ALGAL FLOW-WAY TECHNOLOGIES EXPERT PANEL REPORT

WATERSHED TECHNICAL WORKGROUP

NOVEMBER 5, 2015

SARAH LANE, UMCES@DNR, PANEL CO-COORDINATOR

SARAH.LANE@MARYLAND.GOV

OUTLINE

- ORIENTATION
- BACKGROUND
- PANEL CHARGE AND MEMBERSHIP
- DEFINITIONS AND MODELING
- REDUCTION CREDITS – 2 APPROACHES
- VERIFICATION AND REPORTING
- FUTURE RESEARCH NEEDS

ORIENTATION – WHAT ARE THEY?

- INCLINED RACE-WAYS THAT RECEIVE NUTRIENT-LADEN WATER SO NATURAL ALGAL ASSEMBLAGES CAN ACCUMULATE AND THEN BE HARVESTED FOR AN END-USE.

Figure 1. Example of Algae Filaments Growing on Screen (reprinted from Adey et. al, 1993)

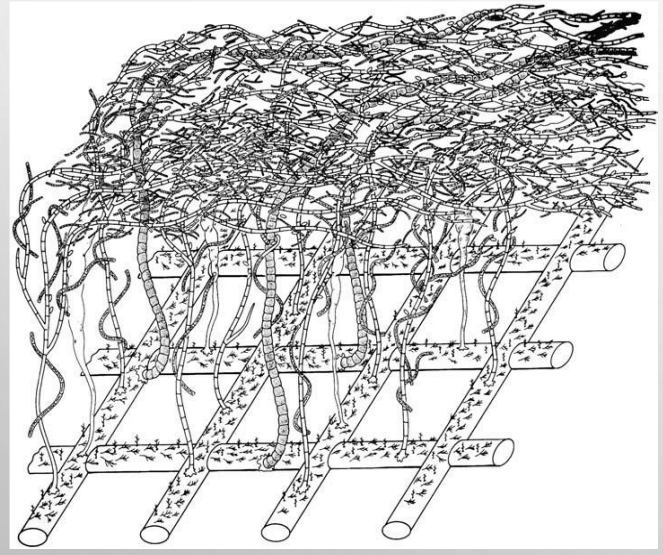


Figure 2. Aerial View of Large-scale Algal Flow-way in Central Florida (courtesy of HydroMentia, Inc.)

Port of Baltimore Algal Flow-way Installation

BACKGROUND – WHY WTWG?

- JOINT WORKSHOP WITH FLOATING WETLANDS IN SUMMER 2012
- IN DECEMBER 2012, WTWG 'APPROVED' FORMATION OF PANEL
- PANEL MEETINGS SPRING 2012 – DECEMBER 2014
- SPRING-SUMMER 2015 'FINE-TUNING' WITH INDIVIDUAL PANEL MEMBERS
- NOVEMBER 2015 PRESENTATION TO WTWG AND BEGIN 30-DAY COMMENT PERIOD

PANEL MEMBERSHIP

Last Name	First name	Affiliation
Bolt	Charles	Hampton Roads Sanitation District
Brush	Mark	VIMS
Canuel	Elizabeth	VIMS
Johnston	Matt	UMD/CBPO (co-facilitator)
Kangas	Pat	UMD CP
Lane	Sarah	UMCES@DNR (co-facilitator)
May	Peter	Biohabitats
Mulbry	Watler	USDA-ARS
Mulholland	Margaret	Old Dominion University
Sample	Dave	VTech
Sellner	Kevin	CRC
Stephenson	Kurt	VTech

CONTRIBUTORS

IN ADDITION TO THE CORE PANELISTS, A NUMBER OF CONTRIBUTORS WERE INVITED TO PROVIDE INPUT FROM TIME-TO-TIME. THESE CONTRIBUTORS WERE TECHNICAL EXPERTS FROM THE INDUSTRY AND THE RESEARCH COMMUNITY. THEY ASSISTED WITH THE FOLLOWING TASKS TO AID THE PANEL:

- PROVIDE DATA ON ESTIMATED REMOVAL RATES AND DESCRIBE THE MONITORING PROTOCOLS FOR SPECIFIC SITES.
- PROVIDE FEEDBACK ON A VARIETY OF ISSUES WHEN SOLICITED BY THE CORE PANELISTS.
- REVIEW THE FINDINGS OF THE CORE PANELISTS AS THEY ARE DEVELOPED AND AT THE END OF THE PROCESS. IT IS IMPORTANT TO NOTE THAT THE CORE PANELISTS AND ULTIMATELY THE CHESAPEAKE BAY PROGRAM'S WATER QUALITY GOAL IMPLEMENTATION TEAM WILL APPROVE THE FINAL EXPERT PANEL RECOMMENDATIONS.

