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Preliminary Scoping of Watershed Planning: Pamet River, Massachusetts

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PURPOSE: The US Army Corps of Engineers (USACE), New England District (NAE) conducted a watershed study of the Pamet River basin in Truro, Massachusetts. The study broadly focused on basin planning with specific goals of establishing baseline hydrologic and ecological condition, identifying management opportunities, assessing the relative effects of management opportunities, and recommending alternative courses of action for the community. This technical note (TN) reviews a rapid reconnaissance effort to guide scoping for the broader watershed study related to problem identification, objective setting, management alternatives, and a potential decision framework.

INTRODUCTION: The USACE, NAE conducted a Planning Assistance to States (Section 22) study for the town of Truro, Massachusetts from July 2016 to November 2019. The scope of the study is broadly focused on basin planning in the Pamet River Watershed with specific goals of establishing baseline conditions of hydrologic and ecological condition, constructing a hydraulic model to quantify flow characteristics, identifying management opportunities to meet social and ecological objectives, assessing the relative effects of management opportunities, and recommending alternative courses of action for the community.

Through the Water Operations Technical Support program (WOTS), NAE requested support to ongoing watershed planning along with guidance regarding recent hydrologic changes in the basin (described below). The focus of this WOTS report largely relates to developing a transparent, multi-objective watershed plan, and it draws heavily from methods developed in the environmental benefits analysis research program (Fischenich et al. 2013). In 2018, technical recommendations were provided on the following subjects based on discussion with the NAE study manager, field visits covering the length of the basin, and meetings with the Truro town manager, director of public works, and town planner.

- Assessment of basin condition.
- Objective setting and metric development.
- Management alternatives and their effects on objectives.
- Potential decision-making frameworks to structure study outcomes.

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PAMET RIVER WATERSHED: The Pamet River Watershed is a small drainage spanning the width of Cape Cod (~3.1 miles) in Truro, Massachusetts (Figure 1). The upstream, eastern portion of the basin is largely undeveloped and managed as part of the Cape Cod National Seashore with the general goal of "allow[ing] natural processes to proceed unimpeded" (NPS). The western portion of the watershed is largely unmanaged salt marsh with an outlet through Pamet Harbor. The central segment of the basin includes a mix of commercial and residential development in addition to two major transportation thoroughfares (Truro Center Road and Route 6), which bisect the basin. Wilder's Dike (now Truro Center Road) was constructed in 1869, and hydrologically separates the basin into a downstream salt marsh and upstream freshwater system with very little transitional zone (USACE 1998). Wilder's Dike is a 3.5-ft diameter, 56-ft long culvert with a tide gate, and the Route 6 embankment also has a 4-ft diameter culvert which is 360-ft long with no tide gate. Constructed in the 1950s, the long period of tide gate operation has altered basin hydrology, sediment deposition, and salinity dynamics substantially.

Figure 1. Pamet River Watershed (Image © 2018 TerraMetrics via Google Earth).

Since 2013, numerous major overwash events have occurred from the Atlantic Ocean at Ballston Beach into the watershed (Borrelli et al. 2016). Historically, events were relatively rare (i.e., three major overwashes prior to 2013). However, more than a dozen events in the last five years indicate that overwash from the Atlantic Ocean is becoming more frequent and the magnitude of these events may be increasing. Overwash introduces a major source of saltwater and sediment, which substantially alter the water, sediment, and salinity budgets of the Pamet Watershed. A period of extended overwash in Marsh 2018 increased water levels in the basin substantially, and subsequently led to the failure of the tide gate at Wilder's Dike. The tide gate was replaced in August 2018 with a newer, lighter gate with different hydraulic performance. Thus, multiple hydrologic conditions have been observed over the prior year, and Figure 2 conceptually summarizes some of the flow regimes experienced in the basin during this period. The USACE study monitored water levels at select locations throughout the watershed developed a hydraulic model to better understand and forecast basin hydrologic regimes.

