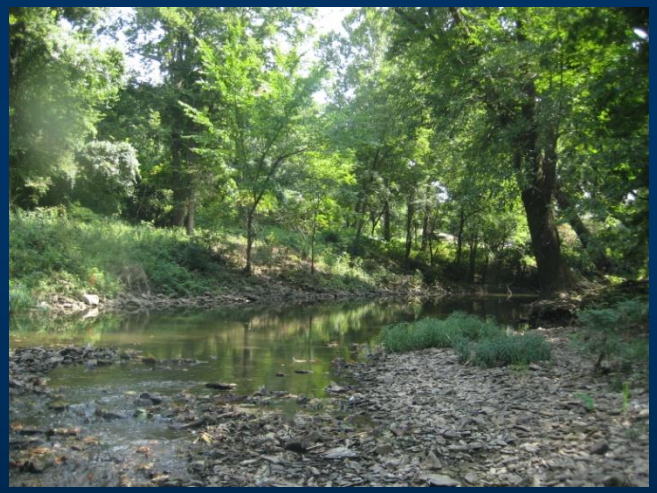
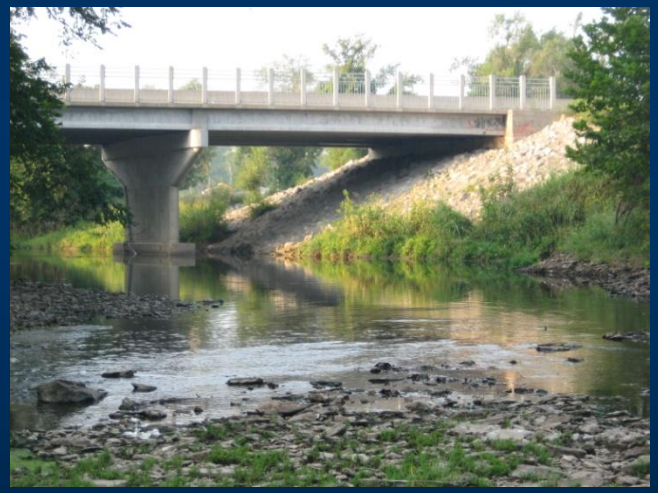
Effects of Wastewater Discharge and Treatment Facility Upgrades on Environmental and Biological Conditions of the Upper Blue River, Johnson County, Kansas and Jackson County, Missouri January 2003 through March 2009





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April 5, 2011

Purpose

- In 2007, the Johnson County Blue River Main Wastewater Treatment Facility (WWTF) was upgraded to include biological nutrient removal and increase capacity; regulatory requirements stipulated an evaluation to characterize the effects of wastewater discharge on the quality and biota of the Blue River after upgrades were complete.

- The purpose of this study was to describe the effects of wastewater effluent discharge and treatment facility upgrades on environmental and biological conditions of the upper Blue River, downstream of the Blue River Main WWTF.

Approach

- Previously and newly collected USGS data from the upper Blue River were used to evaluate environmental and biological conditions.

- Streamflow, discrete and continuously measured stream-water chemistry, streambed-sediment chemistry, and habitat data were used to:
  - Evaluate differences in environmental conditions above and below the WWTF.
  - Develop relations between continuously measured water-quality variables and discrete water-quality samples to define average annual concentrations and loads of total and dissolved nitrogen and phosphorus in the upper Blue River.
  - Determine the percent contribution of nutrients in wastewater discharge to total annual nutrient loads in the upper Blue River.

- Periphyton, macroinvertebrate, and stream metabolism data were used to evaluate differences in biological conditions upstream and downstream of the WWTF.

Study Area

- 6.4 mile study reach
- Study sites
  - Kenneth (~2 miles upstream)
  - 151st (~0.25 miles downstream)
  - Blue Ridge (~4.1 miles downstream)
- Urban land use increases along the study reach

Site identifier (fig. 1)	Site name	Approximate land cover (percent)	
		Urban	Impervious surface
Kenneth	Blue River at Kenneth Road	20.7	5.8
--	Intervening Area	39.8	11.4
151st	Blue River at 151st Street	24.9	7.1
--	Intervening Area	34.3	13.7
Blue Ridge	Blue River and Blue Ridge Boulevard	25.8	7.7

Graham and others, USGS SIR 2010-5248 Fig. 1, Table 1

Data

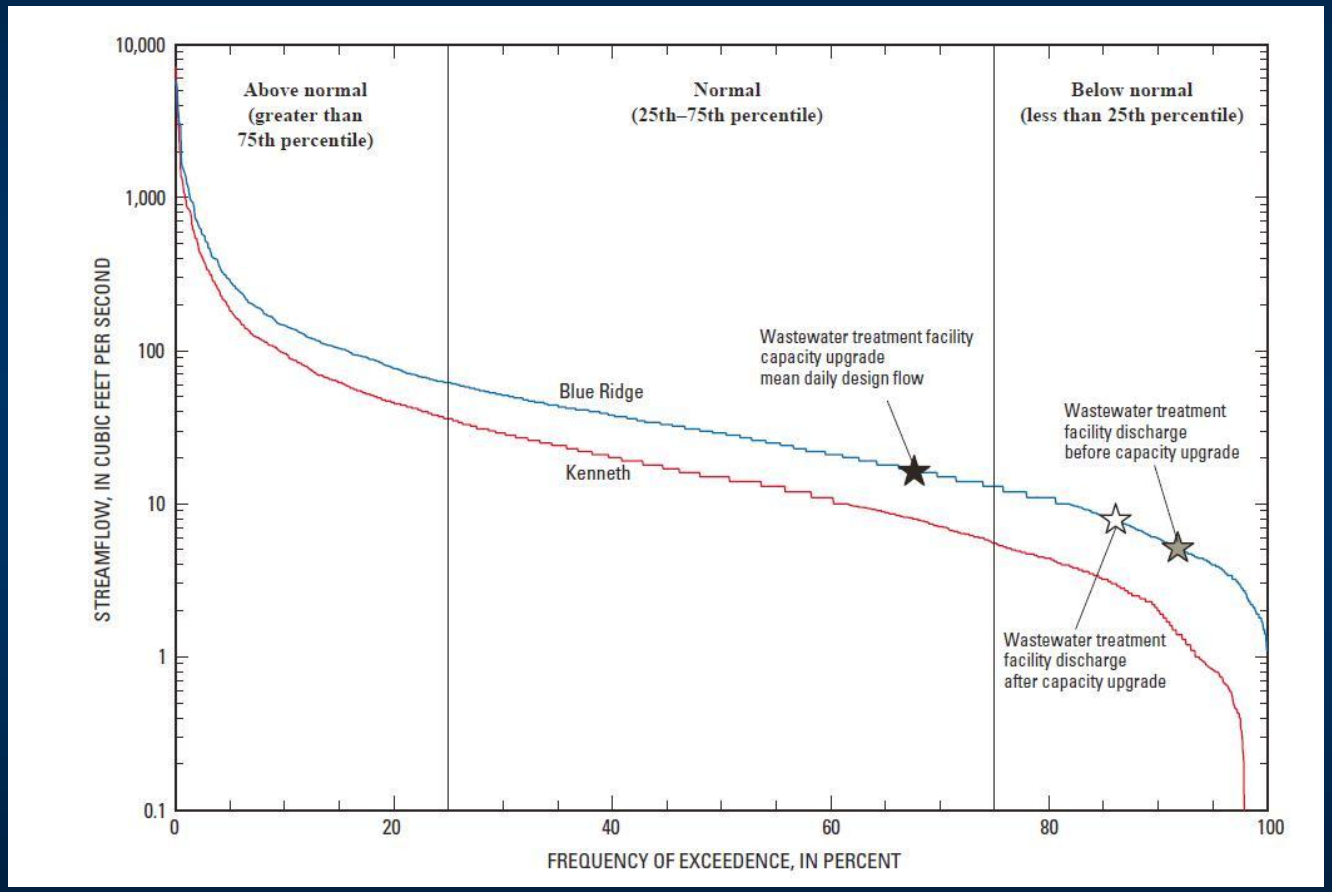
Environmental

- Blue River Main WWTF Effluent Volume and Quality – January 2003-March 2009
- Streamflow
  - Kenneth : April 2003-March 2009
  - Blue Ridge: January 2003-March 2009
- Continuous Water-Quality Data
  - Kenneth: March 2004-March 2009
  - Blue Ridge: April 2008-March 2009
- Discrete Water-Quality Data
  - Kenneth: July 2003-March 2009
  - 151st: April and August 2008
  - Blue Ridge: February 2003-March 2009
- Sediment Quality – 3 sites, April 2008
- Habitat Assessment – 3 sites, June 2008

Biological

- Periphyton and Macroinvertebrate Communities
  - 3 sites, April and August 2008
- Algal Biomass
  - Kenneth and Blue Ridge: June-September 2008
- Stream Metabolism
  - Kenneth and Blue Ridge: April 2008-March 2009

Streamflow Results – Streamflow at the downstream site (Blue Ridge) typically was about two-times larger than streamflow at the upstream (Kenneth) site during January 2003-March 2009. During below-normal streamflows wastewater sustained streamflow at the downstream site.



