Introduction to TMDL Implementation

Ohio EPA Nutrient Criteria Development

Monthly Discussion – Technical Advisory Group (TAG)
Ohio EPA Groveport Field Office – March 14, 2014

Goals

- Review basics…introduction…identify issues for April meeting
- Today…
  - Critical Design Flow Condition
  - TMDL Allocation Methods
  - Water Quality Models Used
  - Reasonable Assurance in TMDLs

Critical Design Flow Condition

Critical Condition (TMDL)

- The set of environmental conditions that represent:
  - The worst-case impairment situation
  - Has a corresponding low frequency of occurrence
- Multiple or single critical conditions could be defined
  - Single –
    - one flow regime (e.g., 7Q10), or
    - one season (e.g., summer)
  - Multiple – various flow regimes and seasons
- The TMDL critical condition is the *period of applicability* of the load allocation.

Critical Design Flow Condition

- Corresponds to applicable water quality criterion
- Must consider…
  - Averaging period
  - Time period of applicability
    - …alternatively flow regime of applicability
    - TMDL critical condition
    - All flows equal to and greater then design flow
  - Magnitude
    - Encompasses…<u>duration</u> of the flow event and <u>frequency</u> of re-occurrence

Mass Balance of Total P

…moving from entire stream to wasteload allocation

…for entire stream

$$L_{ust} + L_{trib} + L_{eff} \quad L_{sub} \quad L_{bio} = L_{dst}$$

Nutrient spiral

…consider a shorter length of stream

$$L_{ust} + L_{eff} = L_{dst}$$

L = load (mass/time)

Mass Balance of Total P

…what is the design flow? …is Q_{ust}

$$L_{ust} + L_{eff} = L_{dst}$$

$$Q_{ust}C_{ust} + Q_{eff}C_{eff} = (Q_{ust} + Q_{eff})WQC_{dst}$$

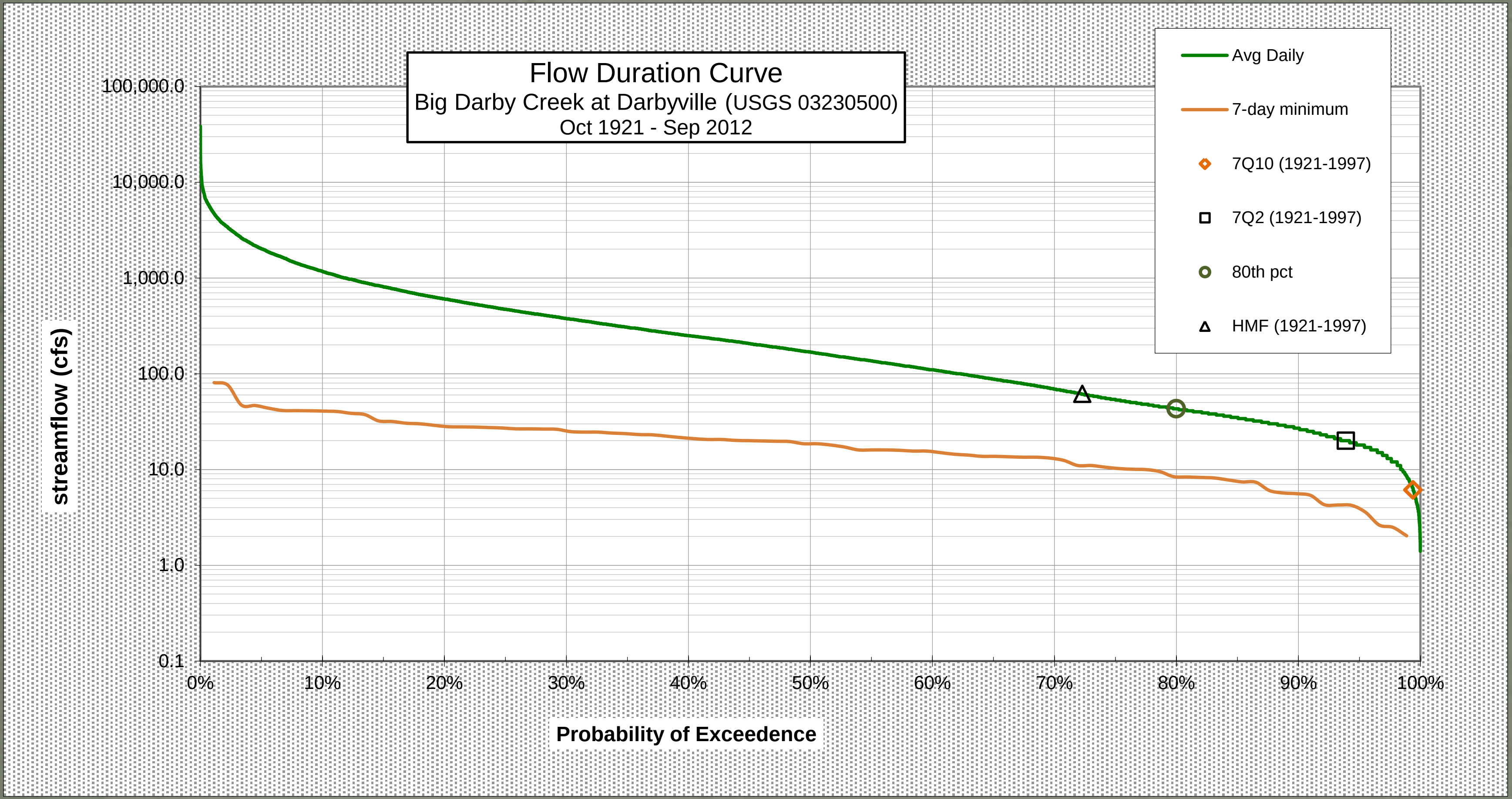
L = load (mass/time)
Q = flow (volume/time)
C = concentration of pollutant (mass/volume)
WQC = WQ criteria or TMDL target(mass/volume)