From March to August 2018, wetland complexes in the freshwater section of the Pamet River experienced a dramatic die-off event. This period included significant overwash inputs from upstream as well as a change in hydraulic controls downstream (i.e., failure of the tide gate). Multiple hypotheses could explain the die-off. First, the duration of high-water levels could induce mortality on woody vegetation, some of which may not have high flood tolerance. Second, flood duration could have been controlled not by the overwash volume, but instead by the inability to drain the system via culverts at Route 6 and Wilder's Dike. Third, the wetland system was historically predominantly freshwater, which could indicate a salinity intolerance from the upstream overwash. Fourth, salinity-induced mortality could have occurred due to the loss of the tide gate and a downstream influx of salinity. Fifth, multiple overwash events could have introduced salinity to the wetland soils and subsequently a critical tipping point could have been reached within the soil (rather than the water column). Additional hydrologic studies (both monitoring and modeling) will be crucial to understanding the mechanisms of the die-off event, and the potential for management actions to improve ecological conditions. From this preliminary basin assessment, a few key observations emerged:

- The range of hydrologic conditions in 2018 provide crucial empirical data and insight on the Pamet River's hydrologic regime, which is driving many socio-ecological outcomes.
- Regardless of the mechanism, wetland die-off is a significant management concern to the town, and guidance on future ecosystem management actions is needed.
- The hydrologic controls at Wilder's Dike and Route 6 are key leverage points for management, given their central location at the freshwater-saltwater interface.

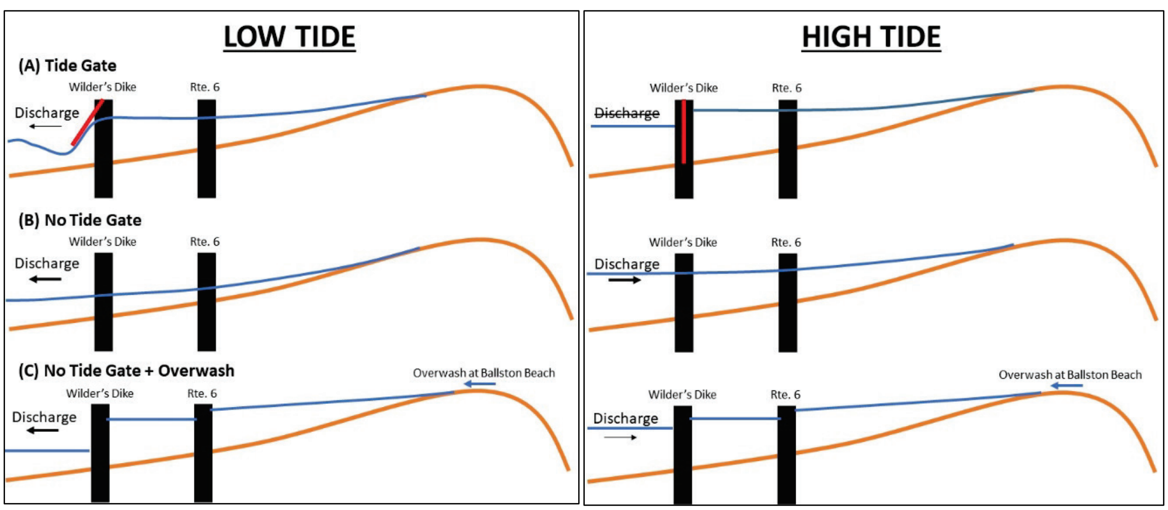

Figure 2. Conceptualization of Pamet River hydrology prior to tide gate washout (A), presently without the tide gate (B), and presently without the tide gate and showing ocean overwash.

OBJECTIVE SETTING: A clear and complete articulation of project objectives has long been acknowledged as crucial to all forms of environmental and water resources decisions (Yoe and Orth 1996; Gregory and Keeney 2002). A "good" set of objectives then provides the template from which decision metrics may be developed, models constructed or selected, and alternatives developed. This section focuses on setting objectives in the Pamet River, and additional information on setting and evaluating objectives may be found elsewhere (e.g., McKay et al. 2010; McKay et al. 2012a, b; Fischenich et al. 2013).