Graham and others, USGS SIR 2010-5248 Fig. 2

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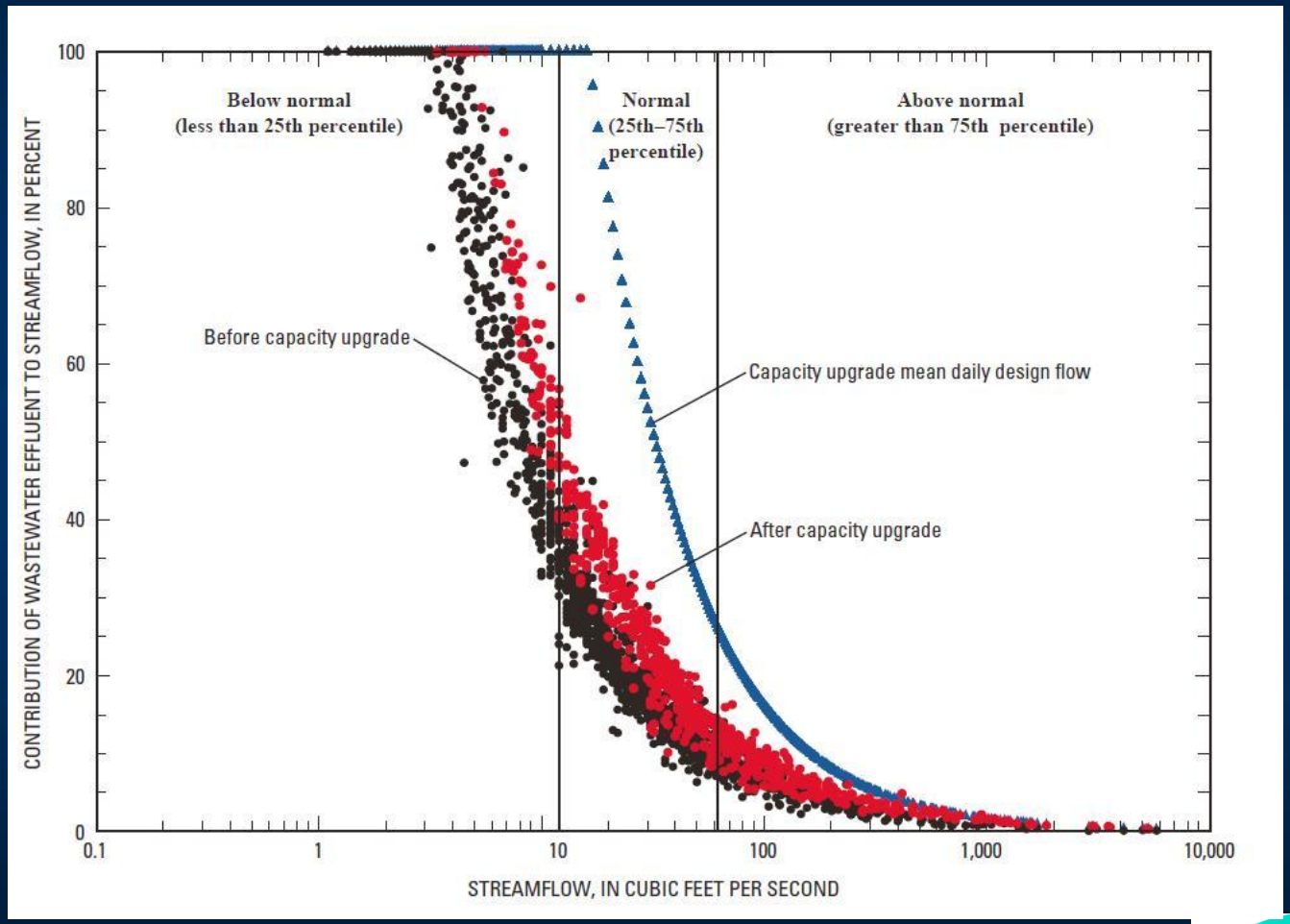
Streamflow Results – Wastewater contributed more than 20% to total streamflow during below-normal and normal streamflows (about 75% of the time). The contribution of wastewater to streamflow during normal flow conditions increased by about 30% after capacity upgrades.



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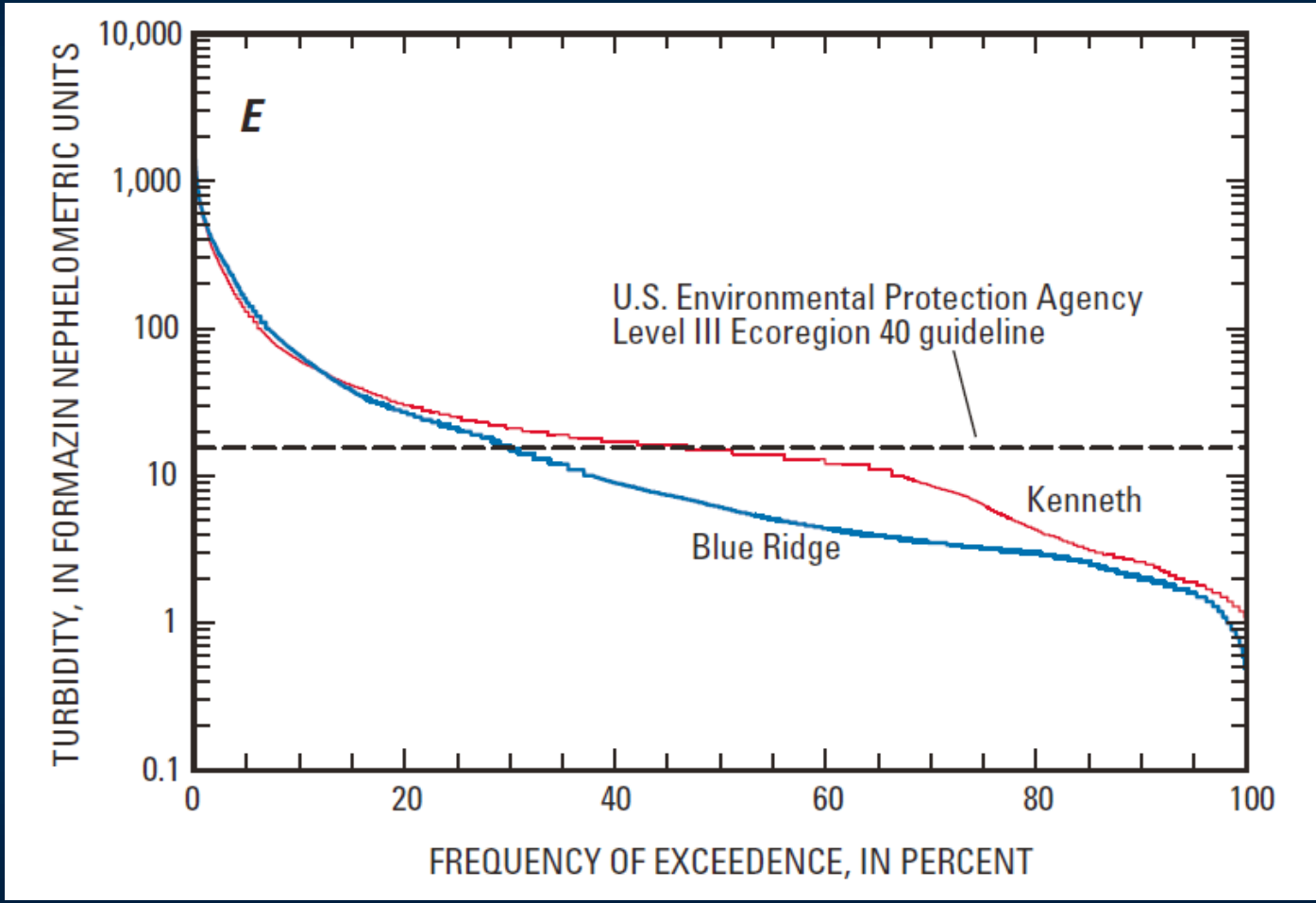
Water-Quality Results –Turbidity downstream from the WWTF is artificially low during below-normal and normal streamflows because of the increased clarity of wastewater discharge relative to natural conditions in the receiving stream.



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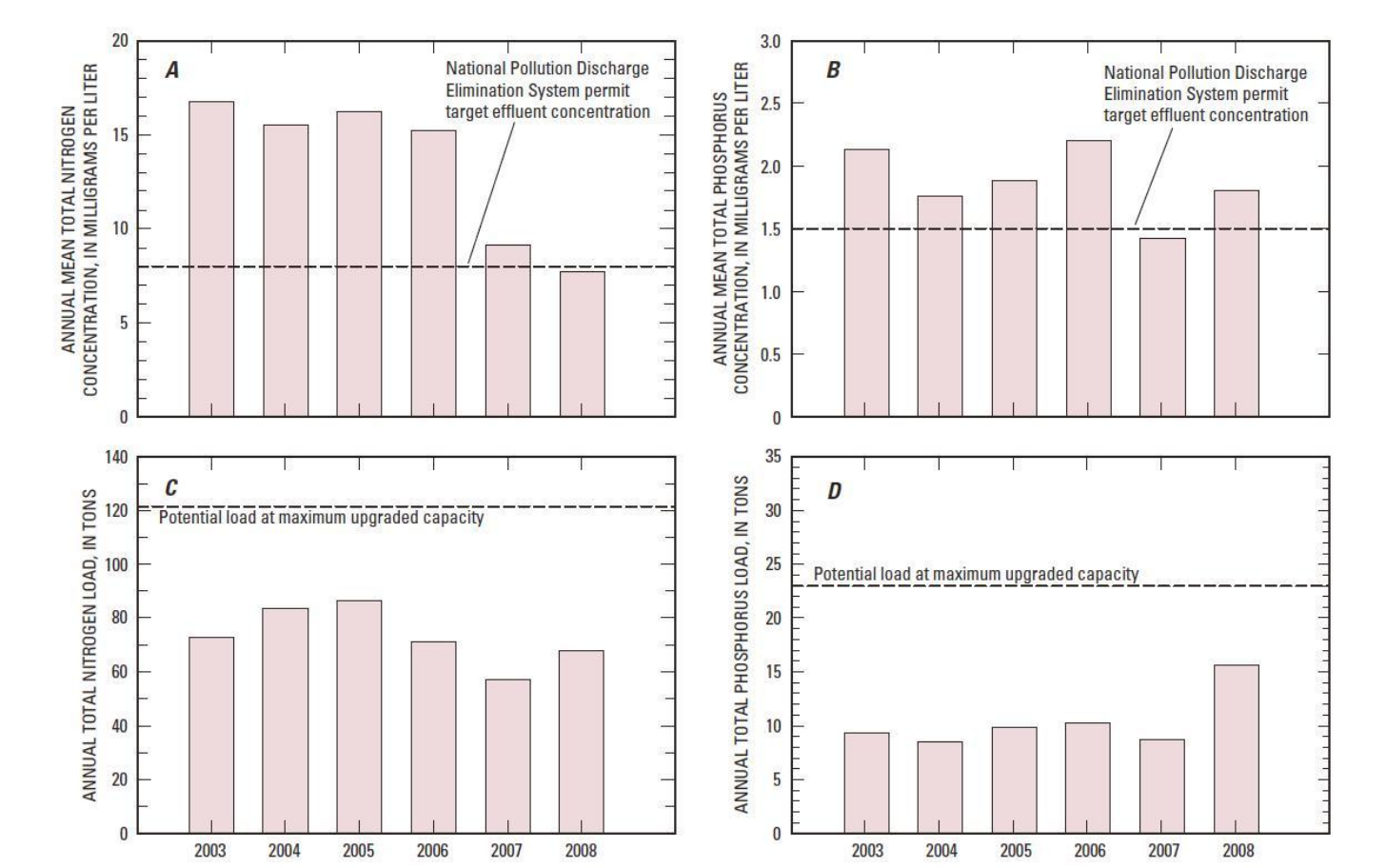
Water-Quality Results – Annual average TN concentrations in WWTF effluent decreased by about 50% after implementation of biological nutrient removal (BNR); TP concentrations decreased by about 30% between 2003 and 2007, but not 2008 because of issues with the biological phosphorus removal process.



