the nine stations that required linear extrapolation are presented in this section.

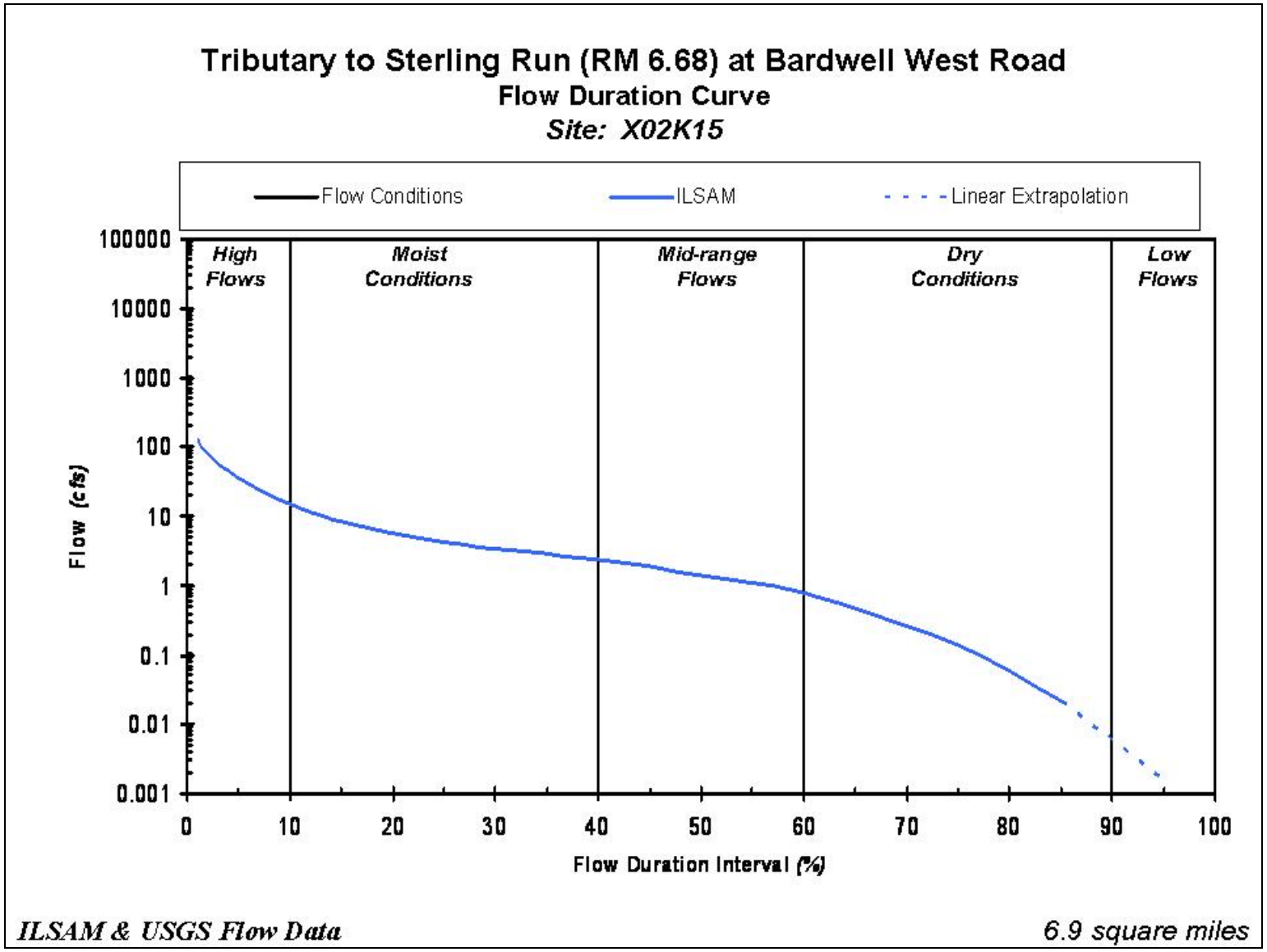

Figure C-1. Flow duration curve for station X02K15.