An overarching goal establishes a consistent vision for a project and sets the general direction for subsequent objective statements. This goal must be aligned with broader goals of the town, but the goal statement must also be system-specific and highlight the unique aspects of this ecosystem and associated management activities. The following statement is proposed as a preliminary goal for refinement with Truro staff.

> **Overarching Goal**: *Highlight the Pamet River as a unique ecological asset that benefits current residents and connects the community with its historical roots*.

A goal provides the vision for a project, and objectives refine and articulate that vision as measurable, achievable, and actionable statements. A hierarchy of objectives is often required, which separates the highest-order, fundamental objectives from the actionable, means objectives. Fundamental objectives represent the highest ideals of a project and are often identified by asking "Why does that matter?" A fundamental objective is often found when the answer is "Because it is what we care about." Means objectives are the steps to achieving that fundamental objective. For example, a fundamental objective associated with restoring an imperiled trout species could involve means objectives of reducing temperatures, improving habitat, or removing movement barriers. Table 1 presents a preliminary set of fundamental objectives (i.e., 1, 2, 3), associated means objectives (e.g., 1a, 1b, 1c), and potential metrics that could be relevant in the Pamet Watershed study. Importantly, all objectives may not be equally important to decision-makers, and the relative importance of objectives could be important to consider in recommending actions.

Table 1. Potential objectives for scoping the Pamet River study.

Objectives and Sub-Objectives	Potential Metrics
1. Minimize impacts to ***basin residents****.*	
1a. Minimize nuisance flooding of private property.	Acreage of flooded land during the 2018 simulation period (based from local tax parcel maps and hydraulic models)
1b. Avoid private groundwater well impacts from salinization.	Number of private wells with ANY potential for salinity impacts
1c. Provide a safe mechanism for wastewater disposal.	Number of septic systems affected by Pamet River hydrology
2. Make the Pamet River a focal point and source of pride for the ***community****.*	
2a. Minimize long-term risk to critical city infrastructure.	Number of critical city assets potentially affected by tidal, overwash, or alluvial flooding (e.g., post office)
2b. Minimize short-term risks to city operations (e.g., transportation routes).	Days of road closure due to construction
2c. Maximize recreational opportunities in the Pamet River.	Number of safe access points for fishing, kayaking, and hunting
3. Restore a lush, verdant mosaic of saltwater, brackish, and freshwater habitats in the unique ***Pamet River ecosystem****.*	
3a. Facilitate flow regime that "allows natural processes to proceed unimpeded" (NPS).	Departure of the water level regime from a "reference" regime defined by unimpounded hydrology (at key gage locations)
3b. Reduce barriers to the movement of wildlife (e.g., otter and other mammals) and fishes (e.g., migratory and resident).	Number of potential movement barriers between the headwater and estuary (relative to a generalized mammal and fish life history).
3c. Minimize the extent of invasive, nuisance plants.	Acreage of Pamet Watershed suitable for *Phragmites australis* (based on depth and salinity)

MANAGEMENT ALTERNATIVES: Pamet River Watershed management could involve actions by partners including the town of Truro, the National Park Service, Department of Transportation, private landowners, and other entities (e.g., USACE, NGOs, etc.). A comprehensive listing of management measures is beyond the scope of this TN, but general families of potential measures and alternatives were identified. Figure 3 presents a conceptual model of how management actions (shown in yellow) could influence project objectives (shown in green). Conceptual models are useful for increasing understanding, identifying potential alternatives, and facilitating team dialog, and ultimately, these models help "tell the story" of a project (Fischenich 2008). A Pamet River conceptual model (or set of conceptual models) is recommended to facilitate communication about this complex ecosystem and the multi-objective outcomes of interest. As an example, Figure 3 shows the relative effects of management actions, and in doing so, highlights salinity and water level as crucial system variables for management.