Graham and others, USGS SIR 2010-5248 Fig. 7

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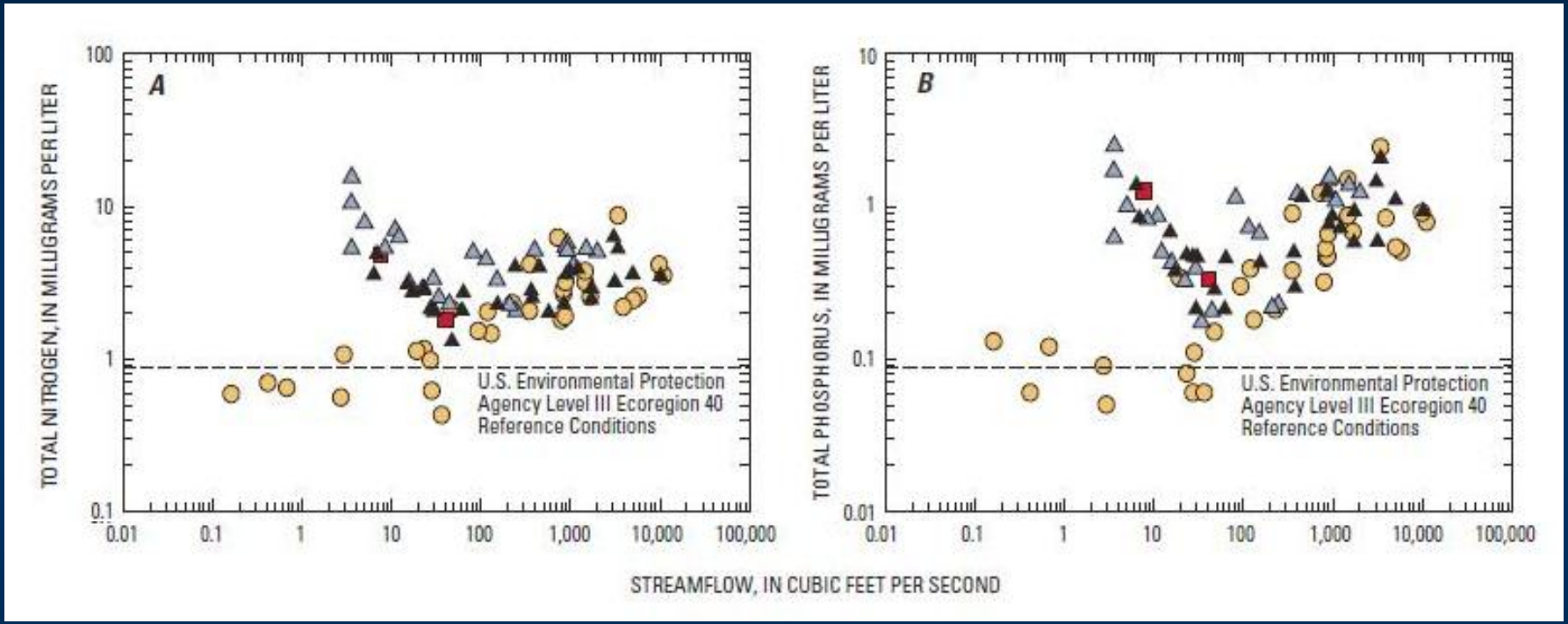
Water-Quality Results – Total nutrient concentrations were 4 to 15 times larger downstream from the WWTF during below-normal and normal streamflows. Total nutrient concentrations downstream from the WWTF were lower after the addition of BNR to the treatment process.



- Kenneth
- 151st
- Blue Ridge before upgrade
- Blue Ridge after upgrade

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Graham and others, USGS SIR 2010-5248 Fig. 5

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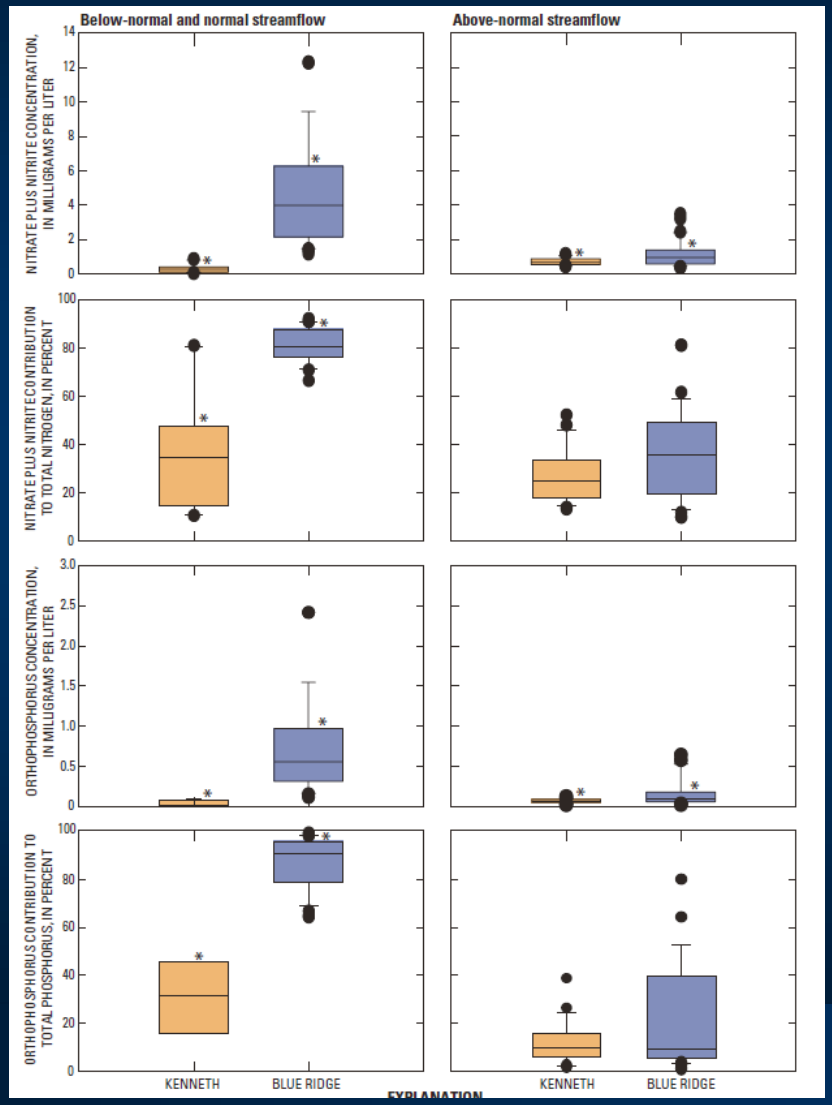
Water-Quality Results – Downstream from the WWTF inorganic nutrients (nitrate and orthophosphorus) comprised the majority of total nutrient concentrations during low streamflows. During above-normal streamflows inorganic nutrient contributions to total nutrient concentrations were similar along the upstream-downstream gradient.