EMMETT DUFFY, VIRGINIA INSTITUTE OF MARINE SCIENCE, WALTER ADEY, SMITHSONIAN INSTITUTION, ALANA HARTMAN, WV DEPARTMENT OF ENVIRONMENTAL PROTECTION, MARK ZIVOJNOVICH, HYDROMENTIA, INC., JEREMY HANSON, CHESAPEAKE RESEARCH CONSORTIUM AND DAVID WOOD, CHESAPEAKE RESEARCH CONSORTIUM.

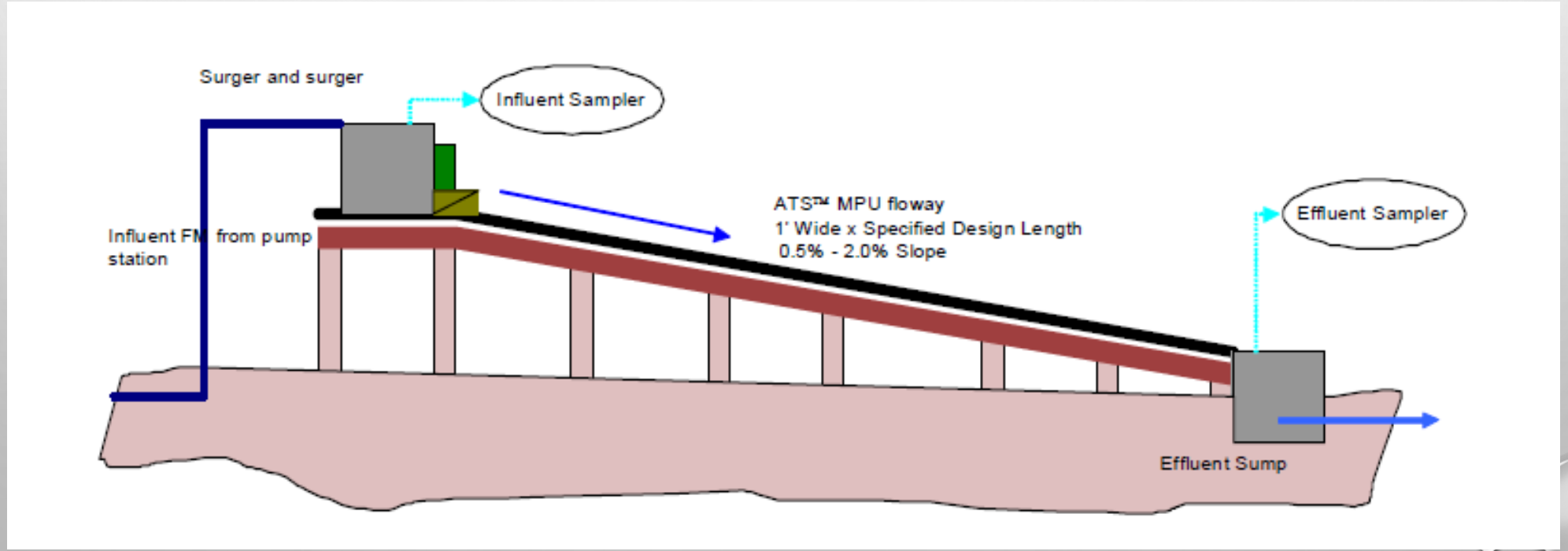
HABITAT GIT, SAV WG INPUT. OVERALL - AGREED THAT PROPER SITING AND DESIGN OF AN AFT SHOULD ELIMINATE ANY UNINTENDED ADVERSE CONSEQUENCES TO WATER QUALITY, HABITAT AND WILDLIFE.