Ohio EPA design flow

- 80th Percentile flow (i.e., $Prob_{exc}$ = 80%)
  - Proposed in initial draft rule
  - Test scenarios indicate HMF too high, 7Q10 too low
  - 7Q10 more for dose-response of toxics
- …further investigating
  - Relationship of 80th percentile flow with 7Q2 and its presence in the indexing period (July-Sept)
  - US EPA (1986)
    - Biological design flow (4B3)…can be multiple extreme values in any given year
  - Other states…

Flow Duration Curve

…graph of $Prob_{exc}$ vs. streamflow (Q)



N = about 32,000 days

Prob_{exc} for a Few Index Periods

…for Big Darby Ck at Darbyville (1921-2012)

Index Period	Mean (%)	Median (%)
July – Sept	69	73
June – Sept	63	68
May – Oct	58	61

Prob_{exc}: percentage of time that a flow of a given magnitude is equaled or exceeded

Index Period: period of nutrient criteria applicability

…further work…

- Explore other stations (USGS gages)
- Only consider "modern" record…say 1970 – 2012

Other States…design flow conditions

- Wisconsin:
  - 7Q2 or 30Q3…stream conditions most often observed during the "indexing" period (May-Oct)
  - US EPA wanted 3-yr recurrence interval
- New Jersey:
  - 30Q10
- Florida:
  - Nutrient thresholds developed at 90th percentile
  - between 10th and 90th percentile of long-term discharge

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

Low-Flow Character
in Ohio through Wat

By David E. Straub

Water-Resources Investigations Rep

In cooperation with the
Ohio Department of Natural Resources,

SCIOTO RIVER BASIN

03230500 Big Darby Creek at Darbyville, Ohio

LOCATION: Lat 39° 42' 02", long 83° 06' 37", Pickaway County, Hydrologic Unit 05060001, on right bank at upstream side of State Highway 316, 0.4 mi northeast of Darbyville, 0.4 mi upstream from Lizard Run, and 3.0 mi downstream from Greenbrier Creek.

DRAINAGE AREA: 534 mi^2.

TRIBUTARY TO: Scioto River.

STREAMFLOW DATA USED: October 1921 to September 1935, October 1938 to September 1997.

REMARKS: None.