Graham and others, USGS SIR 2010-5248 Fig. 6

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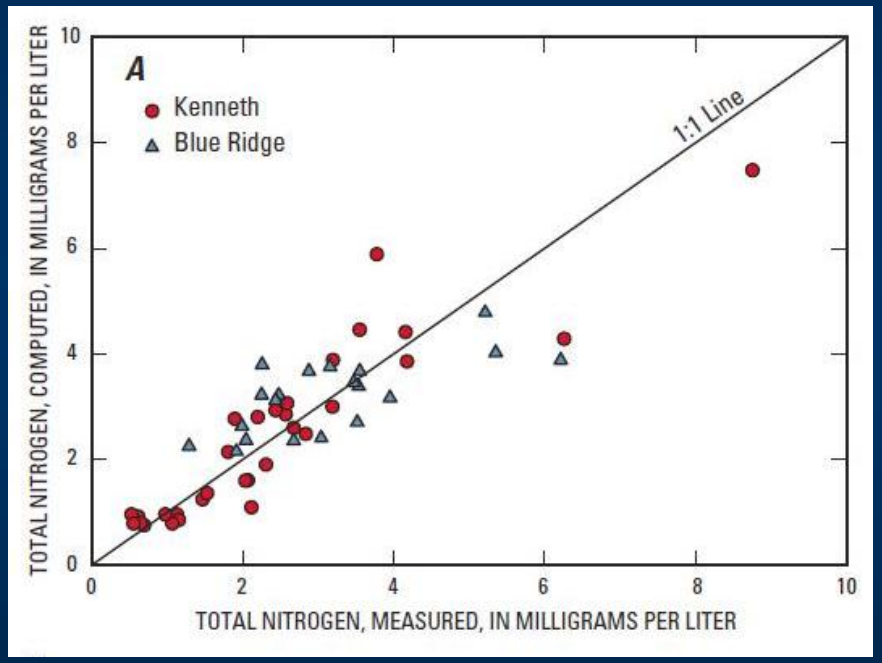
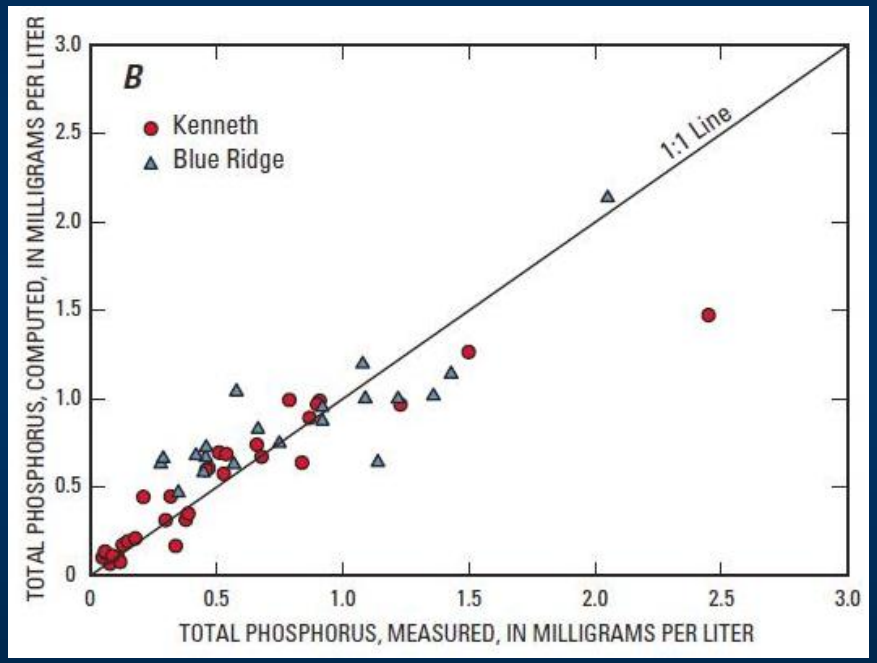
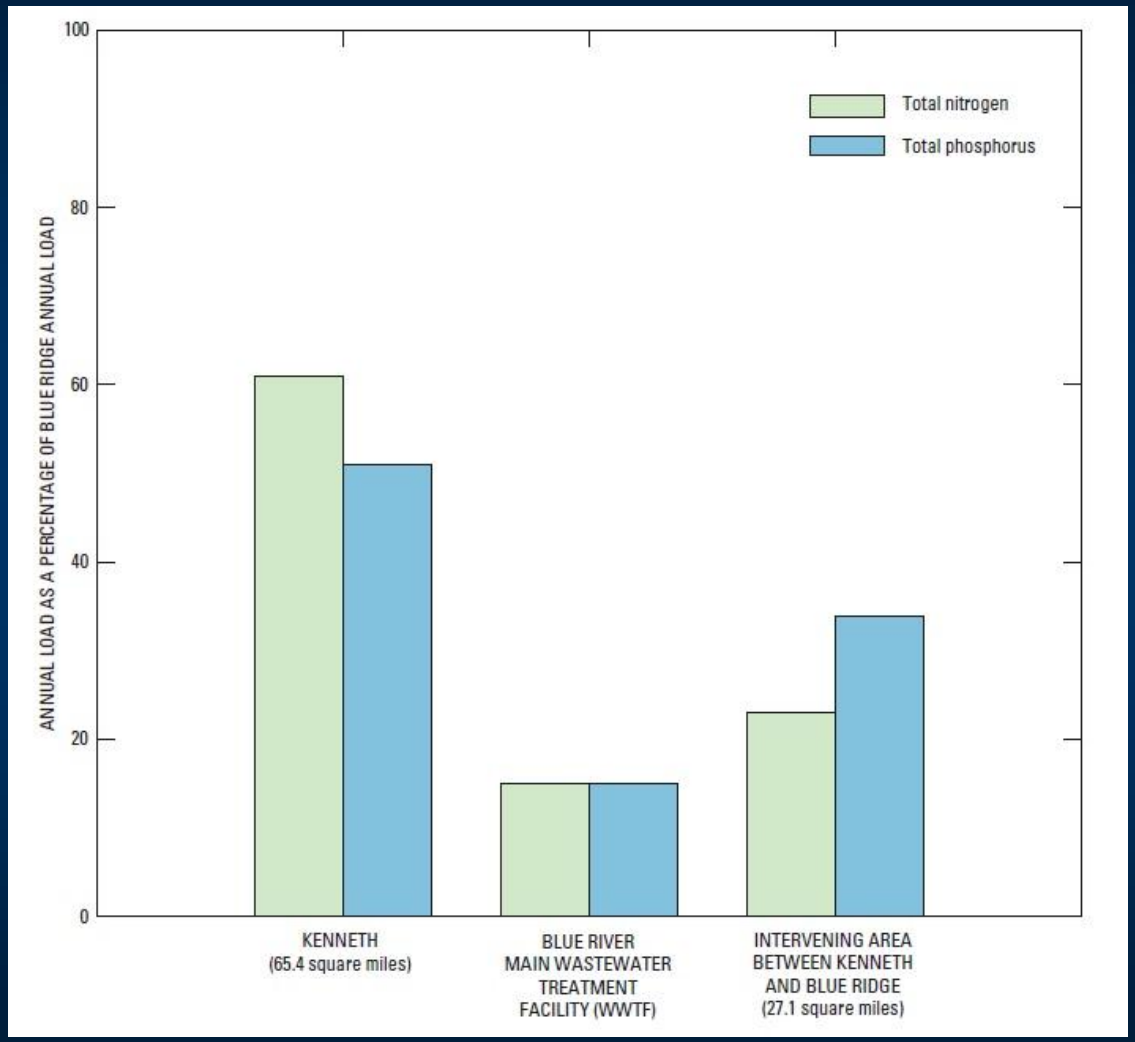
Water-Quality Results – Regression models for TN and TP at both sites included turbidity as the only explanatory variable. Larger uncertainties were associated with the models for the downstream site than the upstream site, likely because of increased urbanization and additional nutrient sources, including WWTF effluent.





Graham and others, USGS SIR 2010-5248 Fig. 8

Water-Quality Results – The WWTF contributed about 15% of the total nutrient load in the upper Blue River during April 2008-March 2009.



Graham and others, USGS SIR 2010-5248 Fig. 9

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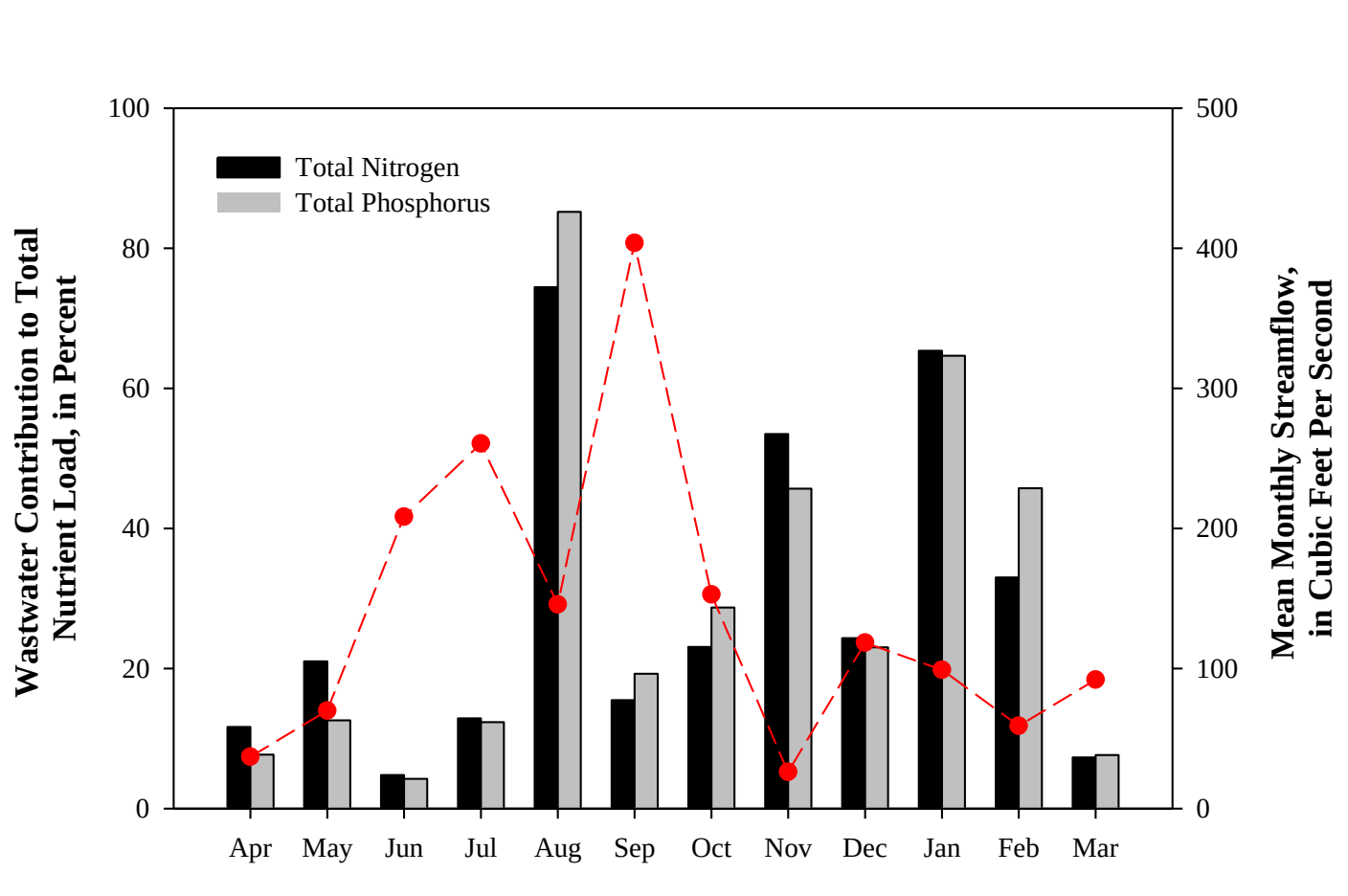
Water-Quality Results – The WWTF contributed substantially (up to 85%) to monthly nutrient loads during low flows in winter and summer.