CHARGE

- REVIEW THE CURRENT LITERATURE REGARDING AFTS;
- REVIEW CURRENT PROTOCOLS FOR QUANTIFYING NUTRIENT AND SEDIMENT REDUCTIONS USED BY RESEARCH SCIENTISTS AND PRIVATE INDUSTRY REPRESENTATIVES;
- REVIEW MONITORING DATA COLLECTED AT A VARIETY OF SITES, BOTH BY RESEARCH SCIENTISTS AND PRIVATE INDUSTRY REPRESENTATIVES;
- DEVELOP A GENERAL DESCRIPTION OF AFTS TO BE USED AS THE DEFINITION OF THE PRACTICE;
- PROVIDE GUIDELINES FOR MODELING AFTS AND OTHER BIOMASS HARVESTING TECHNIQUES;
- DEVELOP PROTOCOLS DESCRIBING STATE REPORTING PROCEDURES FOR REMOVAL RATES FROM EACH PROJECT. THE PANEL SHOULD CONSIDER PROTOCOLS FOR BOTH PERMITTED AND NON-PERMITTED FACILITIES;
- ENSURE THAT REPORTED REMOVAL RATES FROM INDIVIDUAL SITES ARE CONSISTENT WITH RESEARCH OR LITERATURE REPORTED RANGES FOR OTHER AFTS;
- CONSIDER **THE PROPER DISPOSAL AND/OR USE OF THE SPENT WASTE BYPRODUCT** TO ENSURE REDUCTIONS ARE OCCURRING; AND
- DRAFT AND EDIT A REPORT DESCRIBING THE PANEL'S FINDINGS AND RECOMMENDATIONS.

DESCRIPTION

- INCLINED STRUCTURE (TYPICALLY 1 TO 2° SLOPE)
- NATURAL ALGAL ASSEMBLAGES ATTACH TO SCREENS OR OTHER SUBSTRATE
- ALGAE ASSIMILATES NUTRIENTS FROM THE OVERLYING WATER INTO ALGAL BIOMASS
- ALGAE ARE REGULARLY HARVESTED FOR USE AS BIOFUEL, COMPOST, OMEGA-3 OILS, FERTILIZER, SOIL AMENDMENTS OR ANIMAL FEED



NOT URBAN STORMWATER OR AG WASTE BMP

- THE TECHNOLOGY, ALTHOUGH SIMPLE, REQUIRES A CONTINUOUS WATER SOURCE AND THEREFORE THE WET-DRY CYCLE IN URBAN STORMWATER PONDS IS NOT A REASONABLE HABITAT FOR ROUTINE USE OF THE AFT
- MANURE TREATMENT VIA AFT WOULD NOT MEET THE QUALIFYING CONDITIONS UNDER THE DEFINITION
  - CONCERNS OVER LIGHT PENETRATION AND CONTINUOUS FLOW SUPPLY/AVAILABILITY

QUALIFYING CONDITIONS

IN ORDER TO RECEIVE CREDIT WITHIN THE CHESAPEAKE BAY PROGRAM MODELING TOOLS. AFTS SUBMITTED FOR CREDIT MUST HAVE:

1) A CONTINUOUS FLOW, SUBJECT TO NORMAL MAINTENANCE AND HARVESTING ACTIVITIES, OF NUTRIENT-LADEN WATER OVER AN INCLINED RACEWAY STRUCTURE TO PROVIDE WATER COVERAGE AND ALGAL GROWTH OVER THE ENTIRE SURFACE AREA AND THROUGHOUT THE PRODUCTION SEASON;

2) ADEQUATE SHADE-FREE LIGHT FOR PHOTOSYNTHESIS THROUGHOUT THE GROWING SEASON;

3) A HARVESTING PROCESS FOR THE ALGAE;

4) PROPER STORAGE OF HARVESTED BIOMASS TO ELIMINATE RUNOFF OF NUTRIENTS FROM THE SITE YEAR-ROUND;

5) AN END USE FOR HARVESTED ALGAE (ALGAL NUTRIENTS MUST NOT BE APPLIED ONSITE UNLESS APPLICATIONS ARE MADE UNDER A QUALIFYING NUTRIENT MANAGEMENT PLAN); AND