SELECTED STREAMFLOW CHARACTERISTICS: Harmonic mean flow: 61.3 ft^3/s
Average streamflow: 465 ft^3/s (72 years)
Minimum daily streamflow: 1.4 ft^3/s

Magnitude and frequency of low flow for indicated periods

Period	Number of consecutive days	Streamflow (ft^3/s) for indicated recurrence interval (years) 2	5	10	20	50	Period	Number of consecutive days	Streamflow (ft^3/s) for indicated recurrence interval (years) 2	5	10	20	50
Apr.-Mar.	1	18	8.1	5.0	3.0	1.6	Dec.-Feb.	1	65	33	23	17	12
	7	20	9.5	6.1	3.9	2.3		7	75	36	24	17	12
	30	26	14	9.4	6.2	3.9		30	150	59	35	23	14
	90	40	21	15	11	7.8		90	583	236	128	72	35
May-Nov.	1	18	8.1	5.0	3.0	1.6	Sep.-Nov.	1	19	8.7	5.5	3.3	1.7
	7	20	9.5	6.1	3.9	2.2		7	21	9.7	6.0	4.0	2.3
	30	26	14	9.5	6.4	3.9		30	28	13	9.4	6.7	4.2
	90	41	21	15	11	7.9		90	74	29	18	13	8.5

Duration of daily flow for indicated periods

Period	Streamflow (ft^3/s) that was equaled or exceeded for the indicated percentage of time 98	95	90	85	80	75	70	60	50	40	30	20	10
Apr.-Mar.	11	17	25	33	41	51	64	103	157	237	365	588	1150
May-Nov.	8.1	14	19	25	30	36	42	57	83	117	177	280	574
Dec.-Feb.	20	28	40	52	72	95	121	189	267	389	562	867	1630
Sep.-Nov.	5.9	9.1	15	18	21	24	28	35	43	57	81	129	286

Comparison of Design Flows
Annual Record (April – March)

River/Stream	DA (mi^2)	7Q10 (cfs)	$Prob_{exc}$ (%)	7Q2 (cfs)	$Prob_{exc}$ (%)	Q_{Pexc80} (cfs)	HMF (cfs)
Big Darby Ck (Darbyville)	534	6.1	99	20	92	41	61.3
Kokosing R (Mt Vernon)	202	16	99	28	92	42	70.1
Stillwater R (Pl Hill)	503	13	99.5	27	94	52	79.5
Scioto R (Prospect)	567	9.6	99.9	15	95	29	54
Honey Ck (Melmore)	149	0.5	99	1.4	94	5	4.81
Tiffin R (Stryker)	410	8.2	99.9	18	95	36	60

$Prob_{exc}$: probability of exceedence
Q_{Pexc80}: Q at 80% $Prob_{exc}$
HMF: harmonic mean flow

TMDL Allocation Methods

TMDL Allocation Methods

- TMDL phases:
  - Assess waterbody health: biological, chemical, habitat
    - Determine cause/source, TIC
  - Develop a restoration target and a viable scenario
    - Quantify sources / model
    - Select target
    - Calculate load reductions
    - Alternative scenarios
  - Implement the solution: inside/outside Ohio EPA
  - Validate to monitor progress: delist or relist.

TMDL Allocation Methods

- WLA = wasteload allocation
  - NPDES: general permit, individual permit
  - MS4: Phase I (large and medium), Phase II (small)
  - HSTS
    - only those with a general permit
- LA = Load Allocation
  - Non-point source: runoff from agriculture, urban, suburban land use types

Potential Wasteload Allocation Scenarios

VOL. 17, NO. 5 WATER RESOURCES BULLETIN AMERICAN WATER RESOURCES ASSOCIATION OCTOBER 1981

ANALYSIS

Ronald A

ABSTRACT: A study was made to analyze a used for stream assimilation capacity and point cation calculations. This paper describes the sour mation collected and the analysis of alternative developed during the study. The calculation capacity or Total Maximum Daily Load (TMD assumed stream flows, quality standards, reactio procedures. The "critical conditions" selected usually are low flows and warm temperatures. T quality models used for TMDL and allocation from simple, complete mixing to calibrated and models. A list of 20 wasteload allocation (W veloped. Five of these WLA's were applied to permit comparisons based on cost, equity, effici milation capacity, and sensitivity to fundament Based on insensitivity to data errors and curren the WLA method of "equal percent treatment" example stream.
(KEY TERMS: total maximum daily loads; w water quality modeling.)