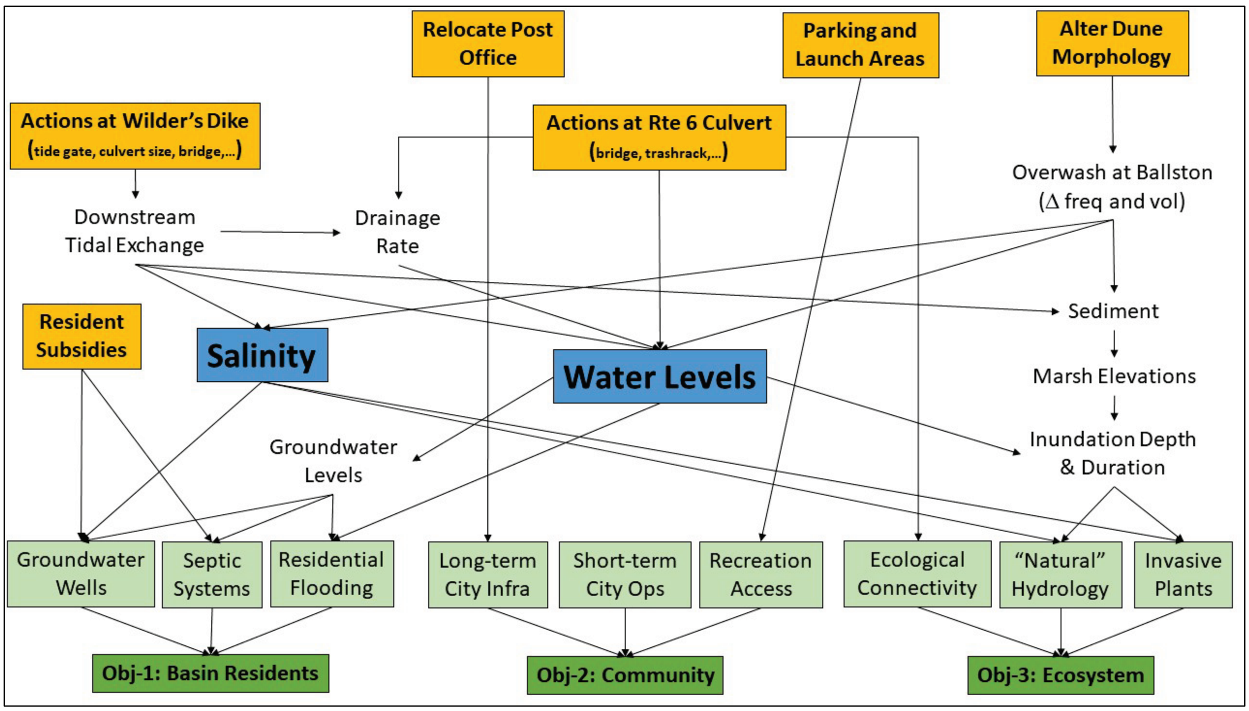

Figure 3. Conceptual model linking management actions to objectives in the Pamet Watershed. Yellow boxes are groups of management actions, blue boxes are key variables impacting many sub-objectives, light green boxes are sub-objectives, dark green boxes are overarching objectives, and variables not in boxes represent intermediate outcomes.

DECISION FRAMEWORK: Environmental management decisions are often characterized by many stakeholders with competing values, multi-objective outcomes, complex ecological processes, and dependencies between actions. Owing to these challenges, structured decision making has emerged as an important tool for organizing values, linking alternatives to those values, and transparently making trade-offs (Gregory and Keeney 2002; Fischenich et al. 2013). A key product of many structured decision processes is a decision matrix or consequences table, which crosswalks alternatives and their relative achievement of objectives. Table 2 presents an example decision matrix for the Pamet Watershed. This consequences table provides a mechanism for organizing project outcomes for decision-makers and explaining the relative benefits and costs of alternatives. Early in project planning, these matrices are often populated with qualitative outcomes (such as those shown here). Typically, these qualitative outcomes are replaced with quantitative metrics as a project gathers data and analyses are conducted. For instance, the objective related to residential flooding (Obj-1a) is currently assessed directionally based on observations and discussions from the August 20-21 site visit, but these data could be replaced with a quantitative metric such as the acreage of flooded private property under a particular alternative assess via the intersection of modeled water levels and local tax maps. Table 1 provides some examples of quantitative metrics that could replace the qualitative outcomes. Importantly, qualitative assessments may be conducted rapidly for many alternatives, which provides a transparent mechanism for screening alternatives prior to cost- or time-intensive quantitative analyses.