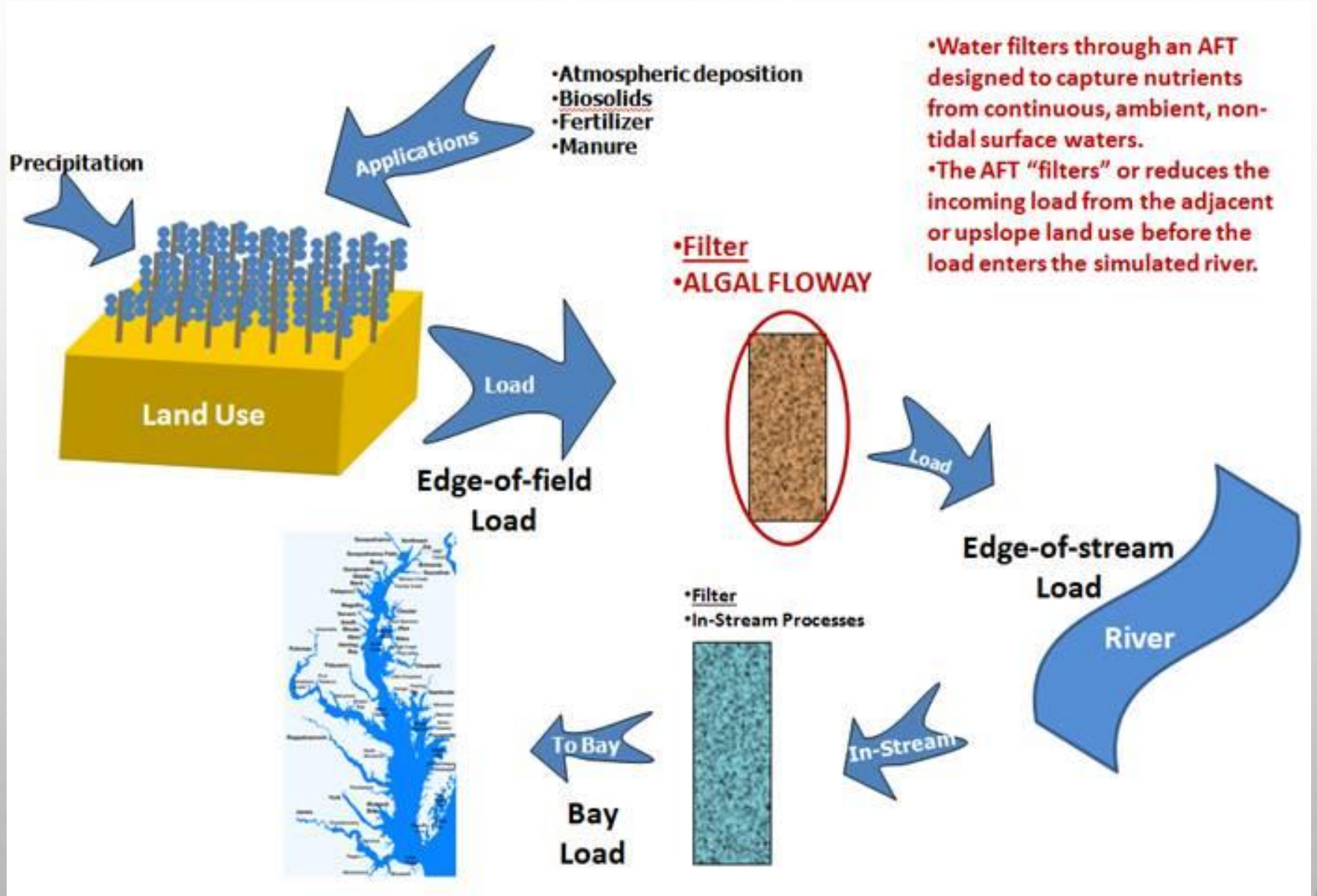
6) AN OPERATING SYSTEM FOR THE DURATION OF THE GROWING SEASON (MOST COMMONLY 240 DAYS THROUGHOUT THE CHESAPEAKE BAY WATERSHED); IF IT IS LESS THAN 240 DAYS, OPERATORS CANNOT CLAIM A DEFAULT CREDIT AND MUST REPORT MORE DETAILED BIOMASS HARVEST INFORMATION.