BACKGROUND INFORMA

A variety of types of information was the study. Major sources of information in survey of technical literature and a review mental publications, particularly reports of

Letters of inquiry were sent to the wate institutes of the 50 states to determine met for stream assimilation capacity determ source allotments, and point source waste the 19 agencies which provided informa state hydraulics modeling while only two sideration of unsteady flows such as storm sign flow conditions are 7-day, 10-year l while one state uses 7-day, 2-year low flow mer water temperatures are specified in 1 consider winter temperatures to be more i conservative parameters most commonly m ammonia while in a few cases, photosynthe benthal demands are also included. Nonpo tants are most commonly included as a bac tion having minimal impact at design low f

TABLE 1. Potential Waste Load Allocation Methods.

1. Equal percent removal (equal percent treatment).
2. Equal effluent concentrations.
3. Equal total mass discharge per day.
4. Equal mass discharge per capita per day.
5. Equal reduction of raw load (pounds per day).
6. Equal ambient mean annual quality (mg/l).
7. Equal cost per pound of pollutant removed.
8. Equal treatment cost per unit of production.
9. Equal mass discharged per unit of raw material used.
10. Equal mass discharged per unit of production.

11a. Percent removal proportional to raw load per day.
   b. Larger facilities to achieve higher removal rates.

12. Percent removal proportional to community effective income.

13a. Effluent charges (dollars per pound, etc.).
   b. Effluent charge above some load limit.

14. Regional authorities (river basin, lake drainage area).
15. Seasonal limits based on cost-effectiveness analysis.
16. Minimum total treatment cost.
17. BAT (industry) plus some level for municipal inputs.
18. Divide assimilative capacity to require an "equal effort among all dischargers."

19a. Municipal: treatment level proportional to plant size.
   b. Industrial: equal percent between BPT and BAT, i.e.,

$$\text{Allowable} = \text{BPT} - \frac{x}{100}(\text{BPT} - \text{BAT})$$

20. Industrial dischargers given treatment levels by flow of stream and by season:

Month	Zero Discharge	BPT
a, b, c, etc.	$Q_{actual} < Q_{lower\ limit}$	$Q_{actual} >$ upper limit

[1]Paper No. 81027 of the *Water Resources Bulletin*. Discussions are open until June 1, 1982.

[2]Respectively, Dept. of Civil Engineering, Villanova University, Villanova, Pennsylvania 19085; and Associate Professor and Professor, Civil Engineering, The Pennsylvania State University, 212 Sackett Building, University Park, Pennsylvania 16802.

TMDL Allocation Methods

- Implementation of Load Development
  - Case-by-case basis with guiding principles
    - Not always equal % reduction…
      - Typically equal effluent concentration by like-sized facilities
  - Ensure PS given WLA in "realm of feasibility"…cannot do more with cost-effective technology
  - NPS sometimes "takes a hit" to help WLA values during low flow

PS implementation…phases

Effluent monitoring
- <None – then start>
- Effluent monitoring

↓

Meet 1 mg/L effluent total P limit
- Stream evaluation – measure attainment

↓

Reduce effluent to about 0.6 mg/L
- Stream evaluation – measure attainment

↓

Reduce effluent to allocation established in TMDL

…a continuum – for each facility determine status

Similar appears in Ohio Nutrient Reduction Strategy (2013)

Table 5. Guidelines for assigning initial phosphorus NPDES limits for POTWs discharging less than 1 MGD. Actions are the same in the Lake Erie and Ohio River basins. If no effluent data available to estimate load, use a concentration of 3 mg/l.

Design Flow	Condition of Water	WLA and NPDES Permit Content
		xisting effluent load in WLA in TMDL. No phosphorus nit; monitoring per guidance
		permit limit at 1.0 mg/l and design flow
		l permit limit at 1.0 mg/l and design flow if us limits will result in a significant improvement in assemblages. Monitoring per guidance if no limit.
		xisting effluent load in WLA in TMDL. No phosphorus nit; monitoring per guidance
		permit limit at 1.0 mg/l and design flow
	contributors to impairment	xisting effluent load in WLA in TMDL. No phosphorus nit; monitoring per guidance
Less than 0.025	Any impairment situation	Include existing effluent load in WLA in TMDL. No phosphorus permit limit; monitoring per guidance

Table 4. Guidelines for assigning initial phosphorus NPDES limits for POTWs discharging 1 MGD or more. If no effluent data available to estimate load, use a concentration of 3 mg/l.