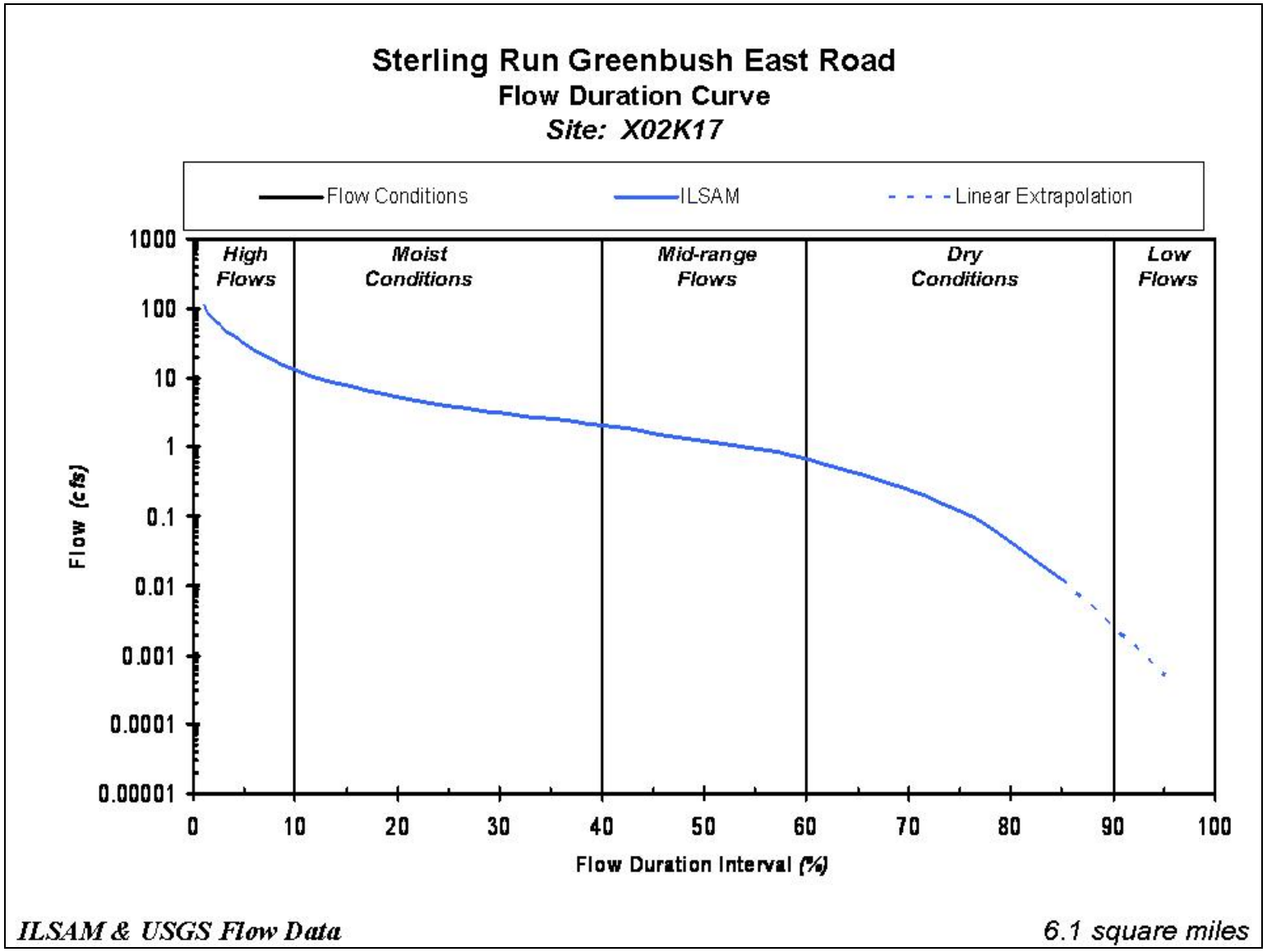

Figure C-2. Flow duration curve for station X02K17.