DEFINITIONS

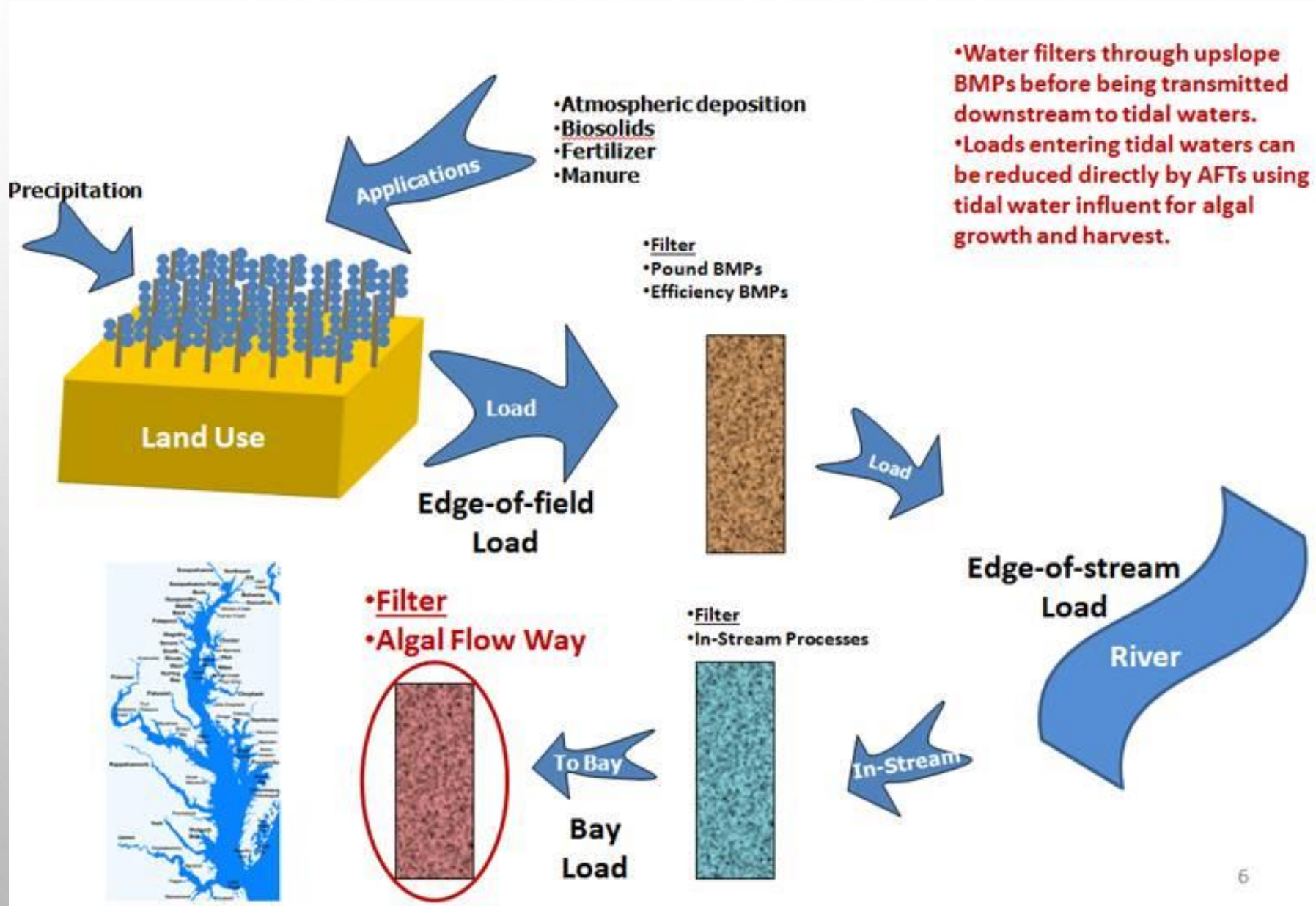
NON-TIDAL AMBIENT WATERS AFT *– ANY AFT DESIGNED TO PROVIDE TREATMENT OF CONTINUOUSLY , AMBIENT, NON-TIDAL SURFACE WATERS INCLUDING PERENNIAL PONDS, LAKES, RESERVOIRS, WETLANDS, STREAMS AND RIVERS.*