	Condition of Water	Guidelines for Initial NPDES Permit Content
Lake Erie Basin	Not impaired for nutrients	Set initial permit limit at 1.0 mg/l at design flow, per long-standing Lake Erie policy
	Impaired for nutrients	Set initial permit limit at the lower of 1.0 mg/l at design flow or existing permitted load (with trading option, habitat fixes). Include permit language requiring POTW to minimize discharge of phosphorus by optimizing existing treatment facility.
Ohio River Basin	Not impaired for nutrients	Include existing effluent load in WLA in TMDL. No phosphorus permit limit; monitoring per guidance.
	Impaired for nutrients	Set initial permit limit at the lower of 1.0 mg/l at design flow or existing permitted load (with trading option, habitat fixes). Include permit language requiring POTW to minimize discharge of phosphorus by optimizing existing treatment facility.

Water Quality Models Used

TMDL Model Eval

Ne

Leslie Shoemaker, Tin
Tetra
Fairfax, V

Contract

Moham
Land Remediation and
National Risk Manager
Cincinnat

National Risk Manager
Office Of Resear
U.S. Environmen
Cincinnat

Each model included in the review is also described in a longer fact sheet (Appendix). The fact sheet includes a narrative discussion of essential features of each model and provides a comprehensive evaluation of the individual model software, tools, and supporting features. Each of the identified models was evaluated on key technical, practical, and software related capabilities. The evaluation format for the fact sheet is structured to support future use in a database format and facilitate comparison of models. The structure of the model fact sheets and definitions for each category are shown in Table 4-5.

Table 4-2. Summary of Receiving Water Simulation Capabilities

	Type			Level of Complexity			Water Quality							
Model	Steady state	Quasi-dynamic	Dynamic	One-dimensional	Two-dimensional	Three-dimensional	User-defined	Sediment	Nutrients	Toxics	Metals	BOD	Dissolved oxygen	Bacteria
AQUATOX	—	—	●	● (vert)	—	—	—	●	●	●	—	●	●	—
BASINS	—	●	●	●	—	—	●	●	●	●	●	●	●	●
CAEDYM	—	—	●	●	●	●	●	●	●	—	●	●	●	●
CCHE1D	—	—	●	●	—	—	—	●	—	—	—	—	—	—
CE-QUAL-ICM/TOXI	—	—	●	●	●	●	●		●	—	●	●	●	—
CE-QUAL-R1	—	—	●	●	—	—	—	●	●	—	●	●	●	●
CE-QUAL-RIV1	—	—	●	●	—	—	—	—	●	—	●	●	●	●
CE-QUAL-W2	—	—	●	—	●	—	—	—	●	—	—	●	●	●
CH3D-IMS	—	—	●	●	●	●	—	●	●	—	—	●	●	—
CH3D-SED	—	—	●	●	●	●	—	●	—	—	—	—	—	—
DELFT3D	—	—	●	●	●	●	●	●	●	●	●	●	●	●
DWSM	—	—	●	●	—	—	—	●	●	●	—	—	—	—
ECOMSED	—	—	●	●	●	●	—	●	—	—	—	—	—	—
EFDC	—	—	●	●	●	●	●	●	●	●	●	●	●	●
GISPLM	—	—	—	—	—	—	—	—	●	—	—	—	—	—
GLLVHT	—	—	●	—	—	●	—	●	●	—	—	●	—	●
GSSHA	—	—	●	—	●	—	—	●	—	—	—	—	—	—
HEC-6	—	—	●	●	—	—	—	●	—	—	—	—	—	—
HEC-6T	—	—	●	●	—	—	—	●	—	—	—	—	—	—
HEC-RAS	—	—	●	●	—	—	—	—	—	—	—	—	—	—

Water Quality Models Used

- Primary characterization:
  - Receiving water: describe hydrology and WQ of rivers, canals, reservoirs, lakes
    - WQ simulation of sediment and pollutant transport & transformation
  - Watershed: describe watershed hydrology and WQ, including runoff, erosion, and wash-off of sediment/pollutants
    - Some have simplified groundwater transport, and internally linked river WQ processes

Models used in ... ess

- Tool for estimating ... Report 1999)
- General approach:
  - *Ohio EPA selects ... xity, pollutant issues, ... familiarity.*
    - Because context ... procedure.