Table 2. Example of a decision matrix for the Pamet Watershed. Matrix is populated with example alternatives and qualitative responses for discussion. THESE VALUES DO NOT REPRESENT USACE study outcomes and are purely illustrative. The qualitative assessments are scored as: **↓ = strong negative effect, ↓ = weak negative effect, 0 = no effect, ↑ = weak positive effect, and **↑** = strong positive effect.**

	Residents			Community			Ecosystem		
Alternative	1a. Flood	1b. Wells	1c. Septic	2a. City Infra	2b. City Ops	2c. Recreation	3a. Hydrology	2b. Connectivity	3c. Invasives
No action	↓	0	0	↓	↓	0	↓	↓	↑
Installation of bridges at both Wilder's Dike and Route 6.	**↑**	0	↑	**↑**	**↓**	0	**↑**	**↑**	↓
Removal of tide gate at Wilder's Dike	↓	0	0	↓	↓	0	↑	↑	**↓**
Installation of bridge at Wilder's Dike + Large box culvert at Route 6 + Access point for recreation at North Pamet Road	**↑**	0	↑	**↑**	↓	**↑**	**↑**	**↑**	↓

As watershed planning proceeds, useful analytical strategies may include:

- *Establish "baseline" hydrology*: Empirical water level data and hydraulic and groundwater modeling will be crucial to informing Pamet River planning. A "reference" condition may provide a useful baseline against which to compare all alternatives. For instance, an unimpeded hydrologic condition (i.e., without any culverts or gates) could provide a useful point of relative comparison for other alternatives. The departure from a "reference" flow regime could be a useful metric.
- *Simulation period*: USACE project planning typically proceeds based on a 50-yr planning horizon. However, watershed planning within the Pamet basin may benefit from a different simulation approach. A consistent 2-yr simulation period may be sufficient for assessing project outcomes. For instance, the 2017-2018 tidal forcing and known overwash dynamics

could serve as a baseline for alternative comparison, which would simplify the challenge of long-term forecasting.

- *Scenario analysis*: This baseline simulation period could then be manipulated to examine scenarios representing alternative futures. At a minimum, the following four scenarios would provide a strong basis for assessing the relative performance of alternatives and "stress testing" them with respect to expected climate change in the region.
    - Existing conditions with 2017-2018 tidal and overwash forcing (but altered infrastructure to reflect the new tide gate for the entire period)
    - Low sea level rise + minor increase in overwash volume and frequency
    - Medium sea level rise + significant increase in overwash
    - High sea level rise + major increase in overwash volume and frequency
- *Monitoring data*: The 2017-2018 water level data will provide a crucial source of calibration data for hydraulic analyses, particularly given the changes in boundary conditions (e.g., gate – no gate – gate). However, a strategy should be developed to transition monitoring to town operational staff (or USGS) for long-term data management. Water level data will provide useful success monitoring metrics, if management actions are implemented.

SUMMARY: This WOTS TN was developed with the intent of providing rapid feedback on the Planning Assistance to States study in the Pamet River in Truro, Massachusetts. Four topics have been addressed briefly: (1) observations about basin condition based on a preliminary site visit, (2) objective setting to inform watershed planning, (3) potential management alternatives and their mechanistic link to objectives, and (4) recommendations for structuring study outcomes and analyses. All recommendations presented here should be considered as qualitative and non-representative of USACE study outcomes.

ADDITIONAL INFORMATION: The study was funded by the Water Operations Technical Support Program (WOTS), and reviews by Drs. Brook Herman and Chuck Theiling improved a prior draft. Opinions reflected here are the authors' and do not necessarily reflect those of the USACE. Please contact Dr. Pat Deliman (Patrick.N.Deliman@usace.army.mil), the WOTS Technical Director, for more information. This technical note should be cited as:

McKay, S. K., and B. Rupp. 2022. *Preliminary scoping of watershed planning: Pamet River, Massachusetts*. ERDC WQTN-22-1. Vicksburg, MS: US Army Engineer Research and Development Center.

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