Based on Graham and others, USGS SIR 2010-5248 Fig. 10

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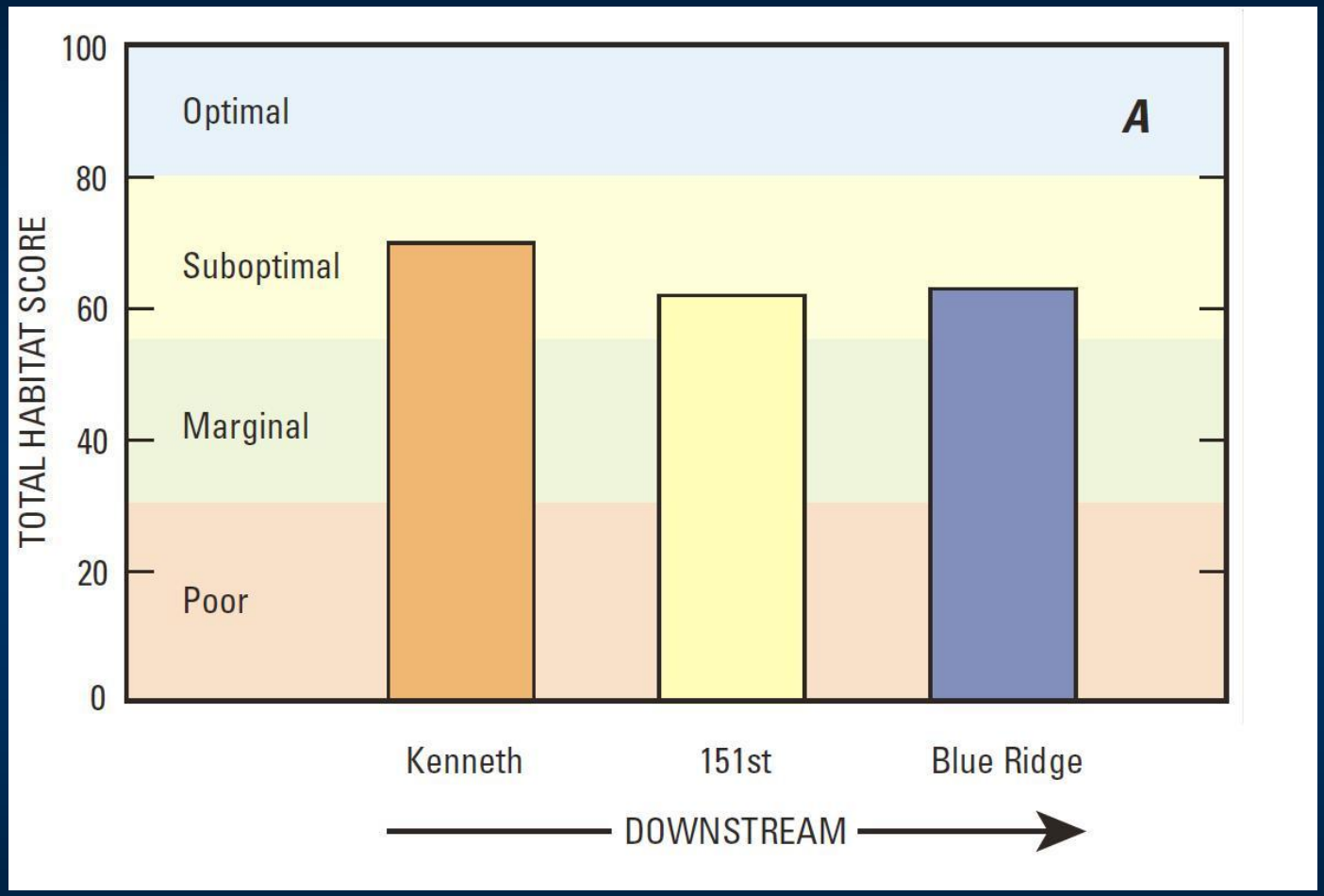
Habitat Assessment – Total habitat scores were indicative of sub-optimal conditions at all sites; however, total scores were about 10% lower at the downstream sites than the upstream site.