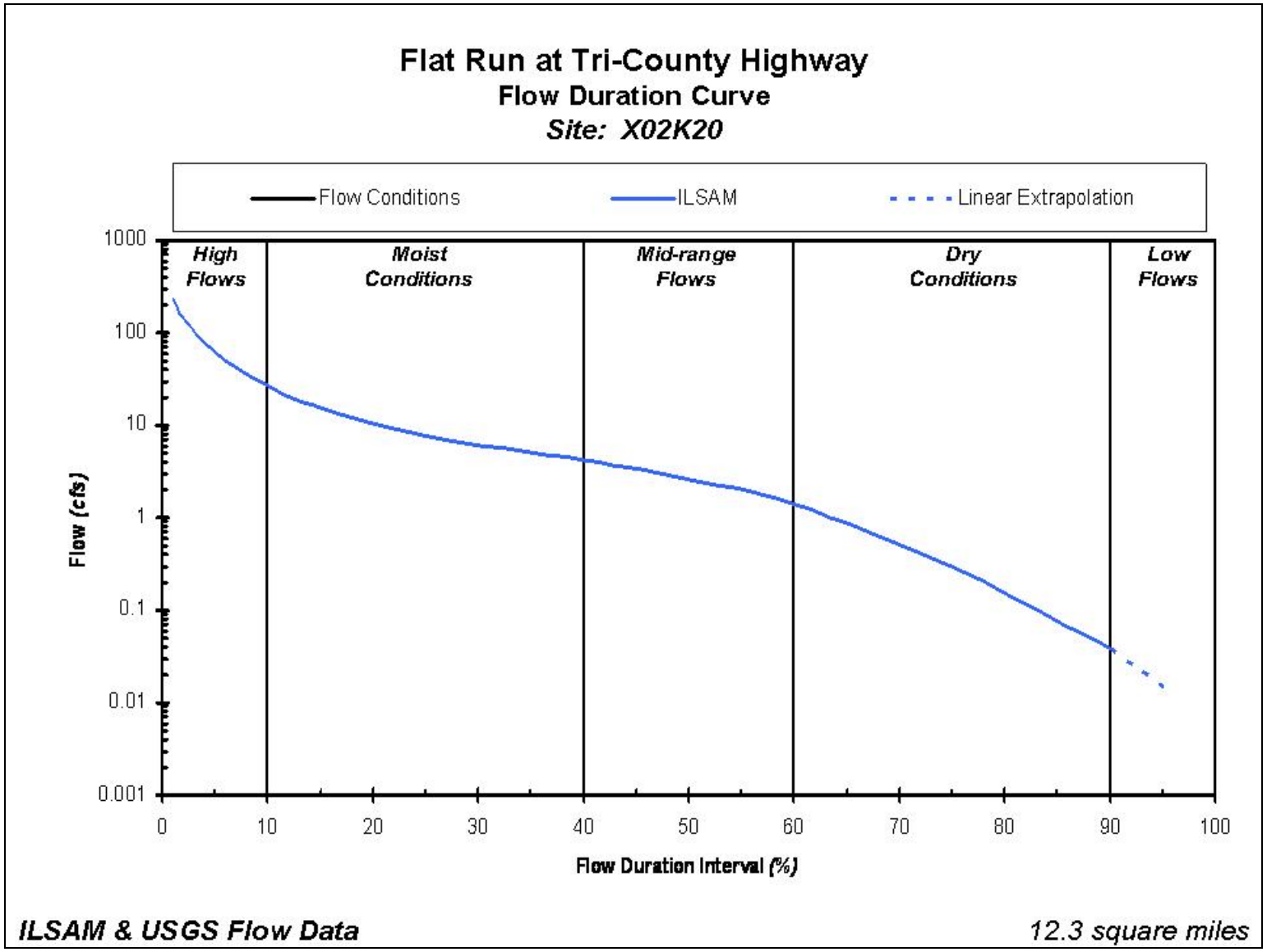

Figure C-3. Flow duration curve for station X02K20.

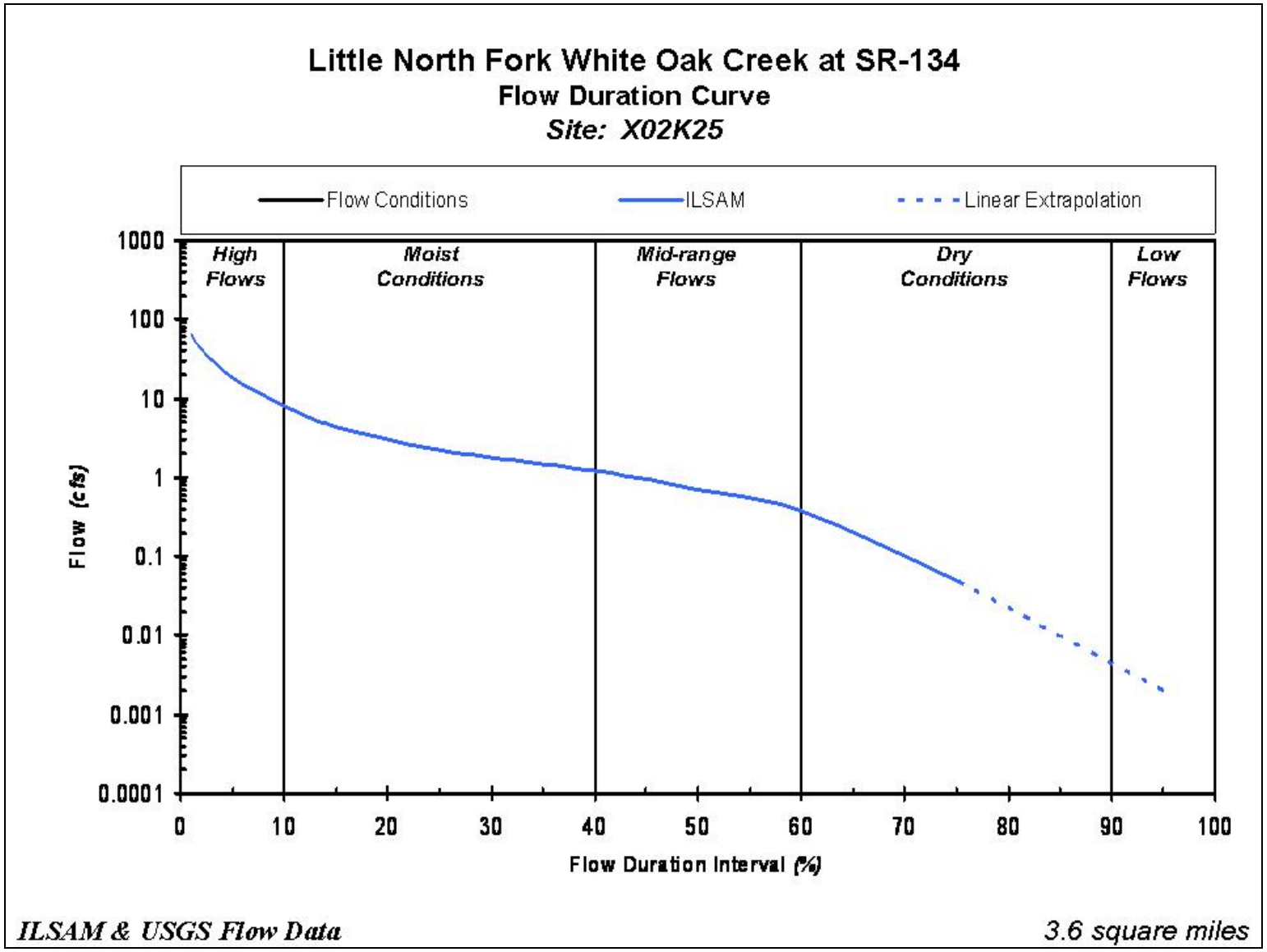

Figure C-4. Flow duration curve for stationX02K25.