TIDAL AMBIENT WATERS AFT *– ANY AFT DESIGNED TO PROVIDE TREATMENT OF CONTINUOUSLY FLOWING, AMBIENT, TIDAL WATERS.*

EXAMPLE MODEL SIMULATION OF NON-TIDAL AMBIENT WATERS AFT



EXAMPLE MODEL SIMULATION OF TIDAL AMBIENT WATERS AFT



CREDIT

- THOUGH SIMULATED DIFFERENTLY BY TYPE IN MODEL, PANEL DOES NOT RECOMMEND DIFFERENT DEFAULT NUTRIENT AND SEDIMENT REDUCTIONS FOR EACH OF THE AFT TYPES
- TWO CREDITING APPROACHES THAT UTILIZE ALGAL NUTRIENT AND SEDIMENT CONTENT AND BIOMASS PRODUCTIVITY:
  - DEFAULT - REDUCTION OF **545** POUNDS OF TOTAL NITROGEN (TN), **45** POUNDS OF TOTAL PHOSPHORUS (TP), AND **3,219** POUNDS OF SEDIMENT PER ACRE OF AFT SURFACE AREA IN OPERATION EACH YEAR.
  - DIRECT SAMPLING TO PROVIDE ACTUAL REDUCTIONS

Nutrient Default Credit. Comparison of AFT Field Studies from Chesapeake Bay Region

Location	Waterbody Treated	Growing Season (months)	Flow Rate (L/minute/meter)	Productivity (gDW/m2/day)	%N (S.D.)	%P (S.D)
Lancaster, PA(1)	Susquehanna River	8	173	12.9	2.5 (0.52)	0.3 (0.06)
Baltimore, MD(2)	Inner Harbor	12	361	7.7	3.2 (0.60)	0.1 (0.01)
Gloucester, VA(3)	York River	12	100	~20	1.3 (0.45)	0.2 (0.05)
Reedville, VA(4)	Great Wicomico River	12	125	15.4 (2D screen)*	2.5 (0.07)	0.2 (0.05)

(1) Kangas et al. 2009; (2) May et al. 2013; (3) Canuel and Duffy 2011; (4) Adey et al. 2013

*A 3D screen at the Reedville location actually produced between 39.6 and 47.7 g DW/m2/day. This result was not included in the conservative estimate of productivity because of it was the only example of a 3D screen.

NUTRIENT DEFAULT CREDIT - ESTIMATED NITROGEN REDUCTIONS FROM AFTS

Study	Productivity (g DW/m2/day)	g DW N/g DW	Growing Days	m2/acre	lbs/g	Estimated Lbs TN Removed/m2/Year
Lancaster, PA (1)	12.9	0.025	240	4047	0.0022	689
Baltimore, MD (2)	7.7	0.032	365	4047	0.0022	800
Gloucester, VA (3)	20	0.013	365	4047	0.0022	845
Reedville, VA (4)	15.4	0.025	365	4047	0.0022	1,251
Average	14	0.024	240*	4047	0.0022	718
Lowest Quartile	11.6	0.022	240*	4047	0.0022	545

(1) Kangas et al. 2009; (2) May et al. 2013; (3) Canuel and Duffy 2011; (4) Adey et al. 2013

Nutrient Default Credit - Estimated Phosphorus Reductions from AFTs

Study	Productivity (g DW/m2/day)	g DW P/g DW	Growing Days	m2/acre	lbs/g	Estimated Lbs TP Removed/m2/Year
Lancaster, PA (1)	12.9	0.003	240	4047	0.0022	83
Baltimore, MD (2)	7.7	0.001	365	4047	0.0022	25
Gloucester, VA (3)	20	0.002	365	4047	0.0022	130
Reedville, VA (4)	15.4	0.002	365	4047	0.0022	100
Average	14	0.002	240*	4047	0.0022	60
Lowest Quartile	11.6	0.0018	240*	4047	0.0022	45