Graham and others, USGS SIR 2010-5248 Fig. 11

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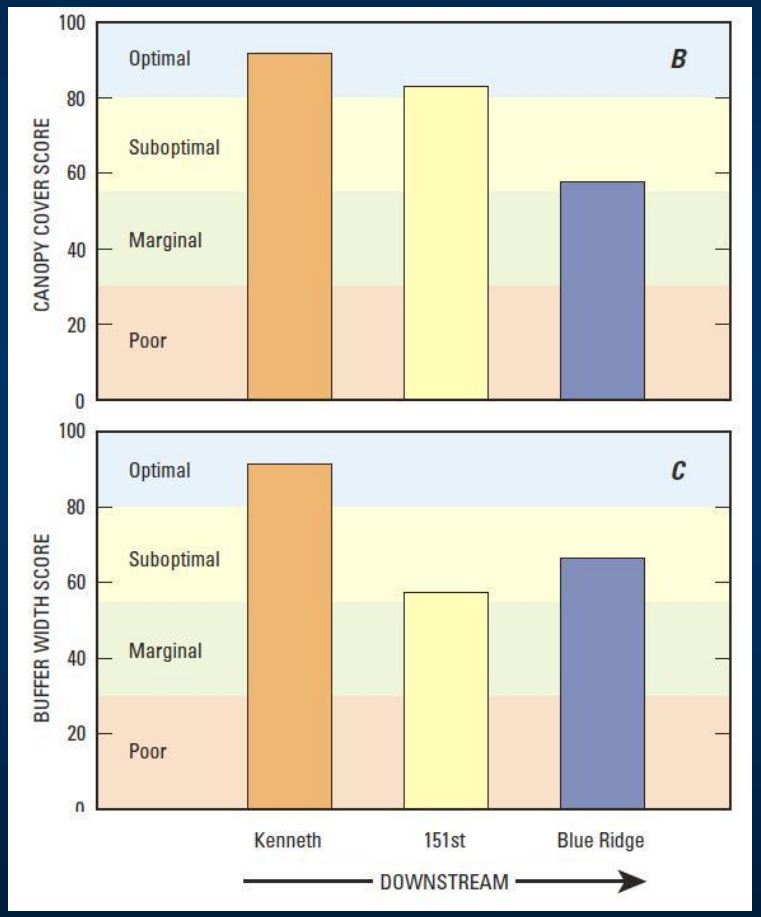
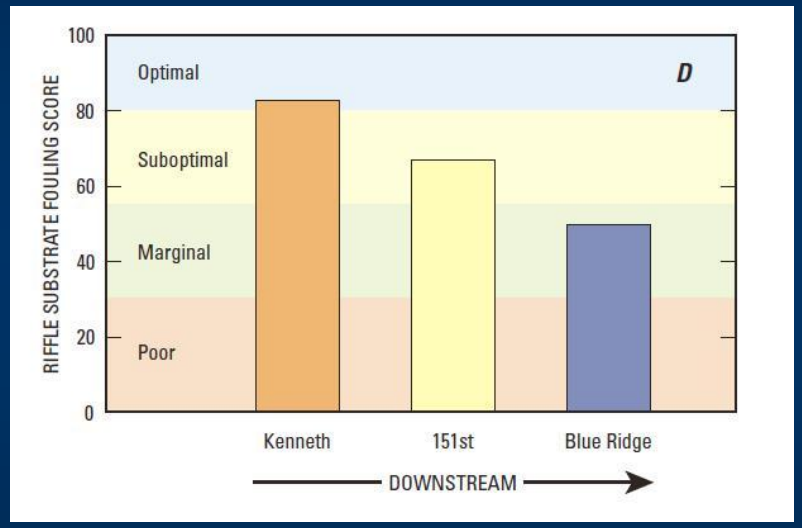
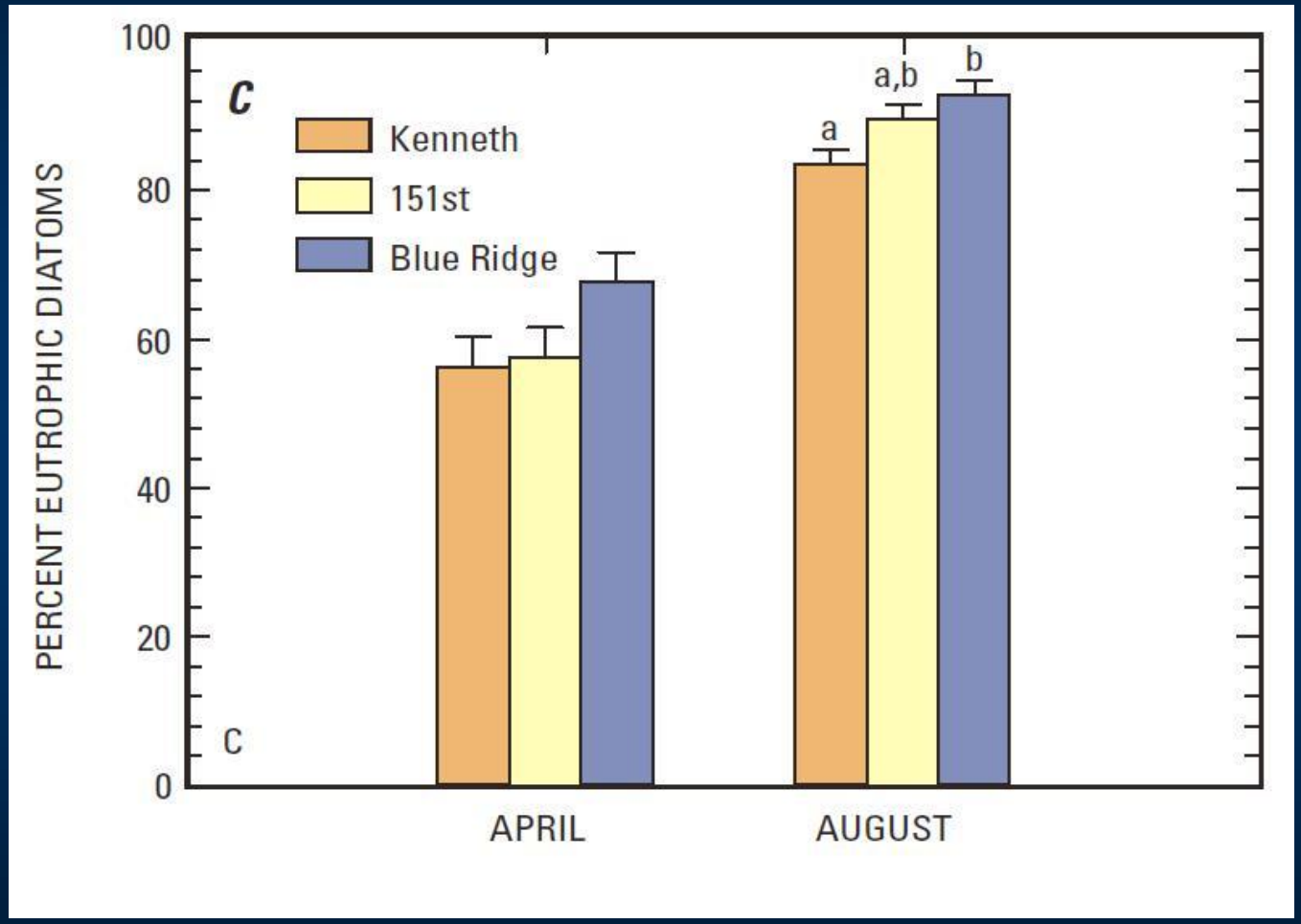
Habitat Assessment – The individual habitat variables with the largest among-site differences in score were canopy cover, buffer width, and riffle substrate fouling. Decreases in canopy cover and buffer width scores along the upstream-downstream gradient were likely because of increased urbanization. Decreases in riffle-substrate fouling scores were largely due to increased algal growth at the downstream sites.





Graham and others, USGS SIR 2010-5248 Fig. 11

Biological Conditions – Nutrient–tolerant diatoms dominated the algal community at all sites; however, the abundance of nutrient-tolerant diatoms increased along the upstream-downstream gradient.



Graham and others, USGS SIR 2010-5248 Fig. 12

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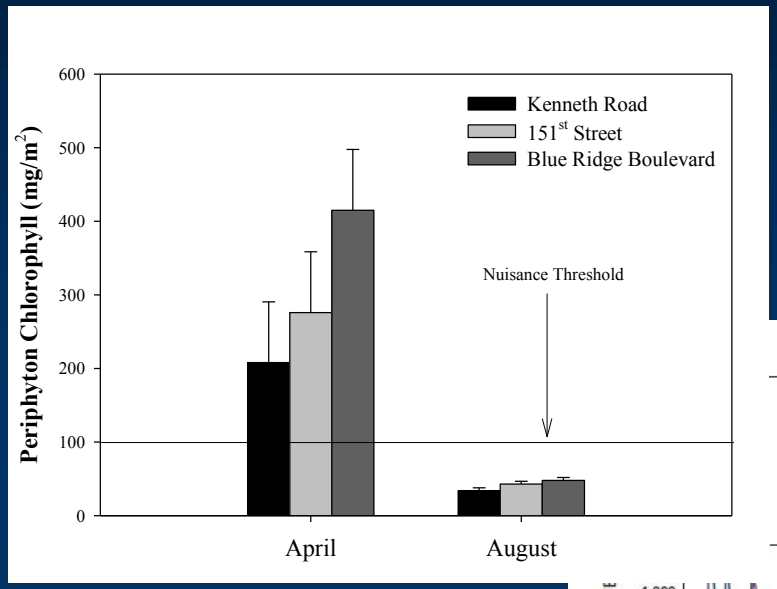
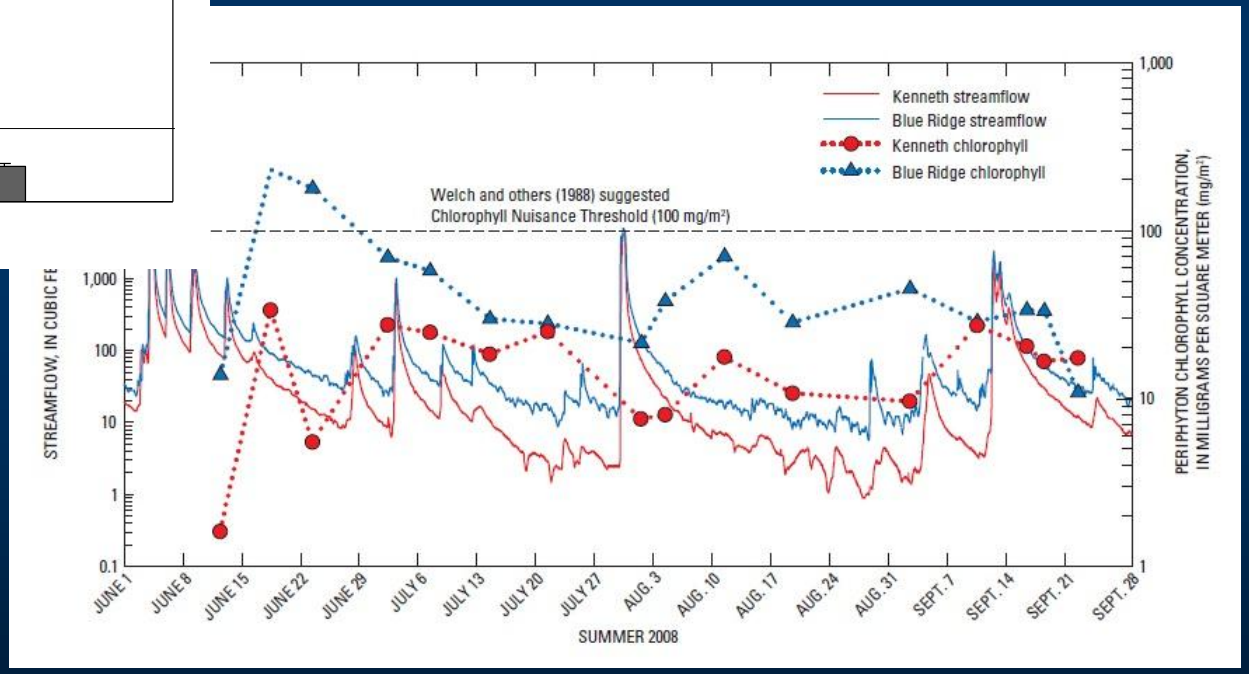
Biological Conditions – Chlorophyll concentrations (algal biomass) increased along the upstream-downstream gradient, likely caused partly by increased light availability because of decreased canopy cover and increased water clarity.