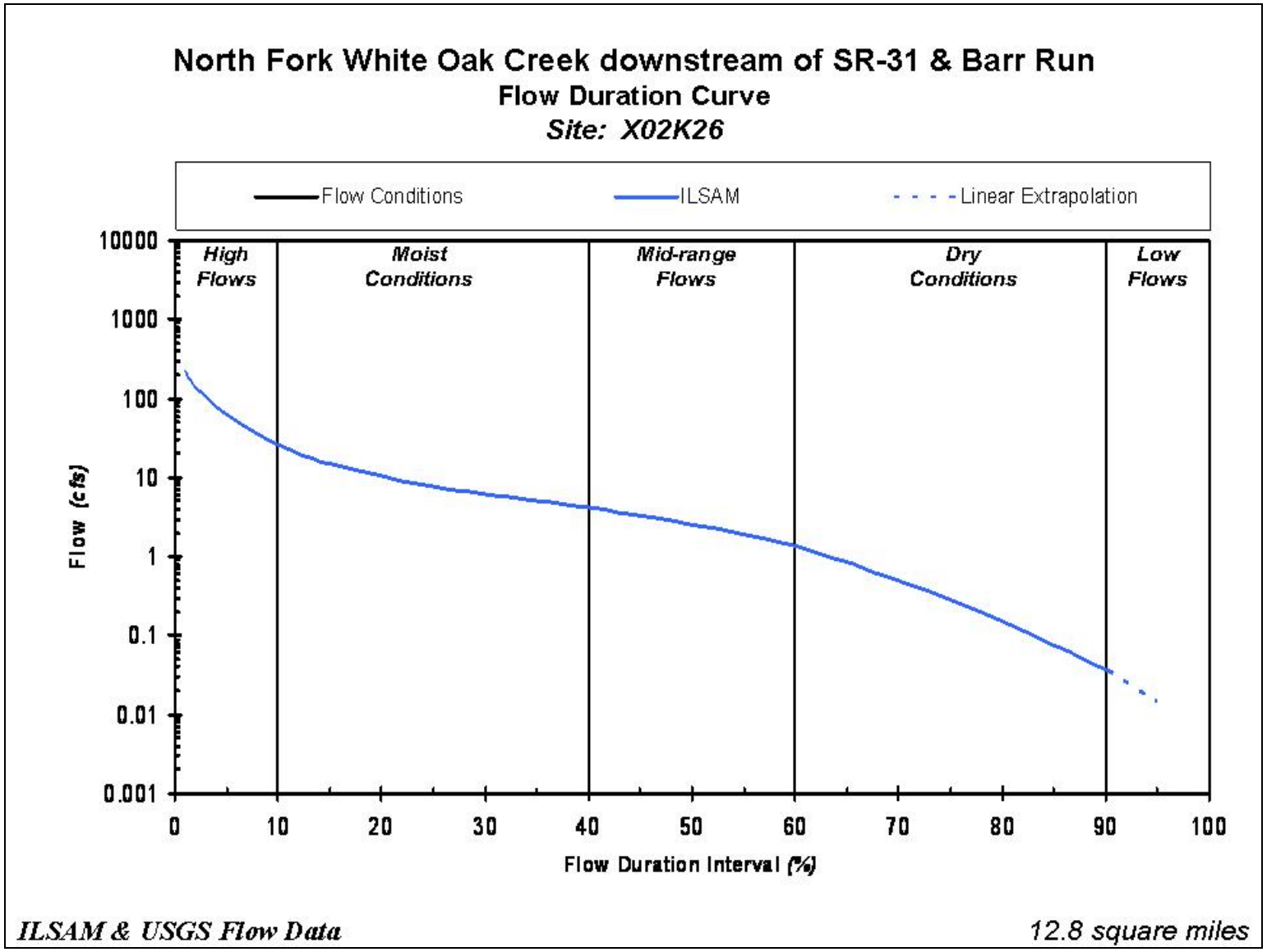

Figure C-5. Flow duration curve for station X02K26.