(1) Kangas et al. 2009; (2) May et al. 2013; (3) Canuel and Duffy 2011; (4) Adey et al. 2013

NUTRIENT CREDIT - DEFAULT

EQUATION 1. CALCULATING YEARLY NUTRIENTS REMOVED BY AN AFT

LBS REMOVED/YR = (G DW/M2/DAY) X (% NUTRIENT CONTENT OF DW BIOMASS) X (GROWING SEASON DAYS) X (4,047 M2/ACRE) X (0.0022 LB/G)

545 LBS TN = (11.6 G DW/M2/DAY) X (0.022 TN) X (240 GROWING DAYS) X (4,047 M2/ACRE) X (0.0022 LB/G)

45 LBS TP = (11.6 G DW/M2/DAY) X (0.0018 TP) X (240 GROWING DAYS) X (4,047 M2/ACRE) X (0.0022 LB/G)

POUNDS EXPRESSED AS PER ACRE PER YEAR

SEDIMENT DEFAULT CREDIT - COMPARISON OF ASH CONTENTS AS PERCENTAGE OF TOTAL MASS FROM AFTS

Location	% Ash Content	Reference
Oyster Farm, Choptake River, MD	93	Ray, 2014
Peach Bottom, PA	85	D. Blersch, personal communication, 2014
Port of Baltimore, MD	70	W. Mulbry, personal communication, 2015
Gloucester, VA	80	Canuel and Duffy, 2011
Patuxent River, MD	77	Mulbry et al. 2010
Bush River, MD	70	Mulbry et al. 2010
Patapsco River, MD	68	Mulbry et al. 2010
Muddy Run, PA	60	W. Mulbry, personal communication, 2010
Inner Harbor, Baltimore, MD	59	May et al. 2013
Average	75	NA
Lowest Quartile	68	NA

SEDIMENT DEFAULT CREDIT - BIOGENIC AND NON-BIOGENIC CONTRIBUTIONS TO MATERIAL ACCUMULATING ON AFT AFTER 7 DAYS

Location	Section of Flow-Way	%Biogenic	%Non-Biogenic
Double Flow-Way, Gloucester Point, VA	Top	68.95	31.05
	Middle	58.75	41.25
	Bottom	41.93	58.07
Boat Basin Flow-way, Gloucester Point, VA	Top	62.83	37.17
	Middle	38.86	61.14
	Bottom	35.49	64.51
Average	NA	51.14	48.87
Lowest Quartile	NA	39.63	38.19

SEDIMENT DEFAULT CREDIT

- **EQUATION 2. CALCULATING YEARLY SEDIMENT REMOVED BY AN AFT**
- *LBS SEDIMENT REMOVED = (G DW/M2/DAY) X (% ASH CONTENT OF DW) X (% NON-BIOGENIC INORGANIC CONTENT OF ASH) X (GROWING SEASON DAYS) X (4,047 M2/ACRE) X (0.0022 LB/G) X (CONSERVATIVE REDUCTION)*
- *3,219 LBS = (11.6 G DW/M2/DAY) X (0.68 ASH CONTENT) X (0.3819 NON-BIOGENIC CONTENT) X (240 GROWING DAYS) X (4,047 M2/ACRE) X (0.0022 LB/G) X (0.5)*

CREDIT – DIRECT SAMPLING

STEP 1: WEIGH THE TOTAL BIOMASS COLLECTED AT EACH HARVEST.

STEP 2: WEIGH A REPRESENTATIVE SUBSAMPLE OF THE BIOMASS, AND THEN DRY TO AT LEAST 55°C (131°F) AND IMMEDIATELY RECORD THE NEW, DRY WEIGHT. THE DIFFERENCE BETWEEN THESE TWO SAMPLE WEIGHTS IS MOISTURE CONTENT.

- PERFORM STEPS 1 AND 2 AT EACH HARVEST.
- A MINIMUM OF FOUR TIMES A GROWING SEASON, ANALYZE A SUBSAMPLE OF THE DRIED BIOMASS FOR PERCENT TN, PERCENT TP, PERCENT ASH SOLIDS AND PERCENT NON-BIOGENIC INORGANIC CONTENT.