Graham and others, USGS SIR 2010-5248 Table 10 and Fig. 13

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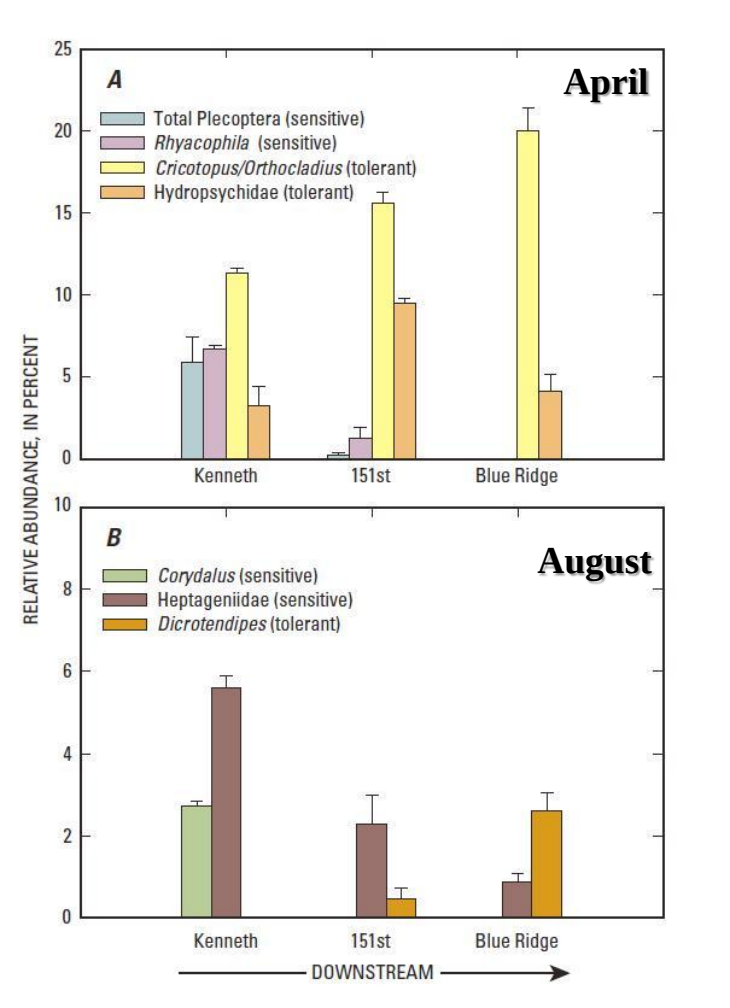
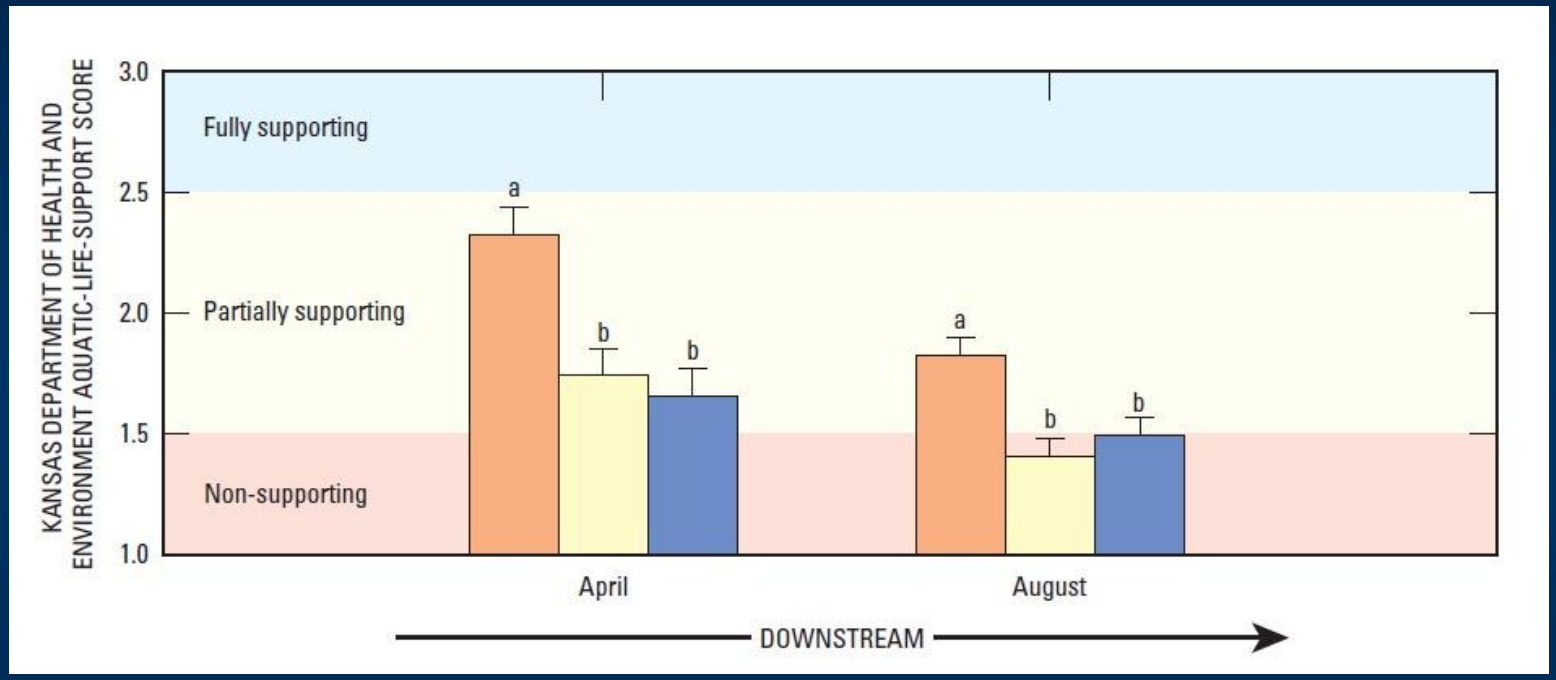
Biological Conditions – Representative intolerant (sensitive) macroinvertebrate taxa were not dominant at the upstream site; however abundance of intolerant macroinvertebrates decreased along the upstream-downstream gradient.



Graham and others, USGS SIR 2010-5248 Fig. 14

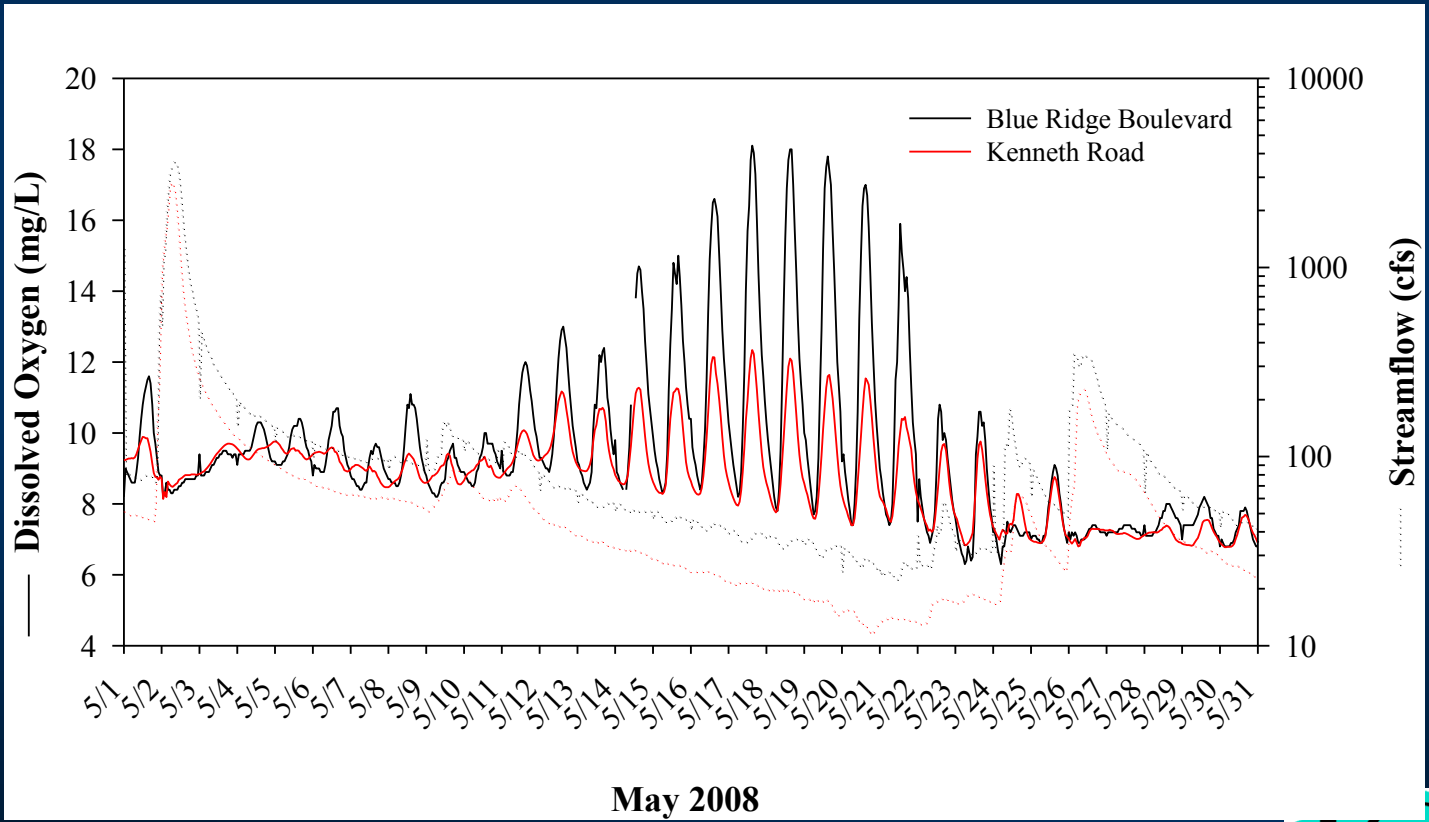
Biological Conditions – KDHE aquatic life support scores were significantly lower at the downstream sites than the upstream site. During August 2008 the site immediately downstream from the WWTF was non-supporting of aquatic life.



Graham and others, USGS SIR 2010-5248 Fig. 15

Stream Metabolism

- Stream metabolism is a measure of carbon production and consumption in an ecosystem.
- Oxygen production (gross primary production) and consumption (community respiration) can be used as a surrogate for carbon.