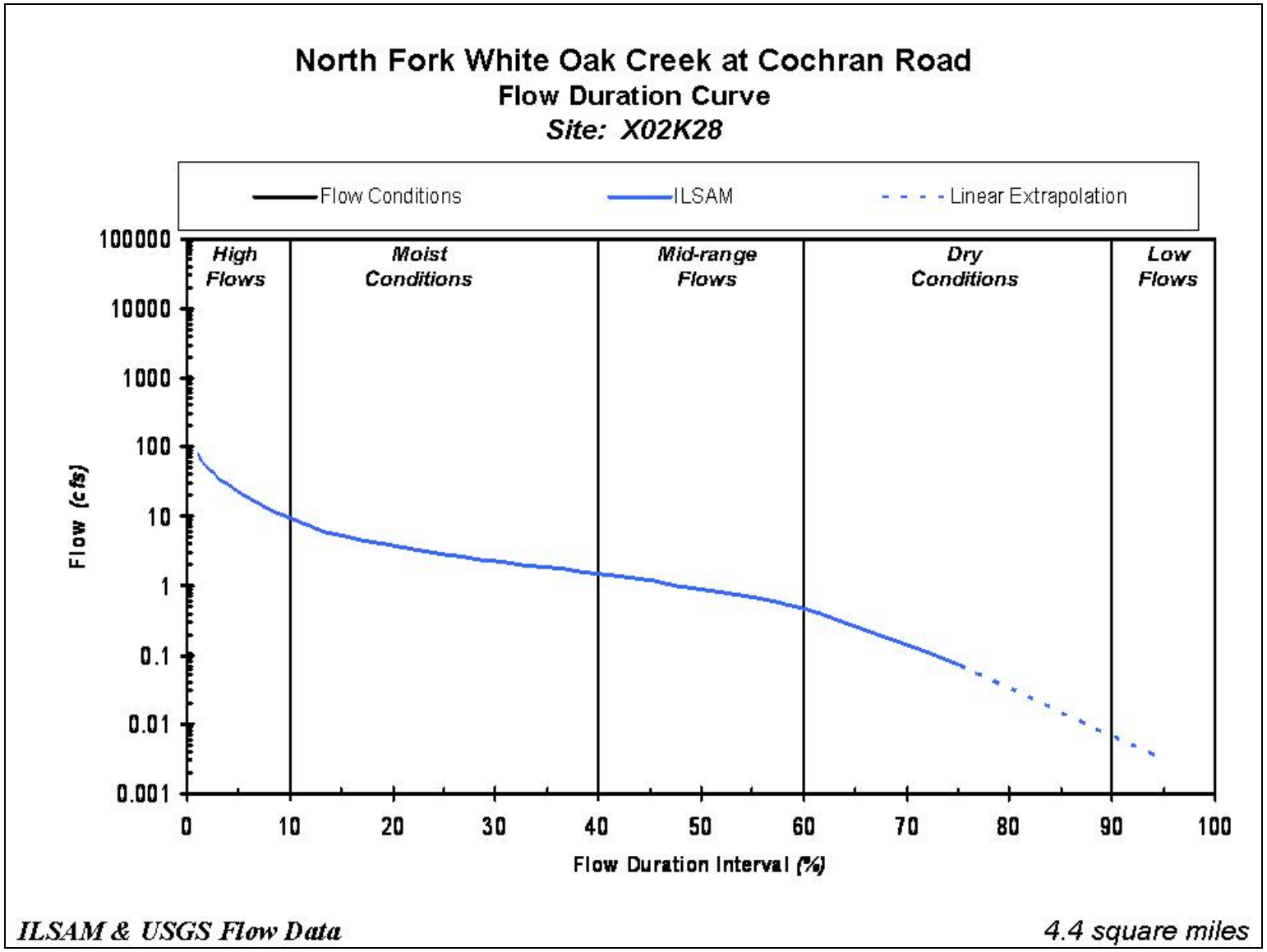

Figure C-6. Flow duration curve for station X02K28.