Figure B.1. Decision Tool for Estimating Required Rigor

Criteria	Description
Ramifications	
Socio-economic	Does the development of a restoration target have high social and economic ramifications (positive or negative)? Ramifications consider a local economy, numbers of direct and indirect jobs, state and local tax revenue, and other factors as appropriate.
Legal	Does the development of a restoration target have high legal ramifications? For example, will omission of a restoration target will result in a legal suit against the Agency by U.S. EPA or other party?
Physical Complexity	
Homogeneity of Sources and Causes (Stressors)	Is the watershed predominantly occupied with nonpoint-source or point-source activity? If the watershed is dominated with nonpoint-source activity, can the nonpoint-source load be quantified?
Capability of Model / Approach / Method	Can the adopted model, approach, or method connect cause with restoration target?
Estimation of Sources and/or Causes (Stressors)	Are sources and/or causes of pollution known with confidence? If not, are they estimable? What is the level of uncertainty in identifying the source and/or cause?
Available Resources	
Data – Existing	Does information on sources, causes (stressors), and endpoints exist or be generated with minimal effort?
Data – Type	Does information collected directly from field sampling exist? Does indirect (indicator) information exist?
Personnel	Do sufficient personnel (person-hours) with corresponding technical expertise exist?
Monetary	Do sufficient financial resources exist to complete field monitoring, laboratory analysis, equipment and additional data purchases, etc.?
Listing/Standards	
Source/Impairment Relationship	Is impairment known to be caused by exceedence of a numeric criterion?
Water Quality Criteria/Impairment Relationship	Were numeric criteria used to list [303(d)] the waterbody segment?

DSW TMDL Team Report - 10/1/99 95

Models used in Ohio EPA TMDL process

Model Acronym	Receiving Water	Watershed	BMP (explicit)	Statistical or Process
SWAT	x	x	x	P
HSPF (LSPC)	x	x	x	P
GWLF		x		P
QUAL-2E, QUAL-2K	x			P
CE-QUAL-W2	x			P
Spreadsheet tools	x	x		S, P
Simplified Analytical Method	x			P
Load Duration Curve				S
BATHTUB	x			P

Reasonable Assurance in TMDLs

Reasonable Assurance in TMDLs

- Assurance that the implementation activity will occur.
  - High degree of confidence that WLA and LA in a TMDL will be implemented…
  - By Federal, State or local authorities, and/or voluntary action.

Reasonable Assurance in TMDLs

- Impaired, but PS only, the NPDES permit is the RA
- Impaired, with PS and NPS, WLA based on assumption that LA <u>will</u> occur
  - NPS controls:
    - Specific to pollutant
    - Expeditious
    - Supported by institutional programs and funding
- Impaired, but NPS only, USEPA can assist State in developing implementation plan

Implementation example…

Great Miami River (upper) Watershed TMDLs

6.2 Implementation Scenarios

- Reduce point source discharges to 1 mg/L, 3 mg/L, or existing load, depending on guidance (see Table 6-1).
- Convert all failed HSTS to conventional systems and maintain existing conventional systems.
- Nonpoint practices:
  - Incorporate manure into soil (i.e., turning soil so that manure does not remain on the surface)
  - Add winter cover crops

Location Description (10-digit HUC) / Location Description (12-digit HUC) / Sources (Causes)	Restoration Categories											
	Bank & Riparian Restoration	Stream Restoration	Wetland Restoration	Conservation Easements	Dam Modification or Removal	Levee or Dike Modification or Removal	Abandoned Mine Land Reclamation	Home Sewage Planning and Improvement	Education and Outreach	Agricultural Best Management Practices	Storm Water Best Management Practices	Regulatory Point Source Controls
Mile Creek (05 02)												
Channelization (habitat alteration)	X	X	X	X		X				X		
Agriculture (nutrients, bacteria from runoff)	X	X	X	X		X				X		
Unsewered community (bacteria)								X	X			
Animal feedlot operation (bacteria)									X	X		

Reasonable Assurance

- Ohio EPA does not have the local contacts…
  - But important to build more *effective* partnership with ODA and ODNR
- Trend is for US EPA to strengthen implementation
  - Subsidy to Sandusky…soon in lower Maumee
  - But not statute…
- Does S.B. 150 have a role?
- TAG members…
  - Do you have constructive input to improve “traction” for implementation?