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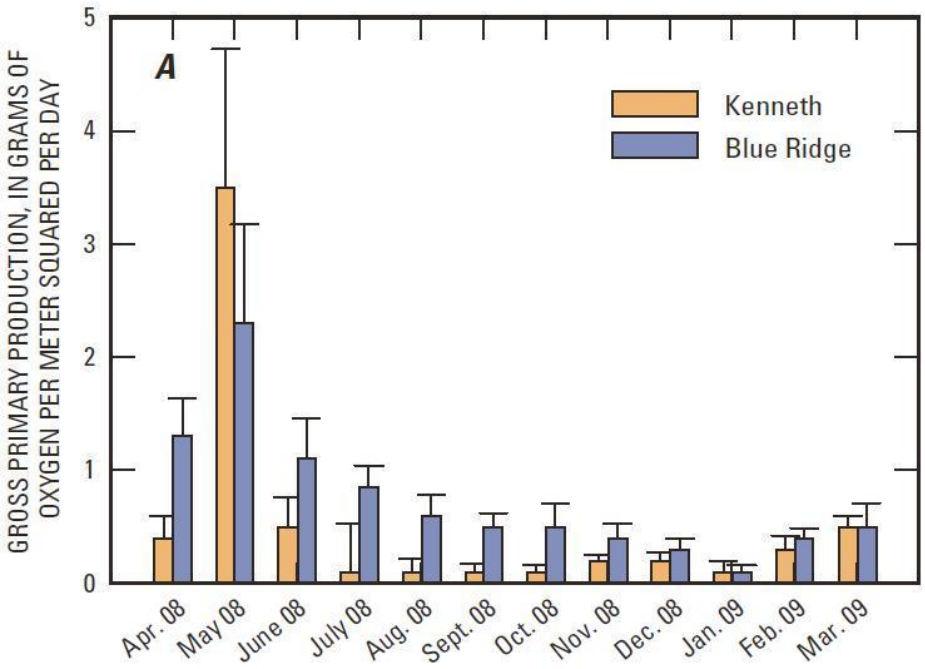
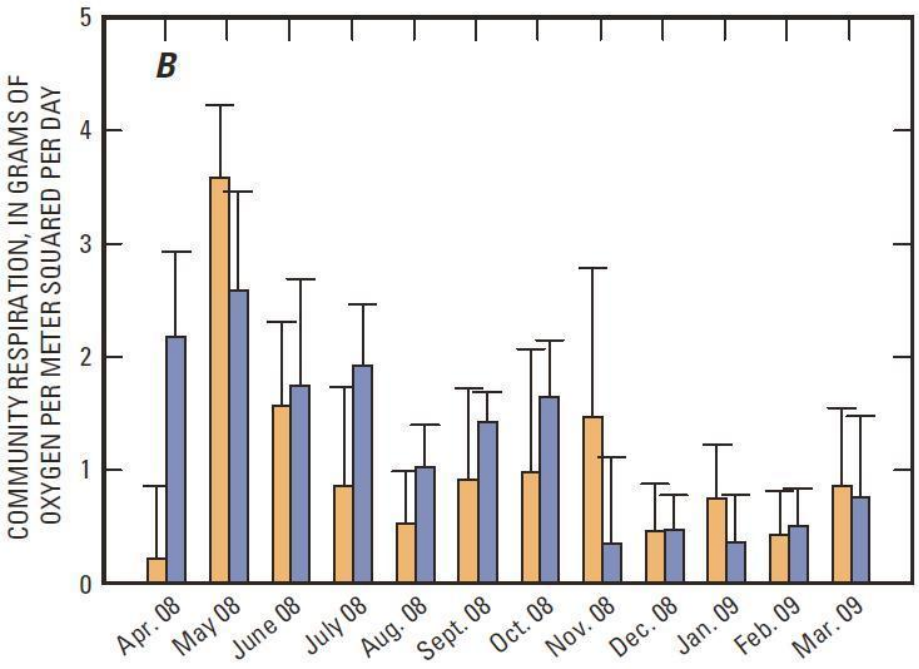
Biological Conditions – Primary production appeared to be more affected by changing environmental conditions along the upstream-downstream gradient than community respiration.





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Biological Conditions – Summer was the only season when stream health was mildly impaired downstream from the WWTF, indicating the declines in environmental and biological conditions along the upstream-downstream gradient were not substantial enough to cause persistent changes in stream health.

After Young and others (2008)

Ecosystem function	GPP_t/GPP_r	CR_t/CR_r
No impairment	<2.5	0.4–1.6
Mildly impaired	2.5–5.0	.2–.4 or 1.6–2.7
Severly impaired	>5.0	<.2 or >2.7

Time period	Kenneth			Blue Ridge			*p*-value	Ratio (Blue Ridge:Kenneth)			Ecosystem function
	n	Range	Median	*n*	Range	Median		*n*	Range	Median	
Gross primary production (g O_2/m^2/day)											
Spring	25	0.10–4.50	0.60	25	0.50–2.70	1.30	0.28	25	0.28–5.00	1.55	No impairment
Summer	54	0–1.80	.10	54	.20–1.10	.70	**<.01**	43	.50–11.0	5.00	**Mildly impaired**
Fall	53	0–.40	.20	53	0–.90	.30	**<.01**	46	0–6.00	2.00	No impairment
Winter	59	0–.70	.10	59	.10–1.10	.30	**<.01**	56	.75–5.00	1.33	No impairment
April 2008–March 2009	191	0–4.50	.20	191	0–2.70	.50	**<.01**	170	0–11.0	2.00	No impairment
Community respiration (g O_2/m^2/day)											
Spring	25	0.06–4.92	2.10	25	0.34–3.18	2.08	0.60	25	0.20–37.2	0.88	No impairment
Summer	54	.01–3.68	.74	54	.49–3.02	1.39	**<.01**	54	.57–133	1.96	**Mildly impaired**
Fall	53	.04–4.82	.91	53	.02–2.28	.67	.13	53	.02–21.3	.78	No impairment
Winter	59	.07–2.21	.59	59	.01–2.48	.55	.39	59	.02–8.3[illegible]	[illegible]	[illegible]
April 2008–March 2009	191	.01–4.92	.80	191	.01–3.18	1.00	.1	191	.02–13.[illegible]	[illegible]	[illegible]

Graham and others, USGS SIR 2010-5248 Tables 13 and 14

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Conclusions

- Nutrient concentrations in the upper Blue River downstream from the wastewater discharge decreased by 30 to 50 percent after nutrient removal was added to the treatment process.

- Despite decreases in nutrient concentrations, nutrient concentrations were still 4 to 15 times larger downstream from the WWTF than upstream during below-normal and normal streamflows (about 75% of the time).

- Abundance of aquatic organisms tolerant of degraded water-quality conditions increased downstream from the WWTF.

- As shown by stream metabolism, the effects of wastewater discharge in the upper Blue River did not cause persistent declines in overall stream health.

USGS SIR 2010-5248

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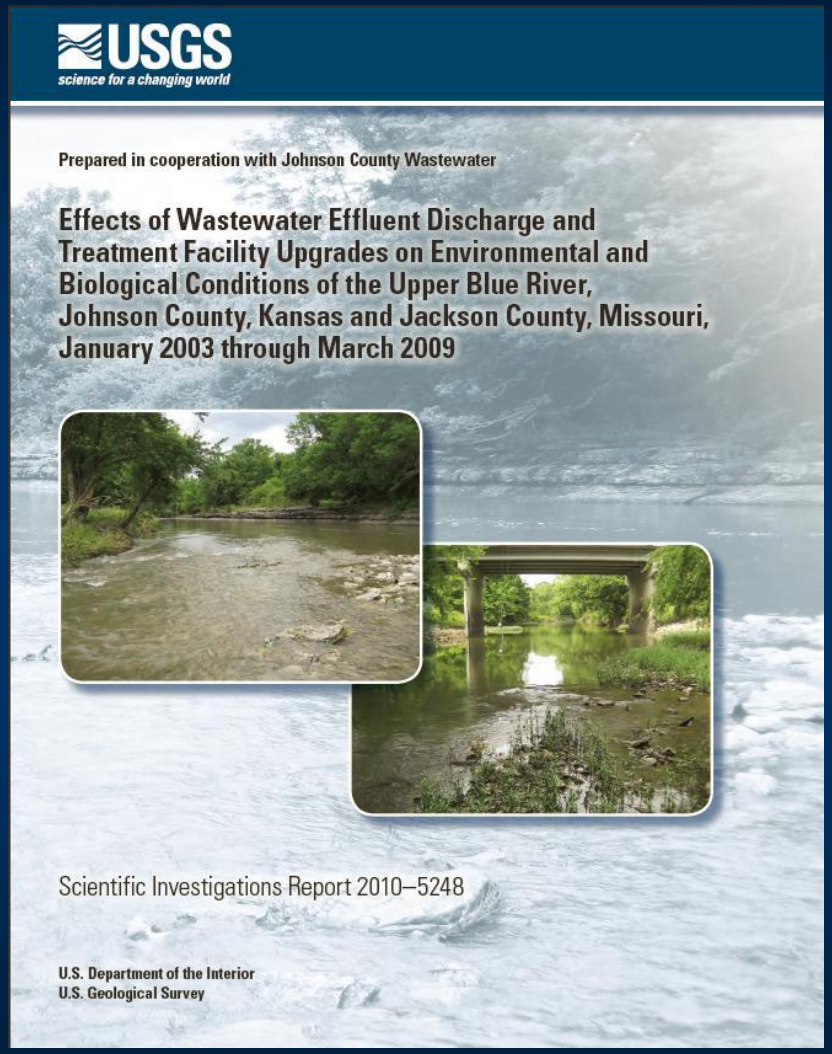

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