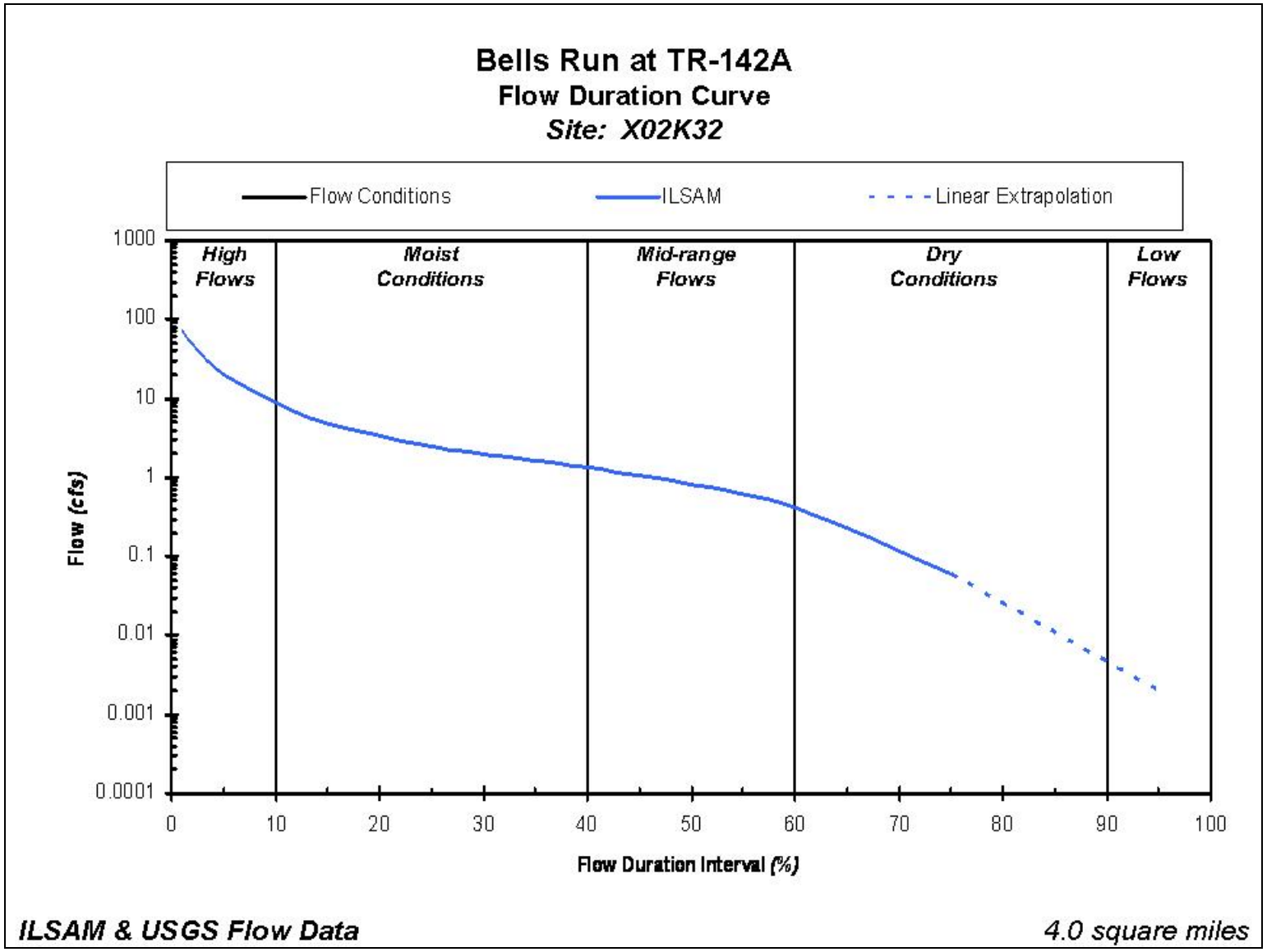

Figure C-7. Flow duration curve for station X02K32.