Goals

- Review basics…introduction…identify issues for April meeting
- Today…
  - Critical Design Flow Condition
  - TMDL Allocation Methods
  - Water Quality Models Used
  - Reasonable Assurance in TMDLs

Additional Slides

Use as time permits…and for discussion and questions

References Cited

- Design Flow
  - Progress of States (USEPA)
    - http://cfpub.epa.gov/wqsits/nnc-development/
  - Biological Design Flow
    - U.S. EPA. 1986. *Technical Guidance Manual for Performing Waste Load Allocations - Book VI: Design Conditions ,Chapter 1: Stream Design Flow for Steady-State Modeling* (EPA 440/4-87-004)
- Load Allocation Schemes
  - US EPA. 1991. Technical Support Document for Water Quality-Based Toxics Control (EPA 505/2-90-001), p 69.
  - Chadderton et al. (1981) Water Resources Bulletin (17)5
  - Chadderton and Kropp (1985) Water Resources Bulletin (21)5
  - US EPA. 1999. *Protocol for Developing Nutrient TMDLs*. (EPA 841-B-99-007).
- Targets
  - Ohio EPA – Division of Surface Water. 1999. *Association between Nutrients, Habitat, and the Aquatic Biota of Ohio's Rivers and Streams*. Published in: Ohio EPA Technical Bulletin, MAS/1999-1-1. Authors: E. Rankin, R. Miltner, C. Yoder and D. Mishne.

References Cited (part 2)

- Models Used
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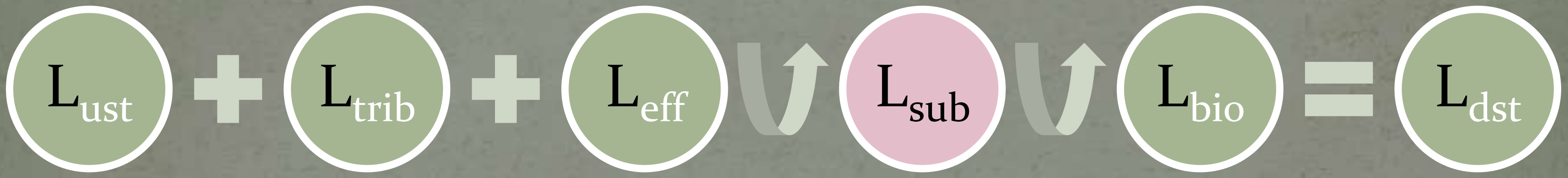
- Other
  - US EPA. 2007. *Appendix B: Identifying Daily Expressions for Non-daily Concentration-based TMDLs in the draft report of Options for Expressing Daily Loads*. U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington DC. June 22, 2007

Critical Design Flow Condition

- Consider…
  - Averaging period
  - Time period of applicability
    - …alternatively flow regime of applicability
    - All flows equal to and greater the design flow
  - Magnitude (Q=flow in cfs)
    - Frequency
      - Percent Exceedence
        - Flow of this magnitude or greater
      - Percent Non-Exceedence or Recurrence Interval
        - Flow of this magnitude or less
    - Duration
      - Extreme value: 7-day minimum, 30-day minimum
      - Unique data distributions…
        - Duration of average daily flow (nobs = 365 x n-yrs)
        - Extreme value (nobs = n-yrs, 1 obs per year)
      - Should correspond to averaging period for criterion.

Mass Balance of Total P

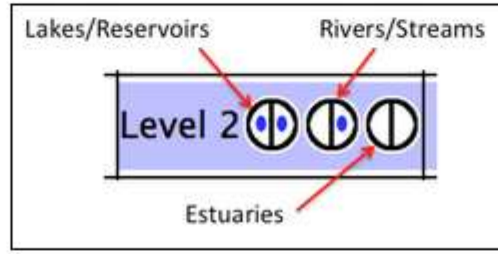
…consider the substrate load – an internal source or sink



- Determines the extent of the critical condition…
  - Delivery or supply mechanism
    - Both dissolved and particulate form
    - Both urban PS and field runoff
  - Retention in depositional areas
  - Re-mobilization given certain environmental factors

What are other States doing?