NOTE: STEP 2 ABOVE DESCRIBES A METHOD TO ESTIMATE DRY BIOMASS HARVESTED. DUE TO THE POTENTIALLY HIGH COST OF SEDIMENT ANALYSIS, FACILITIES ALSO HAVE THE OPTION OF REPORTING TN AND TP FOR DIRECT SAMPLING CREDIT, WHILE ELECTING TO RECEIVE THE DEFAULT CREDIT FOR SEDIMENT.

CREDIT – DIRECT SAMPLING

STEP 3: USE THE EQUATIONS BELOW TO ESTIMATE TN, TP AND SEDIMENT REMOVED.

EQUATION 3. CALCULATE ANNUAL REMOVAL OF NUTRIENTS

LBS REMOVED/YEAR = (G OF TOTAL DW BIOMASS HARVESTED/YR) X (% AVERAGE NUTRIENT CONTENT OF DW SUBSAMPLES) X (0.0022 LB/G)

EQUATION 4. CALCULATE ANNUAL REMOVAL OF SEDIMENT

LBS SEDIMENT REMOVED/YEAR = (G OF TOTAL DW BIOMASS HARVESTED/YR) X (% AVERAGE ASH SOLIDS OF SUBSAMPLE) X (% AVERAGE NON-BIOGENIC INORGANIC CONTENT OF SUBSAMPLE) X (0.0022 LB/G)

REPORTING – DEFAULT

- NON-TIDAL OR TIDAL
- ACRES INSTALLED
- LOCATION
- LANDUSE GROUPS THE AFT TREATS

- ANNUAL BMP

REPORTING – DIRECT SAMPLING

- BASED UPON PRODUCTION WEIGHTS AND DIRECT SUBSAMPLES OF NUTRIENT AND SEDIMENT CONTENT:
- TYPE OF AFT INSTALLED: TIDAL OR NON-TIDAL
- ACRES OF AFT INSTALLED
- LOCATION OF THE AFT
- LAND USE GROUP THE AFT TREATS: URBAN OR AGRICULTURE
- ESTIMATE OF ANNUAL TN, TP, AND SEDIMENT COLLECTED

- ANNUAL BMP

VERIFICATION AND ACCOUNTABILITY

THE PANEL RECOMMENDS THAT ANNUAL REPORTS INCLUDE THE FOLLOWING:

- THE OPERATOR'S WATER APPROPRIATION PERMIT NUMBER;
- WATER DISCHARGE PERMIT NUMBER;
- DESCRIPTION OF HOW THE HARVESTED BIOMASS WAS STORED;
- DESCRIPTION OF THE END-USE OF THE BIOMASS; AND
- OPERATION DATES AND HARVEST DATES (TO ENSURE 240 OPERATING DAYS FOR DEFAULT CREDIT)
- JURISDICTIONS MAY ALSO WISH TO CONSIDER REQUIRING RECEIPTS OF BIOMASS WEIGHT FOR ANY BIOMASS LEAVING THE OPERATION.

END USE

WHEN REPORTING, THE PANEL RECOMMENDS JURISDICTIONS DOCUMENT IN THEIR QUALITY ASSURANCE PROJECT PLANS (QAPP) HOW THE BYPRODUCT OF REPORTED AFTS WILL BE UTILIZED. EXAMPLES OF ACCEPTABLE USES INCLUDE DISPOSAL IN A LANDFILL OR DISPLACEMENT OF NUTRIENTS THROUGH FERTILIZER RESALE AND/OR APPLICATIONS UNDER A NUTRIENT MANAGEMENT PLAN, ANIMAL FEED, ETC.

DEVELOP USES FOR HARVESTED BIOMASS SO THAT NEW MARKETS FOR THE PRODUCT CAN BE ESTABLISHED

FUTURE RESEARCH NEEDS

OPPORTUNITIES TO REDUCE ENERGY CONSUMPTION AND COST

TRADING OR OFFSET CREDIT GENERATION

UPDATING WITH DATA FROM LARGE FACILITIES CONSTRUCTED IN OUR WATERSHED

DATA ON SEDIMENT REMOVAL

LABOR OF LOVE – LITERALLY