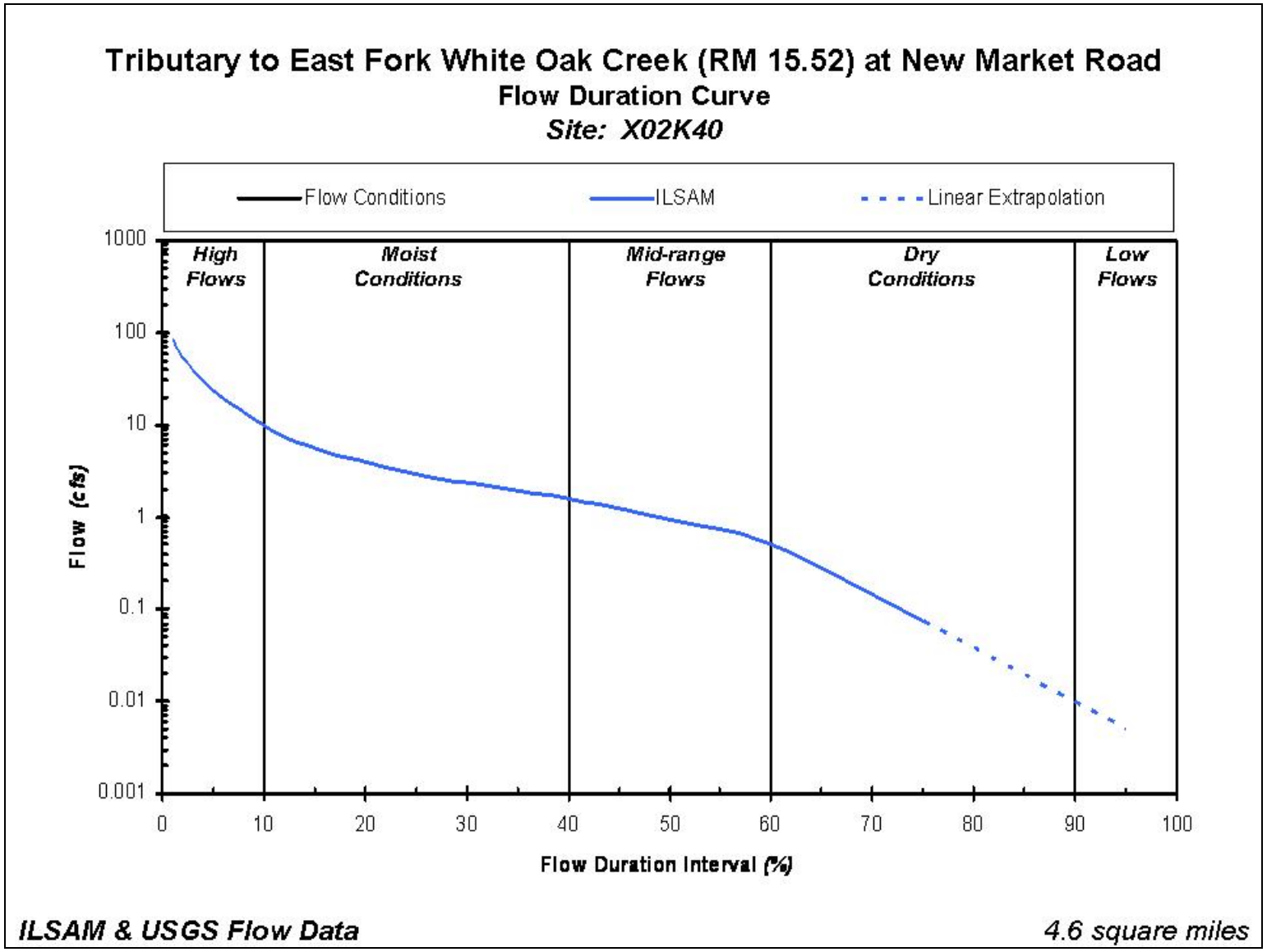

Figure C-8. Flow duration curve for station X02K40.

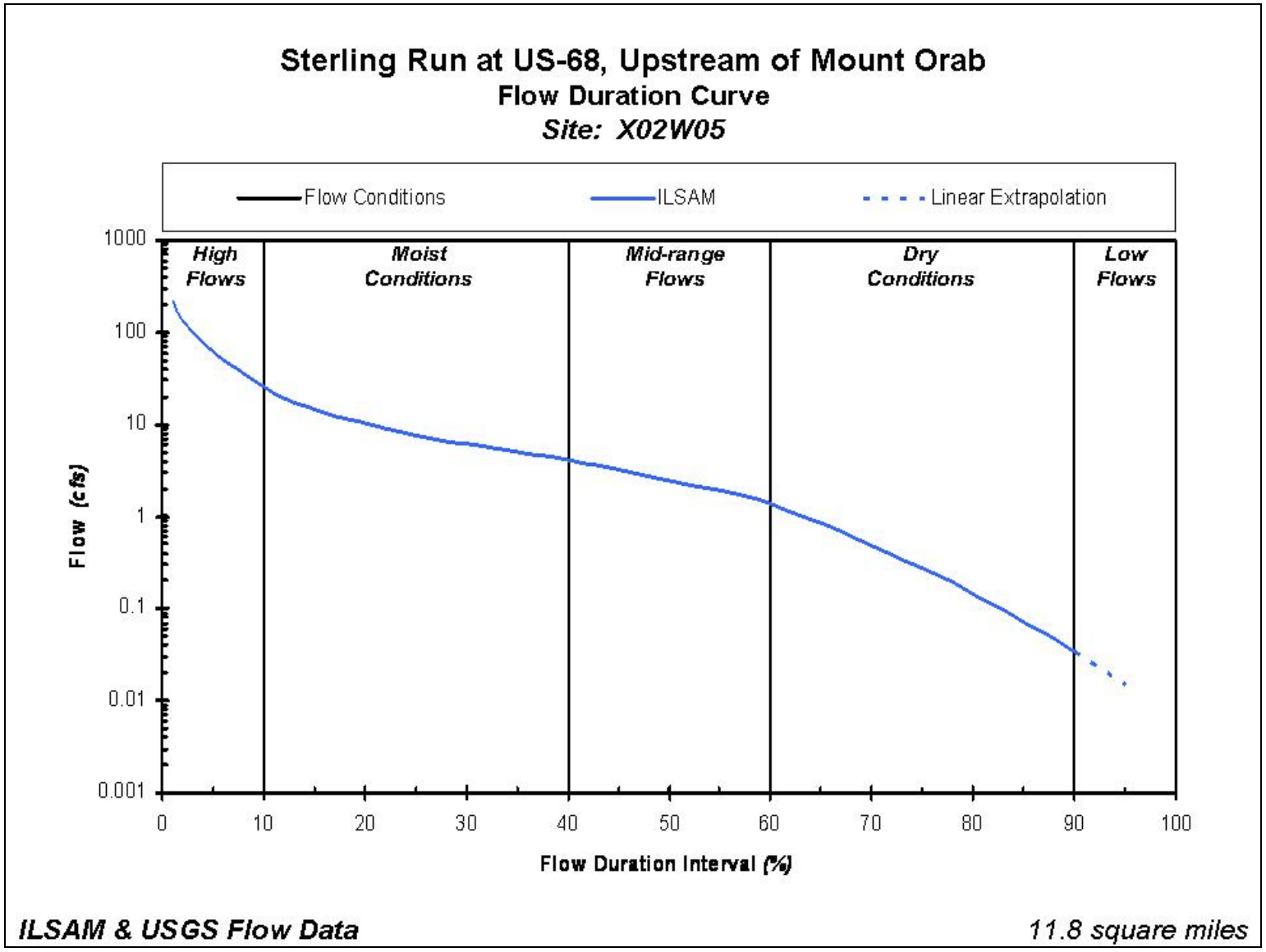

Figure C-9. Flow duration curve for station X02W05.

C-3 Determination of the Percentiles Necessary for the TMDLs

At most stations, only five samples were collected. The samples tended to be collected during conditions representative of two flow zones. When no observed data were available for a certain flow zone, the midpoint of the flow zone was used to calculate the TMDL, and no reduction was calculated. If data were present within a flow zone, the TMDL was calculated at the percentile of the observed data value requiring the maximum potential reduction. The value requiring the maximum potential reduction was not necessarily the maximum value within the flow zone. The percentiles used to calculate the TMDLs and load reductions are displayed in Table C-3.

Table C-3. Percentiles used to calculate TMDLs

Station	Parameters[a]	High Flows[b]	Moist conditions[b]	Mid-range flows[b]	Dry conditions[b]	Low flows[b]
MO-901		5.5	17.2	54.1	67.8	91.6
S-901		5	29.3	49.4	67.8	91.3
X02K04		5	25	55.2	85.4	95
X02K11		5	25	55.2	75.4	95
X02K14	TP	5	25	55.2	75.4	95
X02K14 & OH-0801011[c]	Atrazine	7.1	35	56.4	64.7	90.3
X02K15		5	25	55.2	85.4	95
X02K17	TP	5	25	55.2	85.4	95
	TSS					
X02K20		5	17.2	50	74.1	95
X02K23	NO3NO2	5	17.2	50	75.4	95
	TP				74.1	
	TSS				74.1	
X02K25		5	17.2	50	75.4	95
X02K26	FC	5	25	50	89.4	91.6
	NO3NO2		17.2		81.2	95
X02K28		5	17.2	50	74.1	95
X02K32	FC	5	25	50	89.4	91.0
	NH3		17.2		74.1	95
	TP		17.2		75.4	
	TSS		17.2		74.1	
X02K40		5	25	50	89.4	91.6
X02K41		5	25	50	84.3	90.3
X02W04		5	25	55.2	75.4	95
X02W05		5	25	50	84.3	91.6
X02W06	TP	5	27.5	46.9	69.5	95
	TSS		33.3	44.8	63.5	
X02W12		5	17.2	50	74.1	95

[a] FC = fecal coliform; NH3 = ammonia; NO3NO2 = nitrate plus nitrite; TP = total phosphorus; TSS = total suspended solids. If no parameter is listed, the percentiles apply to all parameters with TMDLs at that station.

[b] If no sample events occurred within a flow zone, the midpoint percentile of the flow zone was used: 5 (High Flow); 25 (Moist Conditions); 50 (Mid-range Flows); 75 (Dry Conditions); 95 (Low Flows). If a percentile other than the aforementioned is displayed, it was used because it represents the maximum potential reduction for the parameter(s) at that station.

[c] At the Mount Orab WTP (stations X02K14 and OH-0801011), the flow duration interval corresponds to the maximum load calculated from observed data for each flow zone. The flow duration interval was selected using the maximum load instead of the maximum potential reduction due to the large amount of available atrazine data.

C-4 Linear Interpolation of Load Duration Curves

ILSAM was used to estimate flows at certain percentiles (1, 2, 5, 15, 25, 40, 50, 60, 75, 85, 90, 95, 98, and 99) that were then used to calculate loads at those percentiles. The loads calculated at the following percentiles were used for TMDLs and load reduction calculations when no data was available in a flow zone: 5 (High Flow); 25 (Moist Conditions); 50 (Mid-range Flows); 75 (Dry Conditions); 95 (Low Flows). However, when observed data was available, the percentile of the maximum potential reduction was used to calculate TMDLs and load reductions. These percentiles were not estimated by ILSAM (see Table C-3). Linear interpolation was used to calculate loads at percentiles not estimated by ILSAM.

The linear interpolation was performed on flow duration data, which was generated from ILSAM-estimated flows. The x-values were the percentiles, and the y-values were the flows. For x_n percentile (see Table C-3), the ILSAM percentiles above and below the x_n percentile and the corresponding ILSAM-estimated flows were used. The interpolated flow was then multiplied by the concentration of the constituent(s) from the water quality sampling and a conversion factor to yield the load. An example is presented in the next paragraph.

On September 27, 2006, a TSS sample was collected at station X02K04. The concentration was 5 milligrams per liter (mg/L). The flow at the USGS gage on that day was 34 cfs, which is the 55.1 percentile of all flows at the gage. ILSAM was used to estimate the 50^{th} and 60^{th} percentile flows at station X02K04: 48.76 and 27.90 cfs. A linear interpolation for 55.1 (x_n) for x values of 50.0 and 60.0 and y values of 48.76 and 27.90 yields 37.92 (y_n). Five mg/L was multiplied by 37.92 cfs and by 2.4465755 to yield a load of 464 kilograms per day.

In most cases, the linear interpolation was performed between percentiles at ILSAM-estimated flows. However, there were a few instances where the linear interpolation was performed on the linear extrapolation of the ILSAM-generated curve. ILSAM, the linear extrapolation of the ILSAM-generated curve, and linear interpolation are all estimation techniques. The few instances where loads were calculated using a linear interpolation of a linear extrapolation of ILSAM likely have very limited accuracy.