State/Territory	Region	N/P 2013		
American Samoa	9	Level 5	Lev	
Guam	9	Level 5	Lev	
Hawaii	9	Level 5	Lev	
Northern Marianas Islands	9	Level 5	Lev	
Vermont	1	Level 2	Lev	
Florida	4	Level 4	Lev	
New Jersey	2	Level 4	Lev	
Puerto Rico	2	Level 4	Lev	
Wisconsin	5	Level 4	Lev	
Minnesota	5	Level 3	Lev	
Delaware	3	Level 2	Level 2	Level 4
Massachusetts	1	Level 2	Level 2	Level 4
New York	2	Level 1	Level 1	Level 4
Rhode Island	1	Level 3	Level 3	Level 3
U.S. Virgin Islands	2	Level 3	Level 3	Level 3
West Virginia	3	Level 3	Level 3	Level 3
South Carolina	4	Level 2	Level 2	Level 3
New Hampshire	1	Level 1	Level 1	Level 3
Ohio	5	Level 1	Level 1	Level 3
Arizona	9	Level 2	Level 2	Level 2



N	P	Chl-a	
			Statewide criteria
			Partial criteria (Categorical criteria, site-specific criteria, etc.)
			No criteria
⊗			Watertype Not Applicable

Critical Design Flow Condition

- Consider…
  - Averaging period
  - Time period of applicability
    - …alternatively flow regime of applicability
    - All flows equal to and greater the design flow
  - Magnitude (Q=flow in cfs)
    - Encompasses…A <u>duration</u> of the flow event and a <u>frequency</u> of re-occurrence
      - Percent Exceedence
        - Flow of this magnitude or <u>greater</u>
      - Percent Non-Exceedence or Recurrence Interval
        - Flow of this magnitude or <u>less</u>
    - Duration
      - Extreme value: 7-day minimum, 30-day minimum
      - Unique data distributions…
        - Duration of average daily flow (nobs = 365 x n-yrs)
        - Extreme value (nobs = n-yrs, 1 obs per year)
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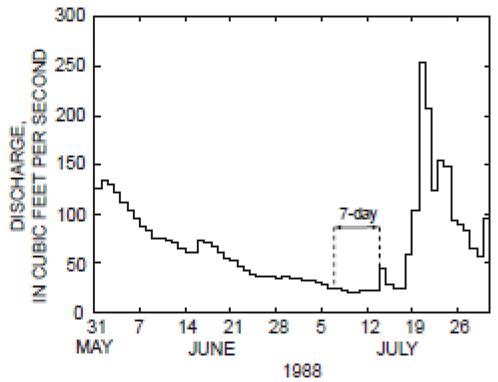

Figure 3. Part of the annual hydrograph showing lowest 7-day daily streamflow for the 1988 climatic year for Little Beaver Creek near East Liverpool, Ohio (03109500).

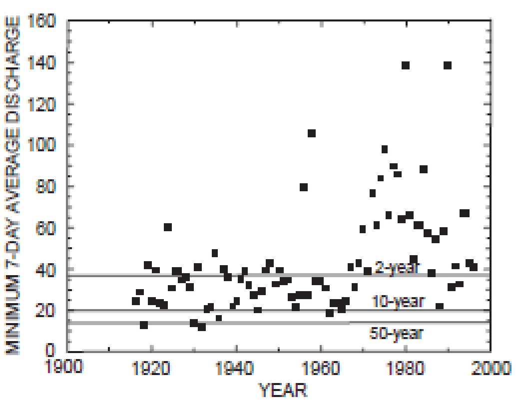

Figure 4. Annual minimum 7-day average streamflow for the period 1917–97 for Little Beaver Creek near East Liverpool, Ohio (03109500).

Prob$_{exc}$ by Month

…for Big Darby Ck at Darbyville (1921-2012)

Month	Average (%)	25th Pct (%)	Median (%)	75th Pct (%)
May	36	20	37	51
June	45	28	47	62
July	59	45	62	75
August	71	61	75	88
September	78	69	84	94
October	76	67	83	92

…further work…

- Explore other stations (USGS gages)
- Only consider "modern" record…say 1970 